Royal terns flushed from a loafing site on Florida coast. Photo by S. A. Nesbitt.

Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida

James A. Rodgers, Jr., and Henry T. Smith

Abstract Sixteen species of waterbirds (Pelecaniformes, Ciconiiformes, Charadriiformes) in north and central Florida were exposed to 4 types of human disturbances (walking, all-terrain vehicle, automobile, boat) to determine buffer zones that minimize flushing of foraging or loafing birds. Both intraspecific and interspecific variation were observed in flushing-response distances to the same type of disturbance. Buffer zones were estimated using a formula based on the mean plus 1.6495 standard deviations of the observed flushing distance plus 40 m (buffer distance = exp [μ + 1.6495σ] + 40). A buffer of about 100 m should minimize disturbance to most species of waterbirds we studied in Florida. We recommend follow-up studies to test our buffer distances for other species and disturbance situations.

Key words all-terrain vehicle, automobile, buffer zone, Charadriiformes, Ciconiiformes, Florida, guidelines, motor boat, pedestrian traffic, Pelecaniformes, set-back distance, shorebirds, waterbirds

Wildlife disturbance and harassment may reduce species diversity and density at the landscape or regional scale (Boyle and Samson 1985, Cole and Knight 1990). As foraging habitat becomes fragmented and human disturbances increase, more skittish species may find it difficult to secure adequate food or loafing sites (Skagen et al. 1991, Pfister et al. 1992). Conflicts arise because many aquatic habitats

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used by foraging waterbirds (e.g., shorelines, beaches, sandbars, islands) are attractive to outdoor recreationists. For example, Burger (1981) found a reduced number of shorebirds near people who were walking or jogging and about 50% of flushed birds were forced elsewhere. Boyle and Samson (1985) found wildlife observers were especially disturbing to animals because of the frequency and duration of their visits. Human disturbances can indirectly (Skagen et al. 1991, Pfister et al. 1992) or overtly (Knight and Skagen 1988, Cole and Knight 1990) disrupt wildlife community dynamics.

Several studies have suggested that distance to human disturbance was a major factor in determining if and when birds flushed and recommended not approaching wildlife or reducing the frequency of disturbances (Burger 1981; Belanger and Bedard 1989; Burger and Gochfeld 1991*a,b*; Grubb and King 1991; Klein 1993; Roberts and Evans 1993). Burger and Gochfeld (1991*a*) found foraging time of sanderlings (*Calidris alba*) decreased and avoidance (e.g., running, flushing) near human activities increased as the number of humans within 100 m increased. Knight and Knight (1984) suggested that flight distances of birds flushed by different types of disturbances could be used to develop zones for restricting human activities. Such buffer zones or set-back distances are 1 strategy to minimize effects of human disturbance to wildlife (Erwin 1989, Rodgers and Smith 1995). Previous recommendations for buffer zones to protect waterbirds have been primarily implemented around breeding colonies and have ranged from 50 to 200 m for tern (Sterninae spp.; Buckley and Buckley 1976, Erwin 1989, Rodgers and Smith 1995) and from 100 to 250 m for wading bird (Ardeidae spp.; Vos et al. 1985, Erwin 1989, Rodgers and Smith 1995). Although Florida began using buffer zones to protect waterbird nesting sites from human disturbances in 1976, distances of buffer zones used by natural resource personnel to protect breeding colonies have only recently been developed on the basis of regional empirical data and recommendations (Rodgers and Smith 1995). However, no specific recommendations for buffer zones have been available to reduce disturbance to foraging and loafing birds.

Our objective was to recommend buffer distances that minimize human disturbance to foraging and loafing waterbirds. We used a technique previously developed for nesting waterbirds in Florida (Rodgers and Smith 1995). To calculate appropriate buffers, we measured flushing distances for 16 species of foraging and loafing waterbirds in response to 4 different types of human disturbances (walking, all-terrain vehicle, automobile, boat). Florida is an important area for providing resident waterbird habitat, winter shorebird refugia, and staging areas for migrating species along both coasts. Pedestrian, all-terrain vehicle (ATV), automobile, and boat traffic are the most frequent forms of human disturbance to waterbirds in Florida, especially at coastal sites.

Study area

We collected data for 9 species of wading birds (Pelecaniformes spp., Ciconiiformes spp.) and 7 species of shorebirds (Charadiiformes spp.) at 24 areas in north and central Florida (Table 1). Sites were chosen randomly with a mix of low, moderate, and high amounts of human activity.

Methods

Data were collected intensively during 1989–1992 and intermittently during 1994–1995. Four types of human disturbance were used to elicit flushing responses: (1) walking (continuous [1 step/sec], direct approach by 1–2 people on foot); (2) all-terrain vehicle (continuous [2.5 m/sec], direct approach by 2 people on a red 350-cc, 4-wheel ATV [noise level 75–80 dBA]); (3) automobile (continuous [2.5 m/sec], direct approach by 2 people in a green half-ton truck [noise level 70–75 dBA]); and (4) motorboat (continuous [0.5–1.0 m/sec], direct approach by 2 people in an olive-green 4.3-m [14 feet], aluminum jon-boat with a 30-hp outboard motor [noise level 80–85 dBA]). Because it was difficult to quantify the initial alert response distance to a disturbance, we used the more readily detected and easily measured flushing distance as an index of disturbance. Flushing distance was defined as the distance from the observer to the bird at the moment it actually began movement away from the approaching disturbance. When approaching a group of birds, we measured distance from the first bird in the group to flush. The distance between the observer and the bird was measured in meters using optical range finders with calibrated accuracies of ±0.5 m (≤30 m) to ±2.0 m (>30 m).

We restricted data collection to between 0700–1600 hours on clear to partly cloudy days, with wind conditions <15 km/hour. To reduce the effect of autocorrelation between the first bird flushing and subsequent flushing events and to minimize our impacts on avian activities, we limited the number of disturbances to 1 or 2 events/species at each site during a visit. Flushing distances for individual birds or flocks were measured only once. Because of these restrictions, sample sizes were unbalanced among species,

Table 1. Study areas in Florida where flush distances were measured in response to 4 types of disturbances.

Site	Habitat description	Disturbance type	Relative impact of human activity
Amelia Island	Beach shoreline	Walk, all-terrain	Moderate
Anastasia Island	Beach shoreline	All-terrain	Moderate
Crescent Beach	Beach shoreline	Automobile	High
Dee Dot Ranch	Freshwater lake shoreline	Automobile, boat	Low
Ft. Pierce	Coastal sandbar	Walk, boat	Low
Gainesville	Isolated freshwater marshes	Walk	Low
Haulover	Coastal marshes and shoreline	Walk, boat	Low
Huguenot Beach	Beach shoreline	Walk, all-terrain	Low
Lake Kissimmee	Freshwater lake shoreline	Walk, boat	Low
Lake Jackson	Freshwater lake shoreline	Walk	Low
Matanzas Beach	Beach shoreline	Walk, all-terrain	Moderate
Merritt Island	Coastal marshes and shoreline	Walk, automobile	Moderate
Ochlocknee Bay	Coastal and freshwater marshes	Walk	Low
Pelican Island	Coastal island shoreline	Walk, boat	Low
Phipps Point	Coastal shoreline	Walk	Low
Ponte Vedra Beach	Beach shoreline	Walk, all-terrain	High
Port Orange	Coastal shoreline	Walk, boat	Moderate
St. Augustine	Coastal shoreline	Boat	Moderate
St. Augustine Beach	Beach shoreline	All-terrain, automobile	High
St. George Island	Causeway shoreline	Walk	Low
St. Marks	Coastal marshes	Walk	Low
Tallahassee	Isolated freshwater ponds	Walk	Low
Tampa Bay	Coastal shoreline	Walk, boat	Moderate
Vilano Beach	Beach shoreline	Walk, all-terrain	High

age classes, and types of disturbances (i.e., not all combinations were represented by sample sizes ≥10). We plotted empirical quantiles against the quantiles of a standard normal distribution and histograms for untransformed flushing distances for species with ≥10 observations using the UNIVARIATE procedure (SAS Inst., Inc. 1990). The Shapiro-Wilk statistic was used to test whether the data were normally distributed for each species x disturbance. Ten of 16 species had normally distributed data, but the remaining 6 had right-skewed data. Log transformation normalized the data for these 6 species. Residuals from an ANOVA model plotted against the predicted values yielded a random scatter that suggested homogeneity of variance for the log-transformed flushing distances.

Black skimmer loafing and shorebirds foraging at a coastal site in Florida. Photo by S. T. Schwikert.

We used an ANOVA/Fisher's protected least-significant-difference test on subsets (i.e., species x disturbance, species x species x disturbance, species x age class x disturbance) to test for differences in flushing distances among species for the same type of disturbance. We were able to collect enough data for 3 species to compare flushing distances between adults and subadults to a walking approach. No significant differences (t-test, $P > 0.05$) were detected between adult and subadult brown pelican (*Pelecanus occidentalis*), little blue heron (*Egretta caerulea*), and tricolored heron (*E. tricolor*) age classes. Thus, we pooled data for these species and did the same for other age classes of species with $n < 10$. However, significant differences among the species x disturbance prevented pooling these data (Table 2).

We recommended buffer distances for individual species using the mean and standard deviation of sampled populations (Rodgers and Smith 1995). Because of concurrent activity of other birds or reactions to prey, we could not always determine when the bird under observation first exhibited a response

Table 2. Flush distances and recommended buffer distances for nonbreeding waterbirds reacting to 4 types of human disturbances.

Disturbance	Species	Flush distance (m)			Recommended buffer (m)[b]
		n	$\bar{x}$[a]	SD	
Walking	Brown pelican (*Pelecanus occidentalis*)	21	27.38	14.77 A B	107
	Double-crested cormorant (*Phalacrocorax auritus*)	15	31.27	12.90 A B	102
	Great blue heron (*Ardea herodias*)	18	30.57	12.39 A B	100
	Great egret (*Ardea alba*)	28	30.55	9.62 A B	91
	Little blue heron (*Egretta caerulea*)	18	23.02	14.29 A B	104
	Snowy egret (*Egretta thula*)	19	26.81	9.27 A B	87
	Tricolored heron (*Egretta tricolor*)	24	24.09	8.18 A B	82
	Willet (*Catoptrophorus semipalmatus*)	12	20.61	6.26 B C	74
	Sanderling (*Calidris alba*)	13	13.73	4.88 C	67
	Ring-billed gull (*Larus delawarensis*)	12	33.80	8.42 A	91
	Black skimmer (*Rynchops niger*)	29	26.63	8.33 A B	85
All-terrain vehicle	Semipalmated plover (*Charadrius semipalmatus*)	24	19.95	7.24 B	76
	Willet (*Catoptrophorus semipalmatus*)	30	19.27	6.41 B C	73
	Ruddy turnstone (*Arenaria interpres*)	35	14.80	6.82 C	72
	Sanderling (*Calidris alba*)	39	14.97	6.10 B C	69
	Ring-billed gull (*Larus delawarensis*)	20	31.84	12.70 A	101
Automobile	Western sandpiper (*Calidris mauri*)	44	18.66	4.45 B	68
	Willet (*Catoptrophorus semipalmatus*)	25	24.24	6.19 A	77
	Ring-billed gull (*Larus delawarensis*)	36	22.04	9.30 A B	84
Motor boat	Brown pelican (*Pelecanus occidentalis*)	22	34.48	19.17 A B	126
	Anhinga (*Anhinga anhinga*)	12	37.40	17.40 A	120
	Great egret (*Ardea alba*)	11	36.05	13.60 A B	107
	Wood stork (*Mycteria americana*)	19	26.47	5.49 B	77

[a] Means with the same letter, within the same disturbance type, are not different ($P > 0.05$, ANOVA, Fisher's protected least significant difference test).

[b] Buffer distance was calculated by using the formula: distance = exp ($\hat{\mu}$ + 1.6495 $\hat{\sigma}$) + 40 m. Values were rounded to the nearest meter.

to our disturbance. Based on our previous observations from blinds (Rodgers and Smith 1995), single birds approached by a walking person became alert 25–40 m prior to flushing. The addition of 40 m to the flushing distances of our sampled populations would be a conservative approach to minimize agonistic responses by birds and take into consideration the suggestion by Thompson and Thompson (1985) that mixed-species assemblages are more vigilant and skittish than single-species groups.

Buffer distances were derived in the following manner. For a given species, let X_i represent the observed flushing distance for an individual approach i, and $Y_i = \ln(X_i)$. We assumed that the X_i were independent, identically distributed, and followed a lognormal distribution with parameters μ and σ such that $\mu = E(Y_i)$ and $\sigma^2 = var(Y_i)$. The desired buffer distance was defined as the upper limit of an approximate 95% 1-sided confidence interval for E(X) + 40 m. That is

$$\text{buffer distance} = \exp(\ + Z_{0.95}\ ) + 40 \text{ m},$$

where μ was the sample mean and σ was the standard deviation for the observed values of $Y_i = \ln(X_i)$, $i = 1, \ldots, n$, and $Z_{0.95}$ was the 0.95 quantile of a standard normal variable (i.e., $Z_{0.95} = 1.6495$). We believe that the 95% criterion provides a sufficiently conservative margin in the establishment of buffer zones for waterbirds.

Results

Walk approach

Ring-billed gulls (*Larus delawarensis*) had the largest mean flushing distance ($\bar{x}$ = 33.80 m) and sanderlings had the smallest mean ($\bar{x}$ = 13.73 m) among 11 species exposed to a walk approach (Table 2). There was a tendency for shorebirds (e.g., sanderling, willet) to flush at shorter distances and pelecaniform and ciconiiform birds to flush at longer distances.

ATV approach

Ring-billed gulls exhibited the largest mean flushing distance ($\bar{x}$ = 31.84 m), whereas ruddy turnstones (*Arenaria interpres*) had the smallest mean ($\bar{x}$ =

14.80 m) among the 5 species exposed to an ATV approach (Table 2). As in the walk approach, ring-billed gulls had the largest mean flushing distance among the species sampled.

Automobile approach

Willets (*Catoptrophorus semipalmatus*) exhibited the largest mean flushing distance ($\bar{x}$ = 24.24 m), whereas western sandpipers (*C. mauri*) had the smallest mean ($\bar{x}$ = 18.66 m) among the 3 species exposed to an automobile approach (Table 2).

Boat approach

Anhingas (*Anhinga anhinga*) exhibited the largest mean flushing distance ($\bar{x}$ = 37.40 m) and wood storks (*Mycteria americana*) had the smallest mean ($\bar{x}$ = 26.47 m) among the 4 species exposed to a boat disturbance (Table 2).

Comparisons among disturbance methods

There were no significant (*t*-test, $P > 0.05$) differences in the flushing distances of brown pelicans to boat ($\bar{x}$ = 34.48 m) and walk ($\bar{x}$ = 27.38 m) approaches or in sanderlings to ATV ($\bar{x}$ = 14.97 m) and walk ($\bar{x}$ = 13.73 m) approaches. Willets exhibited no significant (*t*-test, $P > 0.05$) difference to automobile ($\bar{x}$ = 24.24 m) and walk ($\bar{x}$ = 20.61 m) approaches, and between walk and ATV ($\bar{x}$ = 19.27 m) approaches, but there was a significant (*t*-test, $P < 0.05$) difference between automobile and ATV approaches. Ring-billed gulls exhibited the most variation in flushing distances to the 4 types of disturbances. Whereas no significant (*t*-test, $P > 0.05$) difference was detected between walk ($\bar{x}$ = 33.80 m) and ATV ($\bar{x}$ = 31.84 m) approaches, there was a significant (*t*-test, $P < 0.05$) difference between automobile ($\bar{x}$ = 22.04 m) and ATV approaches and between walk and automobile approaches. Thus, 3 of 8 species comparisons were significantly different, and 5 were not significantly different.

Discussion

Our study showed species varied in their responses to the same disturbance, especially with walk and ATV approaches. Shorebirds often had the shortest flushing distances. The 1 surprising exception was the ring-billed gull; this species exhibited greater flushing distances when approached by ATV or walking disturbances than anticipated, considering its close association with human activities in Florida. Brown pelicans also flushed at relatively large distances considering the species' small flushing distances (Rodgers and Smith 1995) while nesting and association with human activities along Florida's coasts. Burger (1981) also reported interspecific variation among waterbirds: she suggested gulls and terns were the least disturbed of the species studied possibly due to habituation to human activities, while herons and other shorebirds were more easily flushed possibly because they were migrant species that rarely interacted with humans. Differences in Burger's (1981) and our observations regarding flushing distances of shorebirds suggest regional differences in species' responses to similar disturbances or habituation along migratory routes. We also did not observe shorter flushing distances for larger species of birds in Florida as reported by Burger and Gochfeld (1991*b*) in India.

Foraging and loafing wood storks at a coastal site in Florida. Photo by S. A. Nesbitt.

We compared the flushing distances of foraging and loafing birds with the results of our previous study of nesting birds (Rodgers and Smith 1995). Three of 9 species comparisons (walk towards double-crested cormorants [*Phalacrocorax auritus*], great blue herons [*Ardea herodias*], and great egrets [*A. alba*]) were not significantly (*t*-test, $P > 0.05$) different in their flushing distances while foraging or loafing compared to flushing distances when they were nesting (Table 3). However, 5 comparisons (brown pelicans [walk and boat], anhingas [boat], great egrets [boat], wood storks [boat]) exhibited significantly greater flushing distances while foraging or loafing compared to flushing distances while nesting. Only tricolored herons exhibited significantly (*t*-test, $P < 0.01$) greater flushing distances while nesting compared to nonnesting when exposed to walking approaches. Grubb and King (1991) also found that bald eagles (*Haliaeetus leucocephalus*) more often flushed from perches than nests and more easily flushed while foraging than while nesting.

Waterbirds are vulnerable to human disturbances when they are nesting or foraging. However, failure

Table 3. Comparison of flush distances of nesting and nonbreeding birds.

Species	Disturbance	Mean flushing distance (m)		Difference[b]
		Nesting[a]	Nonnesting	
Brown pelican	Boat	9.4	34.5	$P < 0.01$
Brown pelican	Walk	19.2	27.4	$P < 0.01$
Double-crested cormorant	Walk	27.8	31.3	n.s.
Anhinga	Boat	23.6	37.4	$P < 0.01$
Great blue heron	Walk	32.0	30.6	n.s.
Great egret	Boat	28.9	36.1	$P < 0.01$
Great egret	Walk	28.3	30.6	n.s.
Tricolored heron	Walk	31.5	24.1	$P < 0.01$
Wood stork	Boat	14.8	26.5	$P < 0.02$

[a] Data for nesting birds from Rodgers and Smith (1995).
[b] *t*-test performed on log-transformed data.

to protect a nest and its contents from a potential predator or disturbance carries a much greater cost than failure to defend a loafing site or temporary source of food. Nest protection ensures survival of some progeny and reduces the expenditure of energy associated with flushing by parents when exposed to low threshold disturbances. However, waterbirds do not exhibit strong site fidelity while foraging or loafing. Fleeing a disturbance at a foraging or loafing site allows a bird to return later if the disturbance abates. If the larger flushing distances we found for several species are characteristic of foraging or loafing birds in general, then establishing buffer zones around critical or frequently used foraging and loafing sites of resident birds is important. In a study of snow geese (*Chen caerulescens*), Belanger and Bedard (1990) found that human disturbance increased energy expenditure by the birds (via flight and alertness) and reduced their energy intake (via lower feeding rates). Similarly, historical waterbird staging areas along migratory corridors may merit protection to reduce disturbance. Finally, access by birds to disturbance-free foraging areas to secure food for nestlings may be as important as disturbance-free breeding sites with suitable nesting substrate in determining the stability of a population or colony.

Management implications

We believe the most sensitive species (i.e., the most skittish species with the greatest flushing distance) should be used to determine the buffer zones for mixed-species groups of birds at foraging and loafing sites. Based on the mean plus 1.6495 standard deviations of the observed flushing distances plus 40 m (buffer distance = $\exp[\mu + 1.6495\sigma] + 40$), a zone of about 100 m should be adequate to buffer foraging and loafing sites for most of the waterbird populations we studied in Florida (Table 2). Species exposed to several disturbances will require the largest of the calculated buffer distances (e.g., brown pelicans exposed to walk and boat approaches). Association with mixed-species aggregations may even increase the flushing distances for some species (Thompson and Thompson 1985).

Previously, we urged caution in applying nesting-bird buffer distances until further research substantiated our previous recommendations (Rodgers and Smith 1995:97). Similarly, we urge conservation personnel to use discretion when implementing the buffer distances in Table 2. Other species or local populations may be more or less sensitive than those in our study (Burger and Gochfeld 1991*b*). Mitigation also may be possible to shorten buffer distances when physical barriers prevent direct visual contact between birds and disturbances with low noise levels. Furthermore, some evidence suggests that a tangential approach by a disturbance may elicit less response and allow for a shorter buffer distance (Burger and Gochfeld 1981, Rodgers and Smith 1995). Conservation personnel should monitor changes in species composition to adjust buffer distances to reflect the presence of new, more sensitive species with larger flushing distances. It may prove difficult or impractical to post a single site with 2 buffer distances corresponding to nesting and nonnesting times of the year. Buffer distances indicated for nonnesting ciconiiform and pelecaniform birds should be adequate to protect nesting birds from human disturbance.

We recommend additional research to examine the effects of variable approach speeds (especially rapid, erratic movements), tangential approaches, presence of seasonal variation in response to disturbance, and other types of disturbances (e.g., jet-ski vehicles). We realize there are limits to our method of calculating the buffer distances for each species and that the values are somewhat subjective. Because of the variation in flushing distances among individual birds and species, it may be necessary to develop buffer distances on a regional basis. However, we believe the principles and techniques discussed here may be applied elsewhere and serve as a general model for specific buffer-distance design for each species, location, and type of disturbance.

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