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HUMAN DISTURBANCE OF SNOWY PLOVERS *(Charadrius nivosus)* IN NORTHWEST FLORIDA DURING THE BREEDING SEASON

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Abstract.—Snowy Plovers (*Charadrius nivosus*), a state-threatened shorebird in Florida, are subject to human-caused disturbance due to the proximity of their habitat to development and recreation. The degree to which human disturbance is a limiting factor for reproduction is unknown, and even basic data on disturbance rates and behavioral responses are lacking. Fencing often protects nesting areas from disturbance, but foraging and brood-rearing areas are typically unprotected. We measured rates of disturbance in plover habitat and response distances in Northwest Florida in 2010, using focal observations and track counts for unprotected foraging sites and brood-rearing sites as well as protected nest sites. Our results suggested that a 40-m buffer could prevent flushing of foraging adults by pedestrians, while a 50-m buffer could prevent alertness responses by incubating adults to pedestrians and vehicles. Foraging adults were more sensitive to humans than to potential competitors and predators, and chicks did not respond to potential disturbances except for in one observation where a pedestrian approached within 10 m. Current 50-m buffers appear adequate to prevent incubating birds from being flushed by humans in our study area. Consequences of disturbance to foraging adults require further evaluation. Chicks may be susceptible to mortality due to vehicles because they did not exhibit disturbance responses to vehicles as close as 10 m.

Beach-nesting birds often are negatively affected by human recreation and coastal development (Fleming et al. 1988, Burger 1990, Weston and Elgar 2007). Human impacts include habitat loss, disturbance, destruction of nests or chicks, and increased predation by domestic and human-commensal predators that can affect survival, dispersal, breeding behavior, and productivity (Ruhlen et al. 2003, Cohen et al. 2009, Engeman et al. 2010). Snowy Plovers (*Charadrius nivosus*), which breed and winter along the U.S. Gulf Coast, are state-listed as threatened in Florida, with human development and recreation identified as primary threats (Himes et al. 2006). Estimates of breeding plover numbers in Florida in recent decades have remained relatively stable but low, at between 200 and 225 pairs in the state (Himes et al. 2006). Much of the historic nesting habitat for plovers on the southwest Florida coast has been lost to development, with the majority of the current population nesting in northwest Florida. Nest sites of Snowy Plovers in Florida often are protected with symbolic fencing (signed posts connected with roping in the highest human use areas) to prevent disturbance and direct mortality by humans, but foraging and brood-rearing areas in the region typically are not protected from human disturbance. The Florida population of Snowy Plovers is not protected by federal endangered species law, under which disturbance to nesting birds often is considered a violation regardless of demographic effects, and the state's endangered species act prohibits only direct intentional physical harm. However, several natural resource management agencies in Florida with jurisdiction over beach-nesting bird habitat have made the provision of low-disturbance areas for breeding part of their policy. The success of their specific management strategies in preventing the behavioral and demographic impacts of disturbance has yet to be fully evaluated.

In 88% of studies published from 1978-2010 on the effect of non-motorized recreation on birds, a negative impact to physiology, behavior, abundance, or reproductive success was documented (review by Steven et al. 2011). Shorebirds in particular have been found to be more sensitive to disturbance than other waterbirds, often vacating an area completely when other species flush a shorter distance or remain at the site (Burger 1981). For Snowy Plovers, survival of chicks in California was found to be greater on weekdays than weekends, implying a negative effect of human recreation (Ruhlen et al. 2003). Nonbreeding Snowy Plovers in California failed to acclimate to human disturbance over short observation periods, and had lower foraging rates in the presence of human activity than when undisturbed (Lafferty 2001). Human disturbance has long been documented as a factor affecting habitat use and foraging behavior in the closely-related Piping Plover (*C. melodus*) (Burger 1990, Hoopes 1993, Goldin and Regosin 1998), and has been demonstrated to contribute to lower reproductive success (Flemming et al. 1988, Strauss 1990, Goldin 1993). Limiting disturbance by fencing nesting areas or closing parts of beaches to human use has been a major part of the successful recovery strategy for Piping Plovers (Hecht and Melvin 2009). Data is lacking on the effects of human disturbance on Snowy Plovers on the Florida Panhandle, and better information on setback distances for disturbance sources may help managers to reduce disturbance if it appears to be affecting time spent foraging or attending nests or young, or if it is affecting reproductive success.

The objectives of our study were 1) to determine rates of disturbance to incubating, brood-rearing, and foraging plovers in the Florida Panhandle, and 2) to determine the distances at which plovers engaged in different behaviors react to anthropogenic and natural disturbance. Our study provided the first examination of the sensitivity to human activities of adult Florida Snowy Plovers engaged in behavior other than incubation and brood-rearing, and aimed at guidance for beach management to protect and recover this species.

METHODS

Study Area

We studied plover disturbance response at nesting beaches within Camp Helen State Park (30.26980° N, 85.99465° W), Deer Lake State Park (30.30173° N, 86.08143° W), Topsail Hill Preserve State Park (30.36571° N, 86.29820° W), Water Sound Conservation Area (30.29773° N, 86.06893° W), and John C. Phipps Preserve (29.91087° N, 84.43590° W). The sites represented a range of potential disturbance levels, based on local expert opinion and our previous experience monitoring beach nesting birds (Camp Helen and Water Sound = high disturbance, Topsail, Deer Lake, and Phipps = low by comparison). Camp Helen, Water Sound, Deer Lake, and Topsail are mainland beaches with extensive dune systems and coastal dune lakes with temporary inlets. Phipps Preserve is a small barrier peninsula with narrow beaches and patchy, small dunes. The high disturbance sites had pedestrian footpaths bisecting the nesting areas.

At Camp Helen, Deer Lake, Water Sound, and Topsail, Snowy Plovers nest in open, sparsely vegetated interdune and upper beach areas, and forage on Gulf and inlet shorelines and in ephemeral pools. At John C. Phipps Preserve, Snowy Plovers nest in small, isolated pockets of sparse vegetation surrounded by small dunes, and forage on bay and Gulf shorelines.

Disturbance Source Counts

We recorded the presence of potential disturbance sources within 100 m of at least one member of each Snowy Plover (hereafter “plover”) pair in the study area at least once per two week period from 10 May to 31 July, 2010. Observations were typically made from 40 m to 60 m away. Each day, we selected one or more focal birds, ideally until both individuals of all known pairs were sampled within the 2 week period, at which point we replaced all birds for the next round of sampling. If pair members were found together, we collected data first on one, then the other when possible. For birds that were not uniquely banded, we identified sex by darkness of the black in the plumage. Observations were only collected on those unbanded individuals that could be identified based on territory location, age of brood, or association with a banded bird. When a focal bird was located, one observer watched it to keep track of its location, while a second recorded all potential disturbance sources within a 100-m radius circle of the initial location of the focal bird for 10 min. We did not record behavioral responses during these 10-min observations. Disturbance source (with subcategories) included pedestrians (walking, jogging, swimming, ball-playing, kite-flying, resting, fishing), dogs (leashed, unleashed), parked or moving off-road vehicles (ORV) and all-terrain vehicles (ATV), moored or moving vessels, and potential predators [coyotes (*Canis latrans*), raccoons (*Procyon lotor*), domestic cats (*Felis sylvestris*), raptors, crows (*Corvus* spp.), gulls (*Larus* spp.), and other] and competitors (terns and shorebirds including conspecifics). We recorded the time that each disturbance source entered and left the 100-m radius circle so that total disturbance minutes, as well as total unique sources, could be calculated.

Disturbance Responses

After completion of the 10-min disturbance source counts, we recorded responses of the focal bird to disturbance sources continuously for up to 30 min (Altmann 1974). In addition to the disturbance sources recorded during the 10-min counts, we recorded focal bird responses to potential competitors (shorebirds and terns including conspecifics). We discarded all observations where focal birds were not in view for at least 20 min. We recorded the age (adult or chick), sex if known, and initial behavior (foraging, resting, incubating, brooding) of the focal plover. For each potential disturbance source causing a response, we recorded the distance (m) at which the focal bird first exhibited a response and the response type: alertness (upright posture, cessation of prior activity), displacement (movement away from disturbance source), and distress or aggression (crouched charge, alarm calls, distraction displays). If no response was elicited by a potential disturbance source, we recorded the minimum distance between the bird and the disturbance source that occurred during the observation. If a bird exhibited more than one response to a potential disturbance source, the most extreme response (Distress/Aggression > Displacement > Alertness) was used in the analysis. Distances were measured using range finders where possible, otherwise they were visually estimated. All observers were trained in visual distance estimation in the field, using objects set at known distances apart.

Track Evidence

After each 30-min behavioral observation, we recorded track evidence of the presence of human and other disturbance sources as a second method of comparing sites. We walked three transects perpendicular to the water line, from the water's edge to the landward edge of plover habitat (e.g., dense vegetation, human structures), sampling tracks in the sand as we walked and categorizing each type as "fresh" or "old" based on apparent wear, where fresh tracks would likely have been laid down within a day of our observation. The first transect was centered on the initial location of the focal bird. The other two transects were 100 m to either side. We recorded tracks of potential disturbance sources each time our toe touched tracks, and for each potential disturbance source we calculated an index of potential disturbance as "total toe-hits on all three transects" / "total paces on all three transects", which is an indicator of the proportion of the substrate covered by tracks, and can be multiplied by 100 to indicate a percentage (Hays et al. 1991). Combining transects in this way avoided pseudoreplication while allowing us to account for variability within each sampling plot. Unidentifiable tracks were scored as "unknown". With the exception of Phipps which was of low elevation and overwashed frequently, our sites were similar in elevation, aspect, and exposure to tides and weather, so track persistence was likely to be similar among them. At all sites, we assumed that fresh tracks in the intertidal zones were distinguishable from older tracks that would be removed by the daily high tides.

Statistical Analysis

We used SAS (SAS institute, Cary, North Carolina) for all analyses. We used negative-binomial ANOVA controlling for the fixed effect of "pair" to compare the mean disturbance count-minutes among low and high disturbance sites (models did not converge when pair was used as a random effect, possibly due to small sample size). We used mixed logistic regression with a random pair effect to compare track indices among low and high disturbance sites (event = toe intersects a track, trial = toe hits the ground). We used mixed multinomial logistic regression (McFadden 1974) to estimate response distance curves (the relationship between the probability of different responses and distance to potential disturbance sources) by age and initial behavior, where the random effect was "individual". We used mixed effects logistic regression to determine if response probabilities differed among sites.

RESULTS

Disturbance Counts

We collected data on 17 plovers from 13 pairs across five sites. Some plovers carried leg bands from previous studies and were individually identifiable, and some were identified based on territory. Pedestrian-minutes within 100 m of plover locations were higher at *a priori*-designated high disturbance sites (Camp Helen and Water Sound) than at two of the low disturbance sites (Deer Lake and Phipps, Table 1). Mean vehicle-minutes and predator-minutes were near zero or had high variance, and did not differ among sites.

Track Counts

Fresh (< 1 day old) pedestrian tracks covered < 6.2% of the sandy substrate on average at all sites, but covered a greater proportion of the beach at pre-designated high disturbance sites than at low disturbance sites (mixed logistic regression with random pair effect, $F_{4,12} = 5.11$, $P = 0.012$). Tractor, ATV, and ORV tracks were present at all sites and

Table 1. Disturbance source count-minutes (total minute disturbance sources were within 100 m of focal birds) in Snowy Plover (SNPL) habitat, Florida, 2010.

			Disturbance Source Minutes					
			Pedestrian		ATV/ORV[b]		Predator	
Site	SNPL Pairs	Num. obs.	Mean[a]	SE	Mean	SE	Mean	SE
Camp Helen	5	32	29.4 A	8.2	0.00	1.54	0.00	1.10
Watersound	2	6	39.1 A	29.6	0.00	0.39	5.40	7.70
Topsail	1	2	12.0 AB	11.8	1.00	1.04	10.50	18.70
Deer Lake	3	11	3.8 B	2.3	0.36	0.24	2.10	2.20
Phipps	2	2	0.0 B	0.0	0.00	0.00	10.00	17.80

[a]Means with the same capital letter are not significantly different, negative binomial Analysis of Variance controlled for fixed effect of bird, $F4,43 = 4.59$, $P = 0.050$. There were no significant differences in ATV/ORV or Predator disturbance-minutes among sites ($P > 0.050$).
[b]ATV = All-terrain vehicle, ORV = off-road vehicle (i.e., trucks)

were related to cleanup of the Deepwater Horizon oil spill; <5.4% of the beach was covered on average at all sites. Old (> 1 day old) ATV tracks covered a greater proportion of the beach at high disturbance sites than low disturbance sites (mixed logistic regression with random pair effect, $F_{4,12} = 6.63$, $P = 0.004$). Potential predator tracks were detected too rarely using our method to be of use for analyses.

Disturbance Responses

All foraging plovers in our study were outside symbolically-fenced protected areas. Behavioral responses of plovers to pedestrians depended on the distance to pedestrians (mixed multinomial logistic regression with generalized-logit link and random effect of individual, $F_{2,123} = 8.08$, $P < 0.001$, $n = 147$ observations of 14 birds). Pedestrians within 20 m of a foraging adult plover were >50% likely to displace the focal bird (Fig. 1). The probability of displacement decreased to near 0% for pedestrians > 40 m from the focal bird, based on our model prediction (Fig. 1).

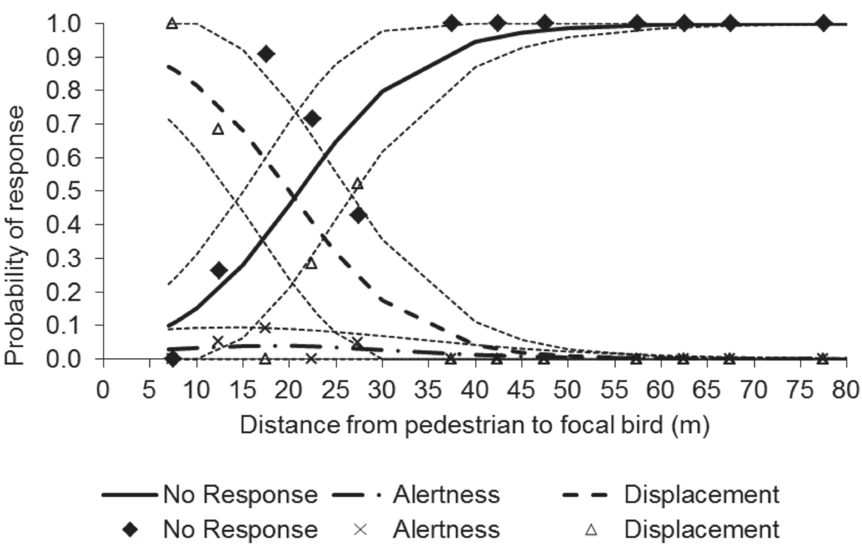

Figure 1. Probability of the most severe response of foraging Snowy Plovers to pedestrians being "none", "alertness", or "displacement" vs. distance to the pedestrian in the Florida Panhandle, 2010. The point symbols are the observed means (the mean proportion of responses of a particular type binned within 5-m categories of distance). The heavy lines are predicted probabilities of response from the best model: (mixed multinomial logistic regression with generalized-logit link and random effect of individual, $F_{2,123} = 8.08$, $P < 0.001$, $n = 147$ observations, $N = 14$ birds). The light dashed lines are 95% confidence intervals around the prediction lines.

Behavioral response to potential competitor species did not significantly depend on distance ($F_{1,72}$ = 2.00, P < 0.162, n = 72 observations of 14 birds). However, potential competitors (terns and shorebirds including conspecifics) elicited disturbance responses only when within 10 m (Fig. 2).

We found no other significant relationships between distance to non-pedestrian disturbance sources and responses of foraging plovers at α = 0.05, but we observed few potential interactions. Of eight potential encounters of foraging adults with ORVs, the most severe response was alertness one time (at 30 m), and displacement four times (at 0.5 to 25 m). Of 49 potential interactions with predators, foraging plovers were displaced four times (at 15 and 90 m) and exhibited distress once (at 5 m).

In 14 of 17 30-min observations of resting birds, the focal animal was outside of protective fencing. Response rates of resting birds in our study

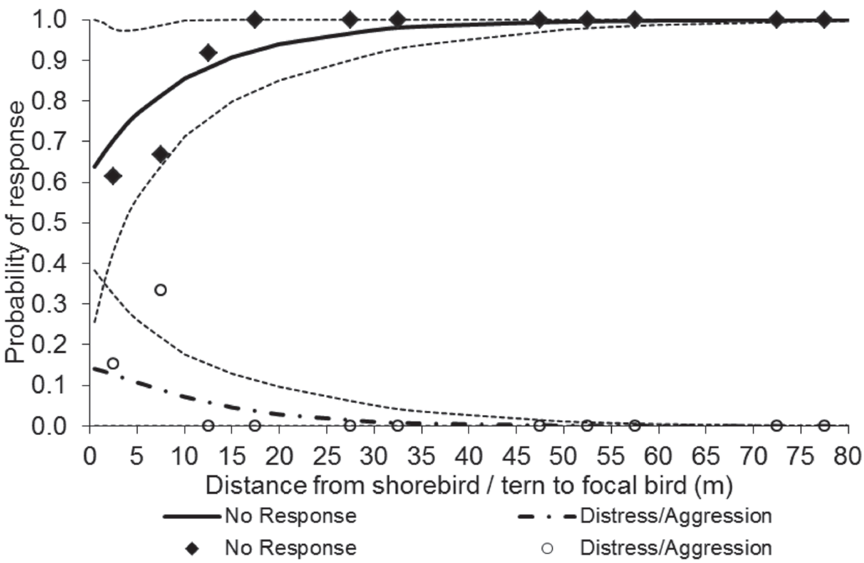

Figure 2. Probability of the most severe response of foraging Snowy Plovers to potential competitors (terns and shorebirds including other Snowy Plovers) being "none" or "distress/aggression" *vs.* distance to the potential competitor in the Florida Panhandle, 2010. The point symbols are the observed mean (the mean proportion of responses of a particular type binned within 5-m categories of distance). The heavy lines are predicted probabilities of response from the model (mixed multinomial logistic regression with generalized-logit link and random effect of individual, $F_{1,72}$ = 2.00, P < 0.162, n = 72 observations, N = 14 birds). The light dashed lines are 95% confidence intervals around the prediction lines.

did not show any relationship with distance to disturbance sources. Of 42 encounters with pedestrians, 62% elicited no response, 23% elicited alertness, and 15% caused displacement (median distance between pedestrian and bird = 10 m). Of 5 encounters with ORVs, 2 elicited no response, 3 elicited alertness, and 1 caused displacement (median distance = 10 m). Of 54 encounters with potential predators, 1 elicited alertness and 1 caused displacement, and the rest did not elicit a response (median distance = 25 m). Of 97 encounters with conspecifics or other shorebirds or terns, none elicited any response (median distance = 20 m).

All incubating plovers in our study were inside symbolically-fenced areas, and pedestrians and vehicles were outside. Incubating plovers demonstrated alertness to the presence of pedestrians, depending on distance ($F_{1,85}$ = 5.55, P = 0.023, n = 87 observations of 14 birds). We did not observe any responses to pedestrians more severe than alertness. Although our model predicts a smooth decline in alertness rate with distance, we did not actually observe any responses to pedestrians > 50 m from the focal animal (Fig. 3).

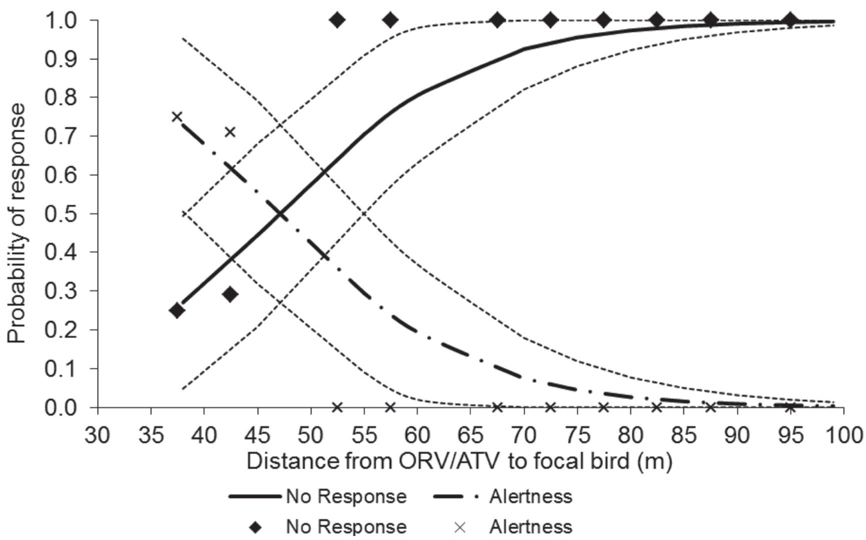

Figure 3. Probability of the most severe response of incubating Snowy Plovers to pedestrians being "none" or "alertness" vs. distance to the pedestrian in the Florida Panhandle, 2010. The point symbols are the observed means (the mean proportion of responses of a particular type within 5-m categories of distance). The heavy lines are predicted probabilities of response from the model: (mixed multinomial logistic regression with generalized-logit link and random effect of individual, $F_{1,85}$ = 5.55, P = 0.023, n = 87 observations, N = 14 birds). The light dashed lines are 95% confidence intervals around the prediction lines.

Incubating plovers also were alert to the presence of vehicles, depending on distance ($F_{1,55} = 6.20$, $P = 0.016$, $n = 63$ observations of 14 birds). As with pedestrians, ORVs and ATVs did not elicit any response more severe than alertness. Predicted response rate declined smoothly with distance, although we did not observe any responses to vehicles > 60 m from the focal bird (Fig. 4).

We did not find a distance-dependent response of incubating plovers to predators. Of 40 potential interactions, 38 caused no response (distances ranged from 5 – 99 m). One crow caused displacement at 45-50 m (10% of the observations in that distance category), and one crow caused distress/aggression at 65-70 m (50% of the observations in that distance category). Of 33 potential interactions with competitors, 28 caused no response (distances ranged from <1 – 99 m) and five (all

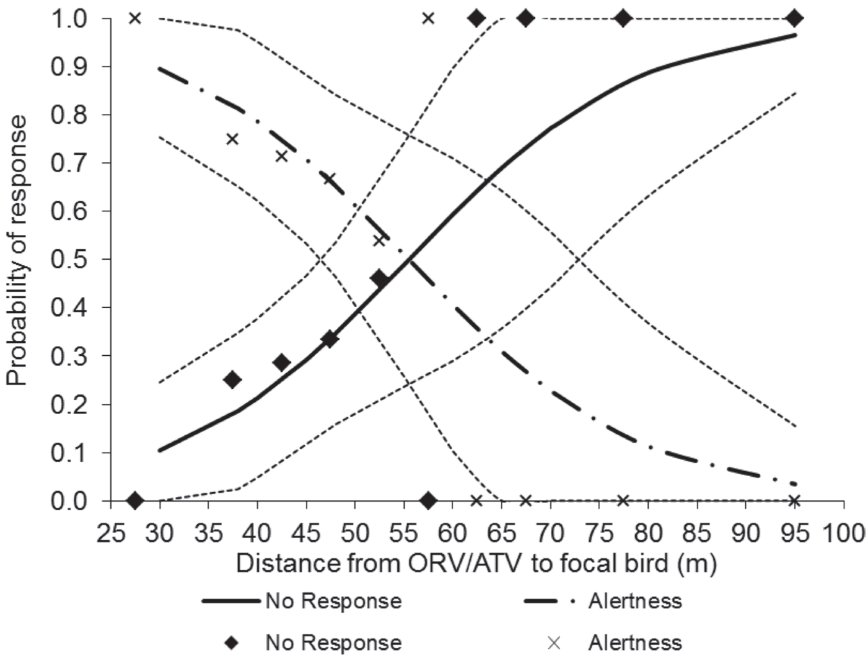

Figure 4. Probability of the most severe response of incubating Snowy Plovers to vehicles being "none" or "alertness" vs. distance to the vehicle in the Florida Panhandle, 2010. The point symbols are the observed means (the mean proportion of responses of a particular type within 5-m categories of distance). The heavy lines are predicted probabilities of response from the model (mixed multinomial logistic regression with generalized-logit link and random effect of individual, $F_{1,55} = 6.20$, $P = 0.016$, $n = 63$ observations, $N = 14$ birds). The light dashed lines are 95% confidence intervals around the prediction lines.

conspecifics) caused distress/aggression response within 5 m, 28% of the potential interactions in that distance category.

We found no significant relationship between distance to disturbance source and response of brood-rearing adults, although we did observe responses at various distances. Of 147 potential pedestrian interactions, adults with broods showed no response 102 times, alertness three times, and displacement 42 times. Of eight interactions with ORVs/ATVs, attendant adults showed no response one time, alertness three times, and were displaced four times.

In one observation where a pedestrian approached within 10 m of foraging chicks, the brood was displaced. In the other 45 observations of the 3 broods in our study area, pedestrians approached within 23 m – 95 m of foraging broods, and never caused a response by the chicks. Of eight potential interactions with ORVs/ATVs at 10 m – 99 m, foraging chicks showed no response.

Foraging adult plovers were more likely to respond to disturbances within 100 m at low disturbance sites (73 ± 18% SE, n = 17) than at high disturbance sites (22 ± 7%, n = 273, mixed logistic regression with random bird effect, $F_{1,15}$ = 5.13, P = 0.039). The reverse was true of incubating birds, which were more likely to respond to disturbance (with alertness only) at high disturbance sites (45 ± 6%, n = 181) than at low disturbance sites (6 ± 4%, n = 54, $F_{1,96}$ = 14.00, P < 0.001). We were only able to collect behavioral observations of broods at high disturbance sites, so we could not compare response rates of attendant adults or their chicks between the two categories.

Discussion

Adult Snowy Plovers in our study responded more frequently and at further distances to pedestrians than to potential predators and competitors. Pedestrians were the largest and most conspicuous potential disturbance source on the landscape apart from vehicles, and possibly were thus perceived as the greatest predation risk (Beale and Monaghan 2004a). Foraging adults rarely flushed in response to disturbances greater than 40 m away. Adult Piping Plovers have been found to flush from humans at similar distances as Snowy Plovers in our study, and to also exhibit different responses to anthropogenic and natural disturbances (Flemming 1988, Hoopes 1993). Also similar to our study, nonbreeding Snowy Plovers in California did not flush from human disturbances that were more than 30 m away (Lafferty 2001). If 40-m buffers were implemented to provide disturbance-free foraging sites and left in place after the breeding season, they could benefit nonbreeding Snowy and Piping Plovers as well.

Human disturbance to beach-nesting birds may lead to demographic effects via direct mortality (such as crushing of eggs), disruption of foraging leading to poor nutrition, reduced vigilance against predators, or induced dispersal increasing the risk of injury or death (Weston and Elgar 2005). Burger (1990) demonstrated increased time spent in alert postures for Piping Plovers in the presence of human disturbance. Maslo (2011) found that Piping Plover adult and chick foraging rates decreased when people were within 50 m.

Lack of flushing in response to human disturbance in some instances has been linked to an individual bird's nutritional condition; some animals may not be able to devote the energy to fleeing from disturbances that are far away (Beale and Monaghan 2004b, Gill et al. 2007). Birds in poor condition, in areas with low food quality, or with a lack of alternative foraging sites may be willing to take a greater risk in remaining in the area despite the presence of a threat (Beale and Monaghan 2004b). Due to the highly fragmented nature of Snowy Plover habitat along the Eastern Panhandle, it is possible that birds simply do not have alternate foraging areas, and are reluctant to flush. However, it is more likely that because the birds in our study were on nesting territories, they were too heavily invested in their selected locations and in the care and defense of their nests and young to flush often or to great distances

Prevention of disturbance to foraging plovers may be important to their energy balance in the breeding season, because each adult may spend 9-12 hours per day incubating, limiting available foraging time (Kosztolányi and Székely 2002). Foraging also tends to occur outside of nesting areas protected by symbolic fencing, as was the case for all observations of foraging birds in our study. The presence of anthropogenic disturbance can alter the normal foraging behavior of adult and juvenile Snowy Plovers (Lafferty 2001, Faillace 2010) and Piping Plovers (Flemming 1988, Burger 1990, Strauss 1990, Hoopes 1993, Maslo 2011). Modeling efforts have indicated that frequent disturbances that result in lost foraging time and an energy cost may be more damaging at the population level than permanent loss of habitat (West et al. 2002).

Although we did record nest and brood fates of the birds we followed, our sample size of pairs was not large enough to draw conclusions about effects of disturbance on population parameters such as reproductive success. However, negative population-level effects of disturbance have been demonstrated for Snowy Plovers, including lowered chick survival and decreased immigration of nesting adults into potential nesting sites (Ruhlen et al. 2003, Lafferty et al. 2006).

Like foraging plovers in our study, incubating birds responded at greater distances to humans than to naturally-occurring disturbances, but they never displayed responses to human disturbance more intense than "alertness." Our results thus suggest that current buffer zones at these state parks are adequate to prevent flushing of incubating adults. Keeping buffer distances for incubating plovers at or above the current level is important, as increased disturbance near the nest has been found to decrease diurnal nest attendance in closely related species (Weston and Elgar 2007).

Track counts and 10-min disturbance counts supported our *a priori* classification of sites into low and high disturbance categories. We found some evidence of increased tolerance of foraging adult plovers to high levels of disturbance, based on comparisons between high and low level sites. Incubating adults, however, were more likely to be alert to the presence of pedestrians at high disturbance sites, possibly because our high disturbance study sites have pedestrian footpaths that bisect nesting areas, bringing pedestrians closer to incubating birds more frequently. Some, but not all shorebird species have been shown to habituate to human disturbance (Lord et al. 2001, Glover et al. 2011). Habituation could be beneficial if plovers are able to conduct normal behaviors in the presence of human activity, but the risks to nests or chicks from the presence of humans may need to be managed (Baudains and Lloyd 2007). Furthermore, physiological responses disturbance (increase in stress hormones, etc.) are not always readily apparent or easily measurable, so outward signs of habituation may not be indicative of all possible effects (Bejder et al. 2009).

Failure of plover chicks to try and evade ORVs or humans further than 10 m may potentially put them at risk (Goldin 1993, Baudains and Lloyd 2007). High levels of anthropogenic disturbance at some Piping Plover breeding sites have been linked to decreased reproductive success due to low fledge rates (Strauss 1990, Goldin 1993). To date there has not been a formal comparison of chick fates among beaches with different disturbance levels. If many of these cryptic young are killed inadvertently by pedestrians or vehicles, protection of brood-rearing areas would merit further attention.

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