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Abstract.—Avian research that involves potential disturbance to the study species may have unintended fitness consequences and could lead to biases in measurements of interest. The effects of band resighting on the behavior of mixed-species flocks of staging waterbirds were evaluated against recreational pedestrian activity that was expected to cause flushing. We found a model with additive effects of distance (near, 0-50 m, or far, 50-200 m) and disturbance type (researcher or pedestrian) best explained flock behaviors. The proportion of staging flocks that flushed in response to pedestrians was greatest when pedestrians were within 50 m of the flock. Virtually no flushes were observed in response to researchers, regardless of distance. These results could assist in alleviating concerns that accepted protocols used for intensive band resighting studies on staging seabirds of special conservation status, such as Roseate (*Sterna dougallii*) and Common (*S. hirundo*) terns, may have adverse effects. Our framework could be used by others to test the effects of similar research on sensitive species. *Received 24 April, 2016, accepted 11 June 2016.*

Key words.—behavior, Common Tern, disturbance, pre-migratory, researcher effects, Roseate Tern, *Sterna dougallii*, *Sterna hirundo*.

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Research to estimate vital rates may cause disturbance to the study species with unintended fitness consequences, and could lead to biased estimates (Lenington 1979). Most avian researcher-disturbance studies have taken place on the breeding grounds. Research effects have been implicated in changes in predator activity around nests (Carney and Sydeman 1999), reproductive success (Safina and Burger 1983; Lloyd and Plagányi 2002), and survival (Hunt *et al.* 2013). However, the effects of research activities on avian species during other life stages are less well-studied. The post-breeding staging period of migratory birds is a critical time for building energy reserves before migration (Schauroth and Becker 2008). Human disturbance has the potential to limit the use of roosting areas (Trull *et al.* 1999) and alter energy budgets (Schummer and Eddleman 2003) of staging waterbirds. Thus, it is important that the activities of researchers at staging areas not unnecessarily disturb birds.

Resighting of unique color marks is a common method to estimate population parameters for waterbirds (Hill *et al.* 1997; Kirk *et al.* 2008; Gillings *et al.* 2009). This technique often cannot be employed without affecting flock behavior, as resighting attempts often cause some individuals to flush. Research is usually designed in such a way that negative effects are minimized, though they can rarely be eliminated altogether (Brown and Morris 1995); the integration of researcher effects into studies of colonial waterbirds is lacking (Nisbet 2000), particularly during staging. Thus, our goal was to determine if the band resighting method, intended to facilitate the recovery of protected species, may have a comparable negative impact to other anthropogenic disturbance sources. We examined the effects of research activities on the behavior of tern flocks during the post-breeding staging period. Flocks included a variety of terns, shorebirds, and other species, notably the federally endangered Northwest Atlantic population of the

Roseate Tern (*Sterna dougallii dougallii*; U.S. Fish and Wildlife Service 2010) and the Common Tern (*S. hirundo*). Our objective was to compare the behavioral response of staging mixed-species flocks to researchers vs. the response of flocks to pedestrians using these areas for recreation, which might be expected to cause disturbance.

METHODS

Study Area

More than 60% of the Northwest Atlantic Roseate Tern population has been documented as highly concentrated in a limited number of staging sites within the Cape Cod National Seashore in eastern Massachusetts, USA (Jedrey *et al.* 2010). We selected 11 study sites spanning 56 km based on published information and preliminary observations by project collaborators indicating significant and consistent Roseate Tern use (Jedrey *et al.* 2010).

Field Methods

Disturbance surveys were conducted by three observers with binoculars and a spotting scope from a distance of at least 100 m to avoid affecting tern behavior. Surveys were performed at one to two sites per day from 7 July-15 September 2014 and 8 July-17 September 2015. We used a stratified sampling scheme to ensure that sites were evenly sampled by tidal state, weekday or weekend, and presence of one or more band resighters (hereafter, researchers). We conducted disturbance response observations at varying times throughout the day to reduce potential sampling bias related to temporal patterns in bird behavior and in disturbance source presence.

We continuously scanned the area within 200 m of focal flocks (containing Roseate and Common Terns, as well as other tern and shorebird species) and recorded the presence of all potential anthropogenic disturbance sources for 2 hr or until the terns left the area. Observers were consistently present within the 200-m study radius, as accurate identification of species and flock behaviors were not possible beyond 120 m. Surveys commenced only after observers had remained stationary for a 10-min cool-down period to minimize the effects of observer presence. The closest distance to the flock that sources attained and the distance associated with any visible flock responses were recorded with a Nikon Prostaff 3 laser rangefinder. We used flock scans to record behavioral responses to human presence (Altmann 1974). We recorded flock responses in several categories as part of a larger study on staging behavior, but for purposes of understanding whether research activities increased flush probabilities, we here used only two broad categories: flush (defined as a flight of any duration) and non-flush.

Methodology to identify marked individuals was adapted from established protocols for resighting Roseate Terns within breeding colonies (Spendelow *et al.* 2008). Once an individual bird or flock was located, the observer slowly walked, waded, or kayaked toward the flock and remained close enough (usually within 40 m of the birds) to make identifications. Measures taken by researchers to reduce flock agitation included: approaching only to the maximum distance at which band readings could be confidently obtained; pausing during a slow, steady approach, and in some cases sitting or kneeling so as to appear smaller; and turning feet and faces while walking to mimic a tangential approach.

Data Analysis

The beta distribution is commonly used to model proportional data, such as ours. However, it does not contain 0 or 1 and thus cannot be used to estimate the probability of response when all members of the flock exhibit the same behavior (i.e., if they all flush). Therefore, we employed a zero-and-one inflated beta mixture model (Ospina and Ferrari 2010). We used a binomial distribution to model the probability that the data came from the binomial rather than the beta distribution. We wrote a function in the statistical program R (R Development Core Team 2014) to fit our model and performed maximum likelihood estimation using "optim" and the packages "gtools" (Warnes *et al.* 2015), "mc2d" (Pouillot and Delignette-Muller 2010), and "MASS" (Venables and Ripley 2002).

We modeled probability of flight as a function of the distance between the flock and the disturbance source, the disturbance source type ("res" = 1 for researchers, 0 for pedestrians), and the interaction between these two variables. Researchers are unable to reliably read unique legband combinations at distances beyond a maximum of 50 m in ideal conditions (Spendelow *et al.* 2008) and therefore had a tendency to approach to an average minimum distance of 25 m. However, in many cases, researchers were more than 50 m from a flock that we were observing for a disturbance survey because they were focused on a separate flock at the same site. Because the distances between researchers and flocks were limited to a narrow range of values, we treated distance as a discrete rather than continuous variable. Our distance variable ("far") was coded as a 1 if the minimum distance was 50 m to 200 m and 0 if less than 50 m. We used multimodel inference and information-theoretic criteria to determine which of our models was best supported by the data, and we considered any model with a relative likelihood of > 0.125 to have some support (Burnham and Anderson 2002). To examine model fit graphically, we calculated the mean observed response within each combination of distance and disturbance type, for comparison to predicted values. We calculated 95% confidence intervals on the predicted values of our model based on 1,000 Monte Carlo simulations (Mandel 2013) from the regression parameters and the variance-covariance matrix of the regression parameters, assuming a logit link function. Figures were created using the statistical program R package "ggplot2" (Wickham 2009).

Results

We recorded 613 observations of human activity (206 researcher, 407 pedestrian) within 200 m of a mixed-species flock across 81 2-hr disturbance surveys (44 in 2014, 37 in 2015). The model with additive effects of distance and disturbance source had a model weight of 1.0. Therefore, this was the model used in all subsequent analyses. Based on the predictions from the top model, the proportion of terns that flushed in response to pedestrians was greater when pedestrians were within 50 m of the flock than when they were further than 50 m from the flock (Fig. 1). However, virtually no flushes were observed in response to researchers, regardless of distance category. Predicted flush probability increased from ~0% to 6% when researchers approached to within 50 m, whereas for pedestrians predicted flush probability increased from ~6% to ~35%. The mean observed proportion flushing for researchers > 50 m away was slightly above the 95% confidence interval for this category, where we had few observations ($n = 48$). However, model predictions were close to the mean observed proportions for all categories.

Discussion

Researchers that approached tern flocks slowly within 50 m, with regular stops to perform scans, did not seem to cause terns to flush, but pedestrians within 50 m did. Tolerance to researchers after frequent exposure has been documented for breeding Common Terns (Burger and Gochfeld 1991) and, to a lesser extent, Roseate Terns (Zingo *et al.* 1997). At many of our sites, exposure of tern flocks to pedestrians was a daily occurrence, so birds may have had the opportunity to develop tolerance, but the short residence time of staging flocks makes habituation unlikely (Koch and Paton 2014). Speed, angle, and consistency of approach may explain the differential responses to the two disturbance sources in our study. Burger and Gochfeld (1981) found that pedestrian sources that approached directly elicited

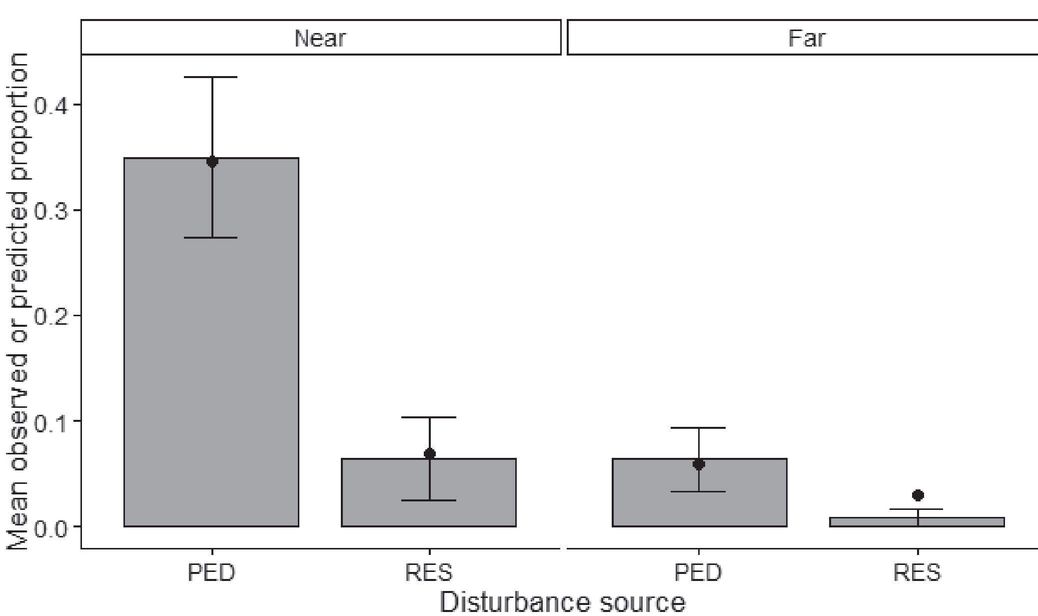

Figure 1. Model predictions with 95% confidence intervals of mixed-species tern flock responses to researchers (RES) and pedestrians (PED) when they are "near" (within a range of 50 m to the edge of the flock) and "far" (50-200 m from the flock) on Cape Cod National Seashore, Massachusetts, USA, 2014-2015. A response of flight initiation with flight duration of any length was considered to be a "flush". Points represent mean observed proportions.

higher levels of disturbance to gulls (*Larus* spp.) than those that moved tangentially. Pedestrians in our study approached tern flocks from a variety of directions and at a variety of speeds. Researchers often attempted to crouch to appear less threatening, whereas pedestrians usually moved in fully erect postures and sometimes ran through flocks. It is likely that these differences in behaviors made pedestrians, but not researchers, appear to be a threat.

Factors affecting flush distance may vary by species (Tarlow and Blumstein 2007). Although it was not possible to distinguish the responses of different tern species in our study due to similarity of appearance, high energy flight responses usually involved large segments of the flock that contained multiple species. Our field and analytical approach, employing a generalized linear model with the appropriate statistical distribution for proportions, can be used to evaluate potential disturbance effects of research activities intended to obtain demographic information for other flocking coastal birds.

Monitoring researcher effects is useful for avoiding adverse consequences to the integrity of the research and to study animals (Carney and Sydeman 1999). We found no evidence that established protocols for band resighting caused high-energy disturbance responses from mixed-species flocks of terns staging on Cape Cod. This result agrees with findings from breeding areas in which terns can be studied intensively without significant behavioral effects (Nisbet 2000), and supports the belief that these methods are compatible with Roseate Tern recovery efforts.

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