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VARIATION IN HUMAN DISTURBANCE DIFFERENTIALLY AFFECTS PREDATION RISK ASSESSMENT IN WESTERN GULLS

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Abstract. Many studies have demonstrated that birds behave differently in areas with different levels of human disturbance. Studies frequently characterize sites as having an overall level of human disturbance, and compare how birds respond at sites with high and low levels of disturbance. Doing so assumes that disturbance has a fairly constant effect on animals throughout a site. We measured the distance at which individual Western Gulls (*Larus occidentalis*) moved away from an approaching observer along a stretch of beach on both sides of the Santa Monica Pier, a heavily visited tourist attraction in southern California. We found that these flight initiation distances decreased in areas where more people visited the beach, and specifically in a small area near the pier. We found that flight initiation distance changed very rapidly within a short distance from the pier. Our results indicate that anthropogenic features may leave a ''behavioral footprint.'' Identifying the scale of such behavioral footprints should be an important goal of studies that seek to reduce anthropogenic impacts on birds.

Key words: flight initiation distance, human disturbance, Larus occidentalis, *predation risk assessment.*

La Variación del Disturbio Humano Afecta Diferencialmente la Percepción del Riesgo de Depredación en Gaviotas *Larus occidentalis*

Resumen. Muchos estudios han demostrado que las aves se comportan de modo diferente en áreas con distintos niveles de disturbio humano. Los estudios frecuentemente caracterizan sitios con base en su nivel general de disturbio y comparan las respuestas de las aves entre lugares con niveles altos y bajos de disturbio. Al hacer esto, se supone que el disturbio tiene un efecto aproximadamente constante sobre los animales a través de un sitio dado. En este estudio medimos la distancia a la cual gaviotas de la especie *Larus occidentalis* se desplazaron alejándose de un observador a lo largo de un tramo de playa en ambos lados del embarcadero de Santa Monica, una atracción turística muy visitada ubicada en el sur de California. Encontramos que las distancias al observador a las que las aves iniciaron el vuelo disminuyeron en áreas donde más personas visitaron la playa, y específicamente en un área cercana al embarcadero. Las distancias a las que las gaviotas iniciaron el vuelo cambiaron muy rápidamente en una distancia muy corta desde el puerto, hasta alcanzar una distancia constante. Nuestros resultados indican que las estructuras antropogénicas podrian dejar una ''huella comportamental''. Identificar la escala de dichas huellas debería ser un objetivo importante de estudios que tengan como fin reducir el impacto antrópico sobre las aves.

Nonlethal human disturbance has a number of detrimental effects on birds. Because human interference shares many characteristics with predation risk (Frid and Dill 2002), disturbed individuals that flee will lose access to resources and incur a cost of flight. Even without flight, human disturbance incurs opportunity costs, such as increased vigilance (Ward and Low 1997), and reduced foraging (Lord et al. 1997). Birds commonly habituate to repeated disturbance (Cooke 1980, Burger and Gochfeld 1991, Lord et al. 2001), but the temporal and spatial scale of habituation is unknown. Ikuta and Blumstein (2003) found that birds on the side of a fence that blocked human visitation responded no differently from birds at a location without much visitation. However, variation in many human impacts are more diffuse than those produced by the sharp boundary of a fence. We examined how Western Gulls (*Larus occidentalis*) habituated to human visitation in the area surrounding a heavily visited tourist destination, the Santa Monica Pier in California. Specifically, we searched for any evidence of highly localized effects.

We measured flight initiation distance, which we used as an indicator of predation hazard assessment (Ydenberg and Dill 1986, Bonenfant and Kramer 1996, Blumstein 2003). Flight initiation distance is the distance at which a bird moves away from an approaching threat, and reflects an economic decision, whereby animals flee when the perceived costs of flight outweigh the perceived benefits of remaining in place. Because variation in flight initiation distance represents variation in predation hazard assessment, variation in flight initiation distance can be used to identify habituation (Ikuta and Blumstein 2003, Runyan and Blumstein 2004).

According to the Santa Monica Pier Restoration Corporation, the Santa Monica Pier receives approximately 3.5 million visitors per year, and the beaches

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on either side are some of the most popular in the region. However, the two sides of the pier are markedly different. The southeast, or Venice, side is more urban and developed, while the northwest, or Topanga, side has lower-density housing and fewer parking opportunities. Western Gulls forage opportunistically on garbage around the Santa Monica Pier. Gulls disturbed by humans may face the opportunity cost of lost food, as well as the cost of flight. To measure the impact that the Santa Monica Pier and its associated human visitation had on the behavior of Western Gulls, we baited gulls with bread and quantified their flight initiation distance in response to direct human approach. We hypothesized that gulls would be more tolerant to human disturbance closer to the pier, and that they would be more tolerant on the Venice side than on the Topanga side, because the areas around the pier receive a lot of visitors, and the Venice side is more developed than the Topanga side. We reasoned that gulls might habituate to human disturbance more in these areas.

METHODS

This study was conducted at Santa Monica Beach in Los Angeles, California, in a 2-km radius from Santa Monica Pier (34°01′N, 118°30′W). All data were collected between 09:00 and 12:00 from 6 October to 27 November 2003. We alternated data collection between the Topanga and Venice sides of the pier and only collected data on one side of the pier per day. Each day, the distance from the pier where we began collecting data was selected randomly. We collected as many as six trials on a given date (mean $\pm$ SD = 3.6 $\pm$ 1.3). A single observer (NVW) collected all data. The observer counted the number of people within a 100-m radius, the number of gulls within 10 m and 50 m of the bait and the presence of any large groups of loafing gulls within 100 m.

We baited gulls with approximately 70 g (two slices) of wheat bread, which had been ground to crumbs in a food processor. This was placed in a small pile either 7.5 or 15 m from the water's edge. The observer would then move either 30 or 50 m from the bait and wait for birds to begin foraging. Distances were alternated between each trial. We also recorded the latency until a bird began to forage.

Following a bird's arrival, we waited 1 min before approaching, during which time the number of nearby conspecifics and heterospecifics were counted. We then directly approached the bird at a pace of 1 m per second and recorded the distance at which the bird looked up at the observer, the distance at which the bird stopped foraging, and the distance at which it moved away. Following flight, the observer continued walking to the bait, turned around and returned to the original position, and then recorded the amount of time it took for the focal bird to return to the food source. On the few occasions that the focal bird flew out of sight, no return time was recorded. We converted distance, in paces, to meters for all analyses. Analyses focused on log-transformed measures of distance to meet the assumptions of data distribution for linear models.

Analyses were performed using SuperAnova (Abacus Concepts Inc. 1991), and StatView (SAS Institute Inc. 1999). Analyses were hierarchal. First, we constructed an ANCOVA model to explain variation in the logarithm of flight initiation distance where the categorical starting distance and distance to pier were factors and covariates, respectively. This model also contained the interaction between the two independent variables. Additional covariates, such as percent cloud cover and number of humans, were added one at a time to this basic model. We also fit a model using distance to pier as the only covariate. Finally, models were fit separately for both the Topanga and the Venice sides of the pier.

In addition to these linear models ($y = ax + b$), we constructed nonlinear power models ($y = ax^b$) to explain variation in logarithm of flight initiation distance as a function of distance to the pier on both the Topanga side and the Venice side.

RESULTS

Using the data from both sides of the pier, we found no relationship between distance to pier and the logarithm of flight initiation distance (ANCOVA, all P-values > 0.17). However, when we looked at birds' responses for each side of the pier (Venice and Topanga) independently, we found that models explained significant variation in birds' flight initiation distance (Venice, model adj. $R^2 = 0.21$, $P = 0.04$; Topanga, adj. $R^2 = 0.30$, $P = 0.03$; Fig. 1). On the Venice side of the pier, we found significant effects of observer starting distance ($P = 0.008$), and distance from the pier ($P = 0.08$), and a marginally significant interaction ($P = 0.06$) that contributed to this model. On the Topanga side of the pier, we found that the nonsignificant effects of starting distance from the bird ($P = 0.89$), the distance from the pier ($P = 0.23$), and the interaction between these two ($P = 0.68$) contributed to the model explaining significant variation in flight initiation distances of gulls. On the Topanga side, a separate model using only distance from the pier explained relatively more variation in the logarithm of flight initiation distance (adj. $R^2 = 0.33$, $P = 0.003$) than our general model (described above).

The power model shows that flight initiation distance increased rapidly at distances close to the pier. Flight initiation distance changed less with increasing distance away from the pier. On the Venice side, this model failed to explain variation in flight initiation distance ($P = 0.87$). The logarithm of flight initiation distance was significantly influenced by the number of humans on the Topanga side (adj. $R^2 = 0.21$, $P = 0.02$), but not on the Venice side ($P = 0.21$). A power model explained more variation in the logarithm of flight initiation distance on the Topanga side (adj. $R^2 = 0.45$; $P < 0.001$) than did a linear model (adj. $R^2 = 0.36$; $P = 0.003$). On the Venice side, neither a linear model (adj. $R^2 = -0.04$; $P = 0.87$) nor a power model (adj. $R^2 = -0.04$; $P = 0.77$) explained variation of the logarithm of flight initiation distance.

Cloud cover varied daily; more birds were present on the beach on cloudy days. When added as a factor to the basic model, percent cloud cover explained more variation in flight initiation distance on the Topanga side (adj. $R^2 = 0.39$, $P = 0.01$; cloud cover, $P = 0.08$; starting distance, $P = 0.91$; distance from pier, $P = 0.21$; interaction, $P = 0.63$). Overall, flight initiation

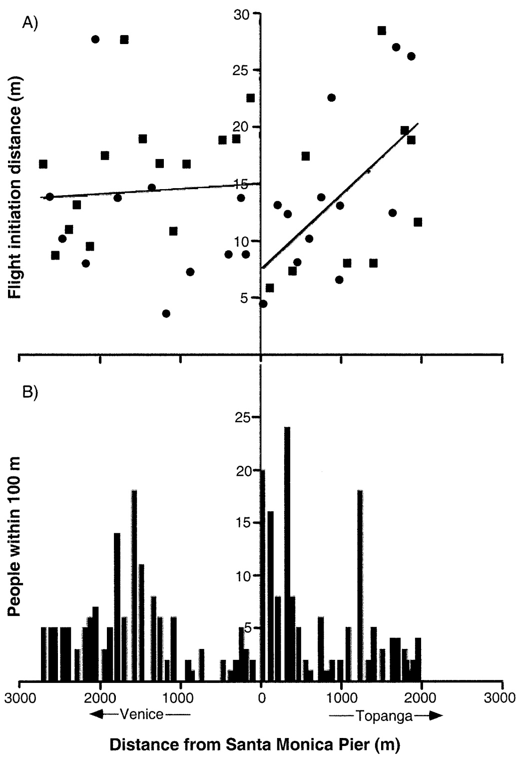

FIGURE 1. A) Western Gull flight initiation distance increased rapidly with distance from the Santa Monica pier on the Topanga side of the pier, and less rapidly on the Venice side of the pier. Circles indicate short (30 m) starting distances, and squares indicate long (50 m) starting distances for the 48 experimental approaches towards gulls. Lines illustrate linear regressions on raw data. Statistical analyses were conducted on log-transformed data. B) Counts of people within 100 m of observer conducting the experimental approach. More people are concentrated around the pier on the Topanga side than on the Venice side.

distances increased with cloud cover. A model fit to data from the Venice side of the beach was not significant when cloud cover was added (adj. $R^2 = 0.211$, $P = 0.06$).

On the beaches of the Venice side, flight initiation distance was not related to distance from the pier. In this area of concentrated human visitation, gulls tolerated closer approach by humans. Despite these differences in human disturbance, there was no significant difference in the gull's flight initiation distance on either side of the pier (paired *t*-test, $t = -0.46$, $P = 0.65$). However, the pattern of flight initiation distance varied with distance. The Venice side showed very little variation over distance, while the flight initiation distances on the Topanga side were initially much lower very close to the pier, and then leveled off with increasing distance from the pier.

The total number of humans observed during data collection on each side of the pier did not vary significantly (paired *t*-test, $t = 0.42$, $P = 0.68$). However, there was a significant negative relationship between the number of humans observed and the distance from the pier on the Topanga side (adj. $R^2 = 0.36$, $P = 0.002$), but not on the Venice side (adj. $R^2 = 0.09$, $P = 0.07$).

DISCUSSION

Differences between the Topanga and Venice side of the pier in flight initiation distance may be a result of differences in human visitation pattern. The Venice side was more consistently used, while on the Topanga side, there were relatively more visitors close to the pier. This is likely a result of the different pattern of development in the two areas. There are many residences, shops, and streets that come right up to the beach on the Venice side, as well as many parking opportunities for visitors. In contrast, parking constraints restrict access to the Topanga side. Additionally, the Topanga side is dominated by residential development, much of it across the Pacific Coast Highway, and only a few businesses cater to beach visitors. A notable exception to this is the area immediately to the North of the pier. Many people visiting the pier also visit this part of the beach, which has direct access to the pier. In contrast, the Venice side of the pier does not receive this additional pier traffic. On the beaches of the Venice side, gulls experience continuous, high level human activity. In contrast, on the Topanga side, human disturbance was concentrated beneath the pier.

The finding that flight initiation distance decreased in areas with greater disturbance is consistent with numerous previous studies (Burger and Gochfeld 1982, Smit and Visser 1993, Lord et al. 2001, Miller et al. 2001, Ikuta and Blumstein 2003). However, these studies focused on separate areas with different overall degrees of disturbance. None of these previous studies examined change in behavior over a continuum. In this case, at least on the Topanga side of the Santa Monica Pier, there was a gradient of disturbance that was reflected in a gradient of behavioral change in Western Gulls.

One possible explanation for the observation that flight initiation distance decreased with distance is that the gulls habituated to their local level of disturbance and became more tolerant in more disturbed areas. While this was possible on the Venice side, where the level of disturbance was more constant, it was unlikely on the Topanga side because the flight initiation distance varied over such a short distance. Casual observation suggests that gulls have fairly large home ranges, they travel quite frequently, and the pier does not appear to act as a barrier separating the two sides. If so, they would routinely be exposed to varying levels of disturbance.

A more likely explanation is that the gulls distributed themselves based on disturbance tolerance with more tolerant individuals preferentially selecting habitats near the pier, taking advantage of food provided by human refuse. Less tolerant individuals would disperse to less disturbed areas farther away from the pier.

Another possibility is that the gulls adjusted their flight initiation distance based on the local level of disturbance. The gulls might remember which areas had greater disturbance in the past, and adjust their degree of tolerance depending on where they were at the time. For example, a gull might learn that disturbance near the pier is largely benign, but they might be more wary in places where disturbance is less common. Alternatively, the gulls might have adjusted their tolerance depending on the number of people around them. However, this did not occur on the Venice side, where there was no association between the number of people and flight initiation distance. If the gulls adjusted their tolerance, they did it based on location, not on the current number of people.

Our results from the nonlinear power models demonstrate that the effects of human disturbance on a small spatial scale are meaningful to the birds. The area just north of the Santa Monica pier is heavily used by people. Birds in this area responded significantly differently than birds outside this area. By measuring flight initiation distance, we have identified a ''behavioral footprint'' of anthropogenic effects. Our finding of an effect on such a small spatial scale has not previously been well documented (but see Ikuta and Blumstein 2003). We expect such effects to be common in areas with spatially concentrated disturbances such as campgrounds within parks or isolated rest stops near highways. We suggest that to better understand the effects of anthropogenic impacts on birds, more effort should go into identifying and understanding the behavioral footprint of human impacts.

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