Impact of human disturbance on the abundance of non-breeding shorebirds in a subtropical wetland

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Abstract
Shorebird populations have declined due to several threats throughout their annual cycle. Anthropogenic disturbance is one of the most ubiquitous threats to shorebird conservation in North America. Here, we studied the influence of human disturbance on shorebird community dynamics during migration and winter in Ensenada de La Paz, a subtropical coastal wetland in Mexico. We used negative binomial generalized linear mixed models to investigate the associations between spatial, biological, and anthropogenic variation and local shorebird abundance that accounted for shorebird body size (small, medium, and large) and foraging strategy (visual and tactile) of 22 shorebird species. After controlling for these different correlates of abundance, human disturbance (people, vehicles, and dogs) was negatively associated with shorebird abundance. During winter, all shorebird species were negatively related to human disturbance but positively associated with presence of raptors. However, small, tactile foraging birds exhibited a proportionally larger negative response to human disturbance than other shorebird types, indicative of guild-level sensitivities to human disturbance regimes. The positive association between shorebird abundance and disturbance from predators was unexpected. Shorebirds likely concentrate in large groups to reduce predation risk, resulting in higher densities of shorebirds occurring in areas with high predation risk. Understanding factors influencing the abundance and habitat use of shorebirds on their non-breeding grounds is paramount to support management and conservation policies for shorebirds and their habitats.

KEYWORDS
anthropogenic disturbance, Baja California Peninsula, body size, foraging tactics, non-breeding season, shorebird counts, Western Sandpiper

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1 | INTRODUCTION

In the Western Hemisphere, shorebirds have experienced population declines with a net loss of 37% since 1970 (Rosenberg et al., 2019). Factors potentially contributing to these declines include climate change, habitat loss, pollution, increasing abundance of predators, and human disturbance (Butler et al., 2003; Senner et al., 2016). Human disturbance is caused by people walking on the beach, people walking with dogs, and vehicles and has been linked with variation in habitat use, body condition, and survival of shorebirds (Gibson et al., 2018; Gill, 2007; Gill et al., 1996, 2001; Stillman et al., 2007). Thus, given the ubiquitous nature of human disturbance throughout coastal areas, shorebird conservation plans have recognized it as a critical threat (Atlantic Flyway Shorebird Initiative Business Plan, 2015; Mengak et al., 2019; Senner et al., 2016).

Human activities disrupt breeding and non-breeding shorebirds by interrupting vital activities such as feeding and resting, and shorebirds often respond to these perceived threats with alert and evasive behaviors (Martin et al., 2015; Schlacher et al., 2013; Yasué, 2005). Such changes in behavior can affect subsequent reproductive success and annual survivorship (Gill, 2007; Goss-Custard et al., 2020). Shorebirds may be unable to gain mass and build fat reserves required for long-distance migration because of exclusion, interrupted access to, or changes in the timing of access to food resources or roosting locations (Lafferty, 2001).

Responses of birds to human disturbance are similar to their responses to predators (Frid & Dill, 2002). Possible effects of disturbance include disruption of normal behavior and the temporary or permanent abandonment of feeding, roosting, and nesting sites (Beale & Monaghan, 2004; Fitzpatrick & Bouchez, 1998; Weston et al., 2012). Further, increased use of coastal habitats for recreational activities (e.g., walking dogs without a leash and use of all-terrain vehicles) likely reduces the quantity and quality of available habitat for shorebirds (Mengak et al., 2019). With the increase of human populations on coasts and the associated recreational activities, human disturbance of shorebirds is likely to increase. However, there are also differences in the responses of shorebirds to predators and human disturbance which may lead to differential broader consequences for their populations. For example, predators may influence shorebirds for shorter periods due to their hunting strategy (Dekker & Ydenberg, 2004; Ydenberg et al., 2007). In contrast, human disturbance is often a more long-term stimulus because human recreational activities occur for more extended periods (Collop et al., 2016; Gibson et al., 2018).

Shifts in behavior in responses due to disturbance on individuals may vary based on availability of alternative habitats (Gill et al., 2001), body size (Blumstein et al., 2005), and foraging strategy (Colwell, 2010). For example, in the presence of humans, visual-feeding plovers had lower intake rates than tactile-feeding sandpipers (Yasué, 2005). This difference is because plovers use visual cues to locate prey, and a decrease in intake rate may result from an increase in vigilance, whereas sandpipers may continue feeding simultaneously with maintaining high vigilance near humans (Colwell, 2010). Also, due to the differences in flight initiation distances between larger and smaller shorebird species (Collop et al., 2016; Koch & Paton, 2014), larger species may have higher energy expenditures than smaller species.

Survival during the non-breeding season limits many shorebird populations (Fernández & Lank, 2008). However, most information on effects of human disturbance on shorebirds comes from breeding and stopover sites in the Nearctic Region (Kimberly & Otis, 2007; Mengak & Dayer, 2020; Pfister et al., 1992; Yasué, 2006) and tropical Asia (Marasinghe et al., 2020). In contrast, little research on impacts of disturbance on shorebird abundance exists from Neotropical non-breeding habitats in developing countries with increasing human activities in high-value shorebird areas. Assessing impacts of human disturbance on wintering shorebirds at tropical sites is needed to disentangle the contributing factors to their hemispheric population declines. Thus, our objective was to assess effects of potential disturbances on the number of shorebirds during migration and winter in a subtropical wetland in Mexico. Because the response of birds to disturbance may be correlated with body size and foraging strategies (Blumstein et al., 2005; Collop et al., 2016; Yasué, 2005), we grouped counts of shorebird species by these categories. We expected that differences in behavior would result in differences in the impact of a potential disturbance between these foraging groups and bird body sizes. We included raptor abundance (potential natural disturbance) and habitat variables in our analyses to control these potential confounding factors and compare the response magnitude to potential human disturbance on bird abundance.

2 | METHODS

2.1 | Study site

Ensenada de La Paz (ELP) (24°06′ and 24°10′ N, 110°25′ and 110°22′ W) is a coastal lagoon located in the southern portion of the Bay of La Paz, Baja California Sur, Mexico (Figure 1). ELP is regularly used by the entire shorebird assemblage found in the Pacific Flyway during the non-breeding season (Page et al., 1997), over 25 species, from July to April. Because of its importance for shorebird conservation, this coastal wetland was designated as a Site of Regional Importance by the Western Hemisphere Shorebird Reserve Network, an Important Bird Area in Mexico (IBA, No. 93), a Ramsar Wetland of International Importance, and a Priority Wetland for shorebirds in Mexico (Morzarria-Luna et al., 2014). ELP is separated from the bay by a sand bar of 15.5 km in length called El Mogote, which protects the lagoon from waves and wind (Álvarez-Arellano et al., 1997). It has a maximum depth of 10 m and a mixed tidal regime with the predominance of semi-diurnal tides (Álvarez-Arellano et al., 1997). The climate is dry or semi-desert, with an average temperature of 24°C (minimum = 5°C, maximum = 41.5°C) and annual rainfall that fluctuates between 180 and 250 mm (Chávez, 1985).

The western zone of ELP is an area with sandy beaches, called El Comitán that is popular for recreation (people running or walking,
with or without dogs). Intertidal and salt marsh habitats that are important to shorebirds are in the south, in front of the towns of Chametla and El Centenario. The most suitable intertidal flats have an approximate length of 8.3 km and an area of 14,148 ha (Figure 1). These intertidal mudflats have an average width of 750 m available for shorebirds during low tides (Fernández et al., 1998). Southwest of the city of La Paz is a sewage treatment plant (24°06′ and 24°20′ N, 110°25′ and 110°22′ W) used by shorebirds as a foraging and roosting habitat during migration, especially when intertidal areas in the coastal lagoon are not exposed (Carmona et al., 2003). The study area also includes a mangrove called El Zacatal, located in the southern part of the lagoon, which has been modified by construction of a hotel and residential area.

2.2 | Field surveys

We conducted an observational cross-sectional study with repeated surveys to determine effects of potential raptor and human disturbance on abundance of shorebirds. Our selection of sampling units captured variation in the intensity of threats and bird abundance. Area search surveys at 12 sampling units followed a monitoring protocol described in detail by Reiter et al. (2020), including documentation of environmental and habitat conditions in each sampling unit during each survey. The area flooded, vegetated, and bare ground was visually estimated at each sampling unit during field surveys. In addition, number of potential human disturbances (e.g., number of humans and number of dogs) and avian predators were recorded as they occurred during the survey period at each sampling unit (see details below). Twelve sampling units were surveyed twice a month, during neap rising tides, from September 2014 to April 2015; each sampling unit was visited 15 times. Sampling units were fixed areas of homogeneous habitat delimited by a polygon and included a mosaic of natural- and human-made habitats within ELP (Figure 1). Intertidal mudflat was the dominant habitat type among sampling units and are mud-sandy areas exposed during low tides, with less than 10% vegetation cover, and was found in Marina Sur (6.1 ha), Zacatal (30.6 ha), Chametla 1 and 2 (7.8 and 23.2 ha, respectively), Centenario 1 and 2 (22.7 and 9.2 ha, respectively), and Granjas Centenario (27.8 ha) sampling units. In
addition, sandy beach habitat occurred at units Comitán 1, 2, and 3 (8.7, 9.3, and 12.6 ha, respectively). Human-made habitats included an abandoned shrimp farm (Granja Abandonada, 10.2 ha) and sewage ponds in the wastewater treatment plant of La Paz (Lagunas de Oxidación, 9.9 ha).

During each survey, a team of one observer and one annotator counted all shorebirds using the sampling unit, including shorebirds arriving or leaving the sampling unit, but not those flying over the sampling unit. Small flocks (<300 birds) were counted, and we used the "blocks" method (Howes & Bakewell, 1989) to estimate numbers in flocks with >300 birds. Distance from the observation point to the birds in each count was generally less than 200 m. We sought a quick survey to assess bird estimates and behavior, so, we tried to limit the time at each sampling unit while counting all birds accurately. Across all surveys, time spent at each sampling unit was between 8 and 44 min (mean = 26 min, SD = 20); duration depended on species richness, number of individuals, and size of the sampling unit. Long-billed (Limnodromus scolopacess) and short-billed (L. griseus) dowitchers were grouped as dowitchers (Limnodromus spp.) because their identification in the field was difficult. All surveys were conducted during daylight hours, in the same tidal condition (neap rising tides), when wind was <25 km/hr, and when there was no rain to control for any effects on bird abundance behavior.

We counted avian predators during surveys and considered them as the baseline of potential natural disturbance as they can disrupt normal activities of shorebirds. Avian predators included Peregrine Falcons (Falco peregrinus), Cooper’s Hawks (Accipiter cooperi), Crested Caracaras (Caracara plancus), Zone-tailed Hawks (Buteo albonotatus), Merlins (Falco columbarius), and American Kestrels (Falco sparverius). In addition, avian predators in, perched adjacent to, or flying over the sampling unit were counted during each survey.

We considered a potential cause of human disturbance to be "any human-induced activity that likely constitutes a sufficient stimulus to disrupt normal activities or the distribution of shorebirds compared with a situation without such activity" (page 2, Fox & Madsen, 1997). We counted number of potential causes of disturbance, as they occurred, during the survey period in the sampling unit (Sutherland & Green, 2004). We categorized potential human disturbances as dogs (without a leash, either alone or accompanied by people), people (running or walking, in a group or alone, or dogs with a leash), vehicles (cars, motorcycles, and ATVs), and other (horses, drones, and fishing boats).

2.3 | Data analyses

We used generalized linear mixed models (GLMM; Zuur et al., 2009) to quantify associations of the count of shorebirds in different groups in each sampling unit with raptor and potential anthropogenic disturbance (events/minute), type of habitat, and percentage of the sampling unit that was flooded. Area (ha) of the sampling unit was also used to control for different sizes of sampling units. All models included a random effect of the sampling unit and a random intercept for species to account for different abundances among species and random slopes of the effect of human disturbance by species to control for variation in the effect of human disturbance across species. In addition, we consider random slopes for other covariates (e.g., raptor disturbance); however, the models would not converge, and since we were most interested in the effect of potential human disturbance, we considered random slopes for that covariate only. Because the distribution of shorebird counts had excess zeros and was overdispersed, we assumed a zero-inflated negative binomial distribution. Shorebird abundance was compared between migration (fall/spring) and winter, between three size classes (small, medium, and large shorebirds, sensu Page et al., 1997), and between two feeding strategies (tactile and visual, sensu Barbosa & Moreno, 1999). Species with <0.02 probability of occurrence were excluded from the analysis. Western Sandpipers (Calidris mauri) represented 67% of all counted birds. Therefore, similar analyses were performed for this single species during winter and migration. In total, we evaluated the model for 14 response variables, each representing a different combination of counts by shorebird species groups and/or seasons, but all with the same covariates considered.

We considered migration (September–October and March–April) and wintering (November–February) seasons separately because we hypothesized that the responses of shorebirds to disturbance might differ during these different periods of the annual cycle.

For each visit to each sampling unit (N = 180), we calculated the rate of raptor disturbance by dividing the number of avian predators by the number of minutes to complete the survey visit. Similarly, the rate of potential human disturbance was calculated by dividing the number of potential causes of human disturbance events by the length of the survey period. Given their different underlying mean frequencies, we standardized each of these covariates to their maximum values across seasons to better compare the magnitude of the effect of potential human and potential raptor disturbance within and across seasons. We plotted residuals against the model fitted values to evaluate model fit and look for the lack of normality, heteroscedasticity, and atypical values (Littell et al., 1996, 2006; McCullagh & Nelder, 1989). We also assessed the deviations in the species-specific effects of human disturbance to determine if there were any particular species driving the global effect of the impact of potential human disturbance on the groups of species. We considered estimates of model parameters where the 95% confidence intervals (CI) did not overlap 0 to be significant. We used the R studio version 1.1.463 programming environment (R Core Team, 2019) and the glmmTMB package (Brooks et al., 2017) for all analyses.

3 | RESULTS

From August 2014 to April 2015, we completed 180 surveys across 12 sampling units and counted a total of 96,845 shorebirds representing 26 species (Table 1). Western Sandpipers dominated the survey, accounting for 67% of the shorebirds counted. Wilson’s (Charadrius wilsonia) and Semipalmated (C. semipalmatus) plovers, Black-necked...
Stilts (Himantopus mexicanus), Willets (Tringa semipalmata), Marbled Godwits (Limosa fedoa), Least Sandpipers (Calidris minutilla), and dowitchers combined accounted for an additional 25% of all shorebirds observed (Table 1). There was high variation in mean count per sampling unit among visits and species. Although Western Sandpipers were most abundant, Willets and Marbled Godwits were the most frequently occurring species (Table 1). Other frequently occurring (>0.50 probability of counts >0) species included Black-bellied (Pluvialis squatarola) and Semipalmated plovers, Whimbrels (Numenius phaeopus), and Spotted (Actitis macularius) and Least sandpipers (Table 1). We used 22 of the 26 species observed in our analyses because these four species had a low occurrence (0.01).

### TABLE 1

Summary of shorebird counts by species on 12 sampling units at Ensenada de La Paz, Baja California Sur, Mexico, from August 2014 through April 2015

| Species | Total<sup>a</sup> | Winter | Migration | Percent of total<sup>b</sup> | CV<sup>c</sup> | Occurrence<sup>d</sup> | Conservation concern<sup>e</sup> |
|---------|------------------|--------|-----------|-----------------------------|----------------|------------------------|----------------------------------|
| Black-bellied Plover | Pluvialis squatarola (M,V) | 938 | 502 | 436 | 1 | 144 | 0.54 | Moderate |
| Snowy Plover | Charadrius nivosus (S,V) | 726 | 559 | 167 | 1 | 106 | 0.22 | ESA listed |
| Wilson’s Plover | Charadrius wilsonia (S,V) | 1851 | 814 | 1037 | 2 | 140 | 0.36 | Greatest |
| Semipalmated Plover | Charadrius semipalmatus (S,V) | 6219 | 3550 | 2669 | 6 | 173 | 0.54 |
| Killdeer | Charadrius vociferus (M,V) | 133 | 61 | 72 | <1 | 89 | 0.08 | Moderate |
| American Oystercatcher | Haematopus palliatus (L,V) | 1035 | 716 | 220 | <1 | 158 | 0.20 | Greatest |
| Black-necked Stilt | Himantopus mexicanus (L,V) | 1704 | 886 | 818 | 2 | 83 | 0.09 |
| American Avocet | Recurvirostra americana (L,T) | 1035 | 716 | 319 | 1 | 155 | 0.25 | Moderate |
| Greater Yellowlegs | Tringa melanoleuca (M,V) | 460 | 265 | 195 | <1 | 141 | 0.41 |
| Willet | Tringa semipalmata (L,V) | 2239 | 983 | 1256 | 2 | 120 | 0.73 | High |
| Lesser Yellowlegs | Tringa flavipes (M,V) | 161 | 130 | 31 | <1 | 138 | 0.20 | High |
| Solitary Sandpiper | Tringa solitaria (N) | 4 | 3 | 1 | <1 | 50 | 0.01 |
| Whimbrel | Numenius phaeopus (L,T) | 880 | 311 | 569 | 1 | 100 | 0.59 | High |
| Long-billed Curlew | Numenius americanus (L,T) | 826 | 392 | 434 | 1 | 95 | 0.47 | High |
| Marbled Godwit | Limosa fedoa (L,T) | 5248 | 2586 | 2662 | 5 | 132 | 0.72 | High |
| Spotted Sandpiper | Actitis macularius (S,V) | 282 | 134 | 148 | <1 | 102 | 0.52 |
| Ruddy Turnstone | Arenaria interpres (M,V) | 9 | 7 | 2 | <1 | 35 | 0.04 |
| Sanderling | Calidris alba (S,T) | 81 | 29 | 52 | <1 | 98 | 0.09 | Moderate |
| Red Knot | Calidris canutus (N) | 1 | 1 | 0 | <1 | 0.01 | Greatest |
| Western Sandpiper | Calidris mauri (S,T) | 64,998 | 34,781 | 30,217 | 67 | 160 | 0.60 | Moderate |
| Least Sandpiper | Calidris minutilla (S,T) | 5723 | 3679 | 2044 | 6 | 133 | 0.53 |
| Dunlin | Calidris alpina (S,T) | 663 | 466 | 197 | 1 | 161 | 0.23 | Moderate |
| Stilt Sandpiper | Calidris himantopus (N) | 1 | 0 | 1 | <1 | 0.01 |
| Pectoral Sandpiper | Calidris melanotos (N) | 1 | 1 | 0 | <1 | 0.01 | High |
| Long-billed or Short-billed dowitcher | Limnodromus scolopaceus or griseus (M,T) | 2238 | 1558 | 680 | 2 | 184 | 0.31 | High/Moderate |

Note: Each species was assigned a size class (S = Small, M = Median, and L = Large; sensu Page et al., 1997) and a foraging method (T = Tactile and V = Visual; sensu Barbosa & Moreno, 1999). However, if the occurrence was <0.02, it was removed from the analysis (N).

<sup>a</sup>Total = total birds counted over all surveys.

<sup>b</sup>Percent of total = percent of all birds counted represented by each species.

<sup>c</sup>CV = coefficient of variation of the counts.

<sup>d</sup>Occurrence = probability of ≥1 bird occurring during a survey of the sampling unit.

<sup>e</sup>According the US Shorebird Conservation Plan Partnership (2016).
There was some type of potential disturbance during 79.4% of surveys (143/180). Of the 902 total potential disturbances recorded, 91.8% (828) were related to human activities and only 8.2% (74) to raptors. Among human causes, the most frequent disturbance was the presence of people (82.2%, 681 events), followed by vehicles (9.8%, 81), dogs without leashes (2.8%, 24), and the rest were grouped as other (5%, 41). The most frequent aerial predators were Crested Caracaras (32.5%, 24), Peregrine Falcons (27%, 20), and American Kestrels (23%, 17); the remaining 17.5% corresponded to Merlins (6), Cooper’s Hawks (4), and Zone-tailed Hawks (3). Raptors observed attacking shorebirds included Peregrine Falcons (5 events), a Merlin (1 event), and Crested Caracaras (3 events). Only the Merlin attack was successful. Some of the raptors migrated and thus were not consistently present in sampling units. Crested Caracaras and American Kestrels had the highest presence throughout the study period, especially in March. Peregrine Falcons only were present during fall migration until December.

After controlling for variability in survey duration, the rate of raptor disturbances (events/minute) during migration (0.011 ± 0.002) was lower than in winter (0.029 ± 0.002) but the rate of potential human disturbances during migration (0.054 ± 0.012) and winter (0.046 ± 0.003) was comparable. Based on our model analyses, the area (ha) of sampling units was positively associated with the abundance of small sandpipers and Western Sandpipers only during winter (Table 2). After accounting for all factors, beaches were used significantly less than ponds in 14 model scenarios. However, there was no significant difference between the intertidal mudflats and ponds. Although, on average, ponds were smaller units than the other sampling units, they also hosted large numbers of shorebirds. Proportion of flooded habitat had a significant negative effect in nine of 14 models. The group of all shorebirds combined, Western Sandpipers, small and tactile foraging birds, were negatively associated with proportion of flooded habitat in winter and migration periods (Tables 2 and 3). The magnitude of significant declines varied among species groups and seasons but ranged from 23 to 63% declines in the expected abundance of shorebirds in units with an average amount of potential human disturbance compared with a site with no potential human disturbance. Conversely, shorebird abundance had a significant positive association with potential raptor disturbance in all shorebirds, small, and visual foraging shorebird models during the winter. However, it was negatively associated with abundance in all shorebirds, Western Sandpipers, small and tactile foraging shorebird models during the migration periods (Tables 2 and 3). Evaluation of the random slopes for the effect of potential human disturbance did not highlight any particular species, including the most abundant species Western Sandpiper, clearly driving the negative global effect.

| Parameter | All | Large | Small | Medium | Visual | Tactile | Intertidal mudflat | Sandy beach | Flooded habitat | Human disturbance | Raptor disturbance |
|-----------|-----|-------|-------|--------|--------|---------|-------------------|-------------|-----------------|------------------|------------------|
| Intercept (Ponds) | 1.75 | 1.32 | 0.42 | 1.40 | -2.03 | 0.56 | -1.68 | -0.56 | -1.11 | -0.56 | -56.34 |
| Area (ha) | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| Parameter estimates and 95% confidence intervals for shorebird models using data from groups of species during the migration periods (Tables 2 and 3). The magnitude of significant declines varied among species groups and seasons but ranged from 23 to 63% declines in the expected abundance of shorebirds in units with an average amount of potential human disturbance compared with a site with no potential human disturbance. Conversely, shorebird abundance had a significant positive association with potential raptor disturbance in all shorebirds, small, and visual foraging shorebird models during the winter. However, it was negatively associated with abundance in all shorebirds, Western Sandpipers, small and tactile foraging shorebird models during the migration periods (Tables 2 and 3). Evaluation of the random slopes for the effect of potential human disturbance did not highlight any particular species, including the most abundant species Western Sandpiper, clearly driving the negative global effect.
Our results show that shorebird abundance at this subtropical study site was significantly associated with several sources of environmental variabilities, such as size of sampling units, habitat type, proportion of flooded habitat, and human and raptor disturbance rates. Perhaps most importantly, we found that, after controlling for these different correlates of abundance, overall shorebird abundance had a significant negative association with potential human disturbance. Furthermore, the magnitude of the negative influence of human disturbance on abundance varied across species groupings and was not influenced by Western Sandpipers, the most abundant species. Overall, our results suggest that habitat quality for shorebirds in ELP could be enhanced by reducing human disturbance. However, the results were somewhat contrary to our expectations. First, susceptibility to human disturbance did not differ with shorebird foraging strategy because both tactile and visual foragers were negatively associated with potential human disturbance. Second, contrary to our expectation, abundance of small species was more affected by human disturbance than was abundance of medium and large species. This difference indicates that, although body size and flight initiation distance are correlated, such that large shorebirds are readily flushed by humans (Blumstein et al., 2003), abundance of small shorebirds is most severely impacted by human disturbance. Based on the Christmas Bird Count in the Ensenada de La Paz circle, during the last 15 years, the number of Western Sandpipers declined from 12,743 individuals in 2005 (Niven & Butcher, 2010) to an average of 5240 in the most recent three years (2017–2019) (National Audubon Society, 2020). Whether this population decline is only local, driven by the human disturbance in ELP, or part of a larger change in Western Sandpiper populations requires additional assessment. We found that human disturbance negatively affected the number of birds in both seasons but was only significant in winter. The magnitude of the negative association was also larger in winter than during migration. In winter, shorebirds were most numerous, so, they may be more likely to be pressed for food and vulnerable to disturbance. In addition, in winter, individual birds are present for a longer period and may be more sensitive to sites with

### TABLE 3  Parameter estimates and 95% confidence intervals for shorebird abundance models using data from groups of species during migration at Ensenada de La Paz, Baja California Sur, Mexico, from August 2014 through April 2015

| Parameter                          | All    | WESA   | Large  | Medium | Small  | Tactile | Visual |
|------------------------------------|--------|--------|--------|--------|--------|---------|--------|
| Intercept (Ponds)                  | 1.72   | (−0.35, 3.79) | 4.69   | (3.01, 6.93) | 1.57   | (−0.61, 3.76) | −0.07  | (−2.90, 2.76) | 2.35   | (−0.24, 4.89) | 2.12   | (0.11, 4.13) | 1.76   | (−1.23, 4.74) |
| Area (ha)                          | −0.07  | (−0.82, 0.68) | 0.44   | (−0.33, 1.21) | −0.57  | (−1.29, 0.15) | 0.28   | (−0.66, 1.21) | 0.14   | (−0.74, 1.01) | −0.27  | (−0.95, 0.41) | 0.17   |
| Intertidal mudflat                 | 0.24   | (−0.77, 0.1.25) | 0.75   | (−0.40, 1.90) | 2.91   | (1.94, 3.89) | −1.11  | (−2.38, 0.16) | 0.14   | (−0.99, 1.27) | 1.35   | (0.44, 2.25) | −1.53  |
| Sandy beach                        | −2.24  | (−3.38, −1.10) | −4.12  | (−5.67, −2.57) | 0.40   | (−0.72, 1.53) | −2.83  | (−4.42, −1.24) | −2.76  | (−4.18, −1.35) | −1.41  | (−2.47, −0.36) | −3.50  | (−5.19, −1.81) |
| Flooded habitat                   | −0.54  | (−0.96, −0.12) | −1.59  | (−2.96, −0.22) | 0.20   | (−0.19, 0.60) | 0.25   | (−0.68, 1.18) | −1.60  | (−2.29, −0.90) | −0.53  | (−1.01, −0.04) | −0.21  | (−0.87, 0.45) |
| Human disturbance                 | −36.99 | (−58.42, −15.56) | −22.46 | (−53.31, 11.39) | −5.80  | (−13.22, 1.61) | −0.72  | (−8.00, −2.40) | −41.20 | (−41.63, −2.46) | −22.05 | (−113.20, −17.47) |
| Raptor disturbance                | −3.36  | (−5.74, −0.99) | −8.11  | (−16.22, −0.002) | −0.70  | (−3.39, 1.99) | −6.25  | (−12.98, 0.48) | −3.78  | (−6.61, −0.95) | −6.80  | (−10.74, −2.86) | −2.95  | (−6.15, 0.26) |

Note: Confidence intervals that do not overlap zero (in bold) were considered significant.
ongoing potential disturbance than are migrating birds, which may only stop for a few days and thus may tolerate sites with higher potential disturbance for that short window.

We found that people were the most frequent source of anthropogenic disturbance in Ensenada de La Paz, followed by vehicles and dogs. These disturbance sources were similar to those found in other shorebird studies during migration or wintering season (Burger et al., 2007; Tarr et al., 2010). Proximity to urban areas can, directly and indirectly, influence the rate of human disturbance, thus degrading the quality and quantity of sites for shorebirds (Kingsford, 1990; Koch & Paton, 2014). At our study site, anthropogenic disturbance was greater near urban areas, such as the sandy beaches of Comitán and El Centenario, relative to less accessible places such as the mudflats of Chametla. Therefore, an education and awareness campaign of shorebirds, wetlands, and human disturbance at our study site would be a useful first step for local shorebird conservation. For example, it has been proposed that the distance of roads to the areas where shorebirds are present should be a minimum of 80 m (Martín et al., 2015), and the presence of people in places important for shorebirds should be restricted (Kingsford, 1990).

The positive association between shorebird abundance and disturbance from predators in winter was unexpected, but consistent with a recent flyway-wide assessment (Reiter et al., 2020). Thus, shorebirds likely concentrate in large groups to reduce the risk of predation, which could result in higher densities of shorebirds occurring in areas with high predation risk (Barbosa & Moreno, 1999; Reiter et al., 2020). In addition, the positive associations between aerial predators and small species, tactile and visual foragers, and Western Sandpipers were more evident than for medium and large species. This relationship was not surprising because Peregrine Falcons and Merlins are known to prey on small shorebird species (Dekker & Ydenberg, 2004; Ydenberg et al., 2007).

Human disturbance is considered a potentially significant threat to shorebird populations (Senner et al., 2016). While controlling for other factors, our results confirm that human disturbance negatively impacts shorebird abundance during the non-breeding season in a subtropical coastal wetland. Although we did not characterize shorebird behavior, which might help to tease apart further the impacts of different kinds of human disturbance and their behavioral and physiological consequences on shorebirds, our study shows that places with high human disturbance will mostly have fewer birds regardless of habitat or habitat condition (e.g., flooding). Gibson et al. (2018) found that body mass and survival rates of Piping Plovers (Charadrius melodus) were substantially lower for individuals in non-breeding areas with greater anthropogenic disturbance than for those in less disturbed habitats. This evidence of the impact of human use on shorebirds in this region needs to be accounted for in conservation and management strategies in Ensenada de La Paz and, more broadly, in the Baja California peninsula, Mexico. Although limiting access to beaches and wetlands is often not popular with local communities, our results indicate the need for this conservation strategy during winter and possibly during migration. Given the varied threats that shorebirds face across their annual cycle, human disturbance is one threat that may be mitigated through proactive education, outreach, and conservation actions.

AUTHOR CONTRIBUTIONS
Eduardo Palacios involved in conceptualization (lead); collected the data; original draft (lead), and writing. Jonathan Vargas collected the data (lead); and review and editing (equal). Guillermo Fernández involved in writing—review and editing (equal). Matthew Reiter designed the methodology (lead); formal analysis (lead); and writing—review and editing (equal). All authors contributed critically to the drafts and gave final approval for submission for publication.

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CONFLICT OF INTEREST
The corresponding author confirms on behalf of all authors that there have been no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are openly available in the Dryad Digital Repository: https://doi.org/10.5061/dryad. cjsxksn85 (Palacios et al., 2022).

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