Effects of Human Activity on the Structure of Coastal Marine Bird Assemblages in Central Chile

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Abstract: *In comparison with the effects of the collection of marine intertidal organisms by humans, the effects of human recreational activities on assemblages of marine birds have received scarce attention. We evaluated whether in central Chile the spatial and temporal variation in the composition and abundance of the avian assemblage is affected by the presence of humans on the coast. We studied a 1.5-km stretch of rocky coast, in the center of which is a small marine reserve where no fishing or recreational activities take place. At 15 observation points, we conducted 12 monthly surveys of birds that roost in the supralittoral zone, between the high-tide mark and the terrestrial vegetation, and/or that forage in the intertidal zone. In addition, within the reserve we conducted daily bird surveys over 2 years to evaluate whether abundance or composition changed according to the activity of people outside the reserve. We recorded 19 species of coastal marine birds. Eleven species used the supralittoral zone only for roosting (roosting assemblage), whereas the others foraged on intertidal organisms and roosted in the supralittoral zone (foraging assemblage). Although the largest negative effect of human activity on bird abundance occurred in summer, the period of greatest recreation intensity, the presence of humans negatively affected birds year round, changing both the spatial and temporal distribution of birds along the shore. Bird abundance was higher at observation points inside the marine reserve, although the pattern was stronger for birds roosting on the supralittoral zone than for birds actively foraging in the intertidal zone. Similarly, the number of birds recorded during weekends inside the reserve was higher than during week days. Our results illustrate the important role played by this marine reserve, which offers marine birds safe roosting sites without human interference. Larger marine reserves than the one we studied are needed because the dynamics of birds inside the reserve were strongly influenced by human activities in immediately adjacent areas. Our results emphasize the need to consider human recreational activities along the coast when establishing conservation programs because harvesting refugia or "no-take" zones will not provide protection to coastal bird assemblages unless human access is restricted.*

Efectos de la Actividad Humana sobre la Estructura de Ensamblajes de Aves Marinas Costeras en Chile Central

Resumen: *En comparación con estudios de los efectos de la recolección de organismos intermareales marinos por humanos, el efecto que pueden tener actividades humanas las recreativas sobre ensambles de aves marinas ha recibido escasa atención. En Chile Central evaluamos si la variación espacial y temporal de la composición y abundancia del ensamblaje es afectada por la presencia de humanos en la costa. Estudiamos una sección de costa rocosa de 1.5 Km, al centro de la cual hay una pequeña reserva marina en la que no se realizan actividades pesqueras ni recreativas. En 15 puntos de observación, realizamos 12 censos de aves que perchan en la zona supralitoral, entre el límite de la marea alta y la vegetación terrestre, y/o que forrajean en la zona intermareal. Adicionalmente, en la reserva efectuamos conteos de aves diarios durante 2 años para evaluar si la abundancia o composición cambiaba de acuerdo con la actividad de humana fuera de la reserva. Registramos 19 especies de aves marinas costeras. Once especies utilizaron la zona supralitoral solo para perchar (ensamblaje perchador), mientras que las restantes forrajearon organismos intermareales*

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marinos y percharon en la zona supralitoral (ensamblaje forrajero). Aunque el mayor efecto negativo de la actividad humana sobre la abundancia de aves ocurrió en el verano, el período de mayor intensidad recreativa, la presencia de humanos afectó negativamente todo el año, cambiando distribución tanto espacial como temporal de las aves a lo largo de la costa. La abundancia de aves fue más alta en puntos de observación dentro de la reserva marina, aunque el patrón fue mayor para aves que perchan en la zona supralitoral que para las aves que forrajean activamente en la zona intermareal. Similarmente, el número de aves registradas dentro de la reserva durante los fines de semana fue mayor que durante los días de semana. Nuestros resultados ilustran el importante papel que tiene esta reserva marina, que ofrece sitios seguros para perchar sin interferencia humana para aves marinas. Se requieren reservas marinas mayores a la que estudiamos porque la dinámica de las aves dentro de la reserva estuvo fuertemente influenciada por actividades humanas en áreas inmediatamente adyacentes. Nuestros resultados enfatizan la necesidad de considerar actividades humanas recreativas a lo largo de la costa cuando se establezcan programas de conservación porque refugios o zonas de "no captura" no proporcionarán protección a ensamblajes de aves marinas a menos que se restrinja el acceso a humanos.

Introduction

Harvesting of intertidal organisms by humans can have dramatic effects on the structure and function of marine communities (Siegfried et al. 1985; Hockey & Bosman 1986; Agardy 1994; Dayton 1995; Botsford et al. 1997; Castilla 1999). In central and southern Chile, several studies have documented the consequences of human harvesting of invertebrates and macroalgae on the population dynamics of target species, and on the rest of the intertidal community (Moreno et al. 1984, 1986; Castilla & Durán 1985; Bustamante & Castilla 1990). These studies demonstrate the need for the establishment of "no-take" zones, or harvesting refugia, to protect benthic resources (Férnandez & Castilla 1997; Castilla 1999). Such restricted areas protect species from the direct effect of harvesting on intertidal organisms, but they do not offer protection from disturbance caused by human recreation or tourism on the coast.

Probably because the effect of fishing is so obvious along the coast of Chile, the effects of other human activities on the coast have not been investigated with the same intensity. For instance, several studies have documented the immediate and long-term effects of human recreational activities on wildlife populations (e.g., Knight & Cole 1995). Disturbance caused by recreational use of beaches and shores may have important effects on the population dynamics of shorebirds (Robertson & Flood 1980; Burger 1995). Along the coast of central Chile, weekend and summer vacationers are particularly abundant. Thus, in order to set up guidelines for the protection of coastal areas, it is important to characterize the nature and intensity of human recreational uses of the coast.

In North America, human harvesting of intertidal organisms negatively affects shorebirds, many of which are high-level predators in intertidal food webs (Burger & Gochfeld 1991; Boer & Longamane 1996; Lindberg et al. 1998) and can themselves have important effects on invertebrate assemblages (Schneider 1978; Marsh 1986; Wootton 1992, 1997; Sewell 1996). The assemblage of coastal birds on Chilean rocky shores, including species composition, abundance, and the spatial and temporal variations of these attributes, have been poorly studied. Some information is available on the distribution and conservation status of seabirds (Schlatter 1984; Morrison & Ross 1989) and on the trophic ecology of *Larus dominicanus* (Bahamondes & Castilla 1986, Navarrete & Castilla 1990), species of the genus *Cinclodes* (Hockey et al. 1987), and *Arenaria interpres* and *Aphriza virgata* (Espoz 1989), but no studies have characterized the composition of the entire assemblage or evaluated the effects of human activity.

We quantified the effects of the presence of humans on the composition and abundance patterns of the bird assemblages that inhabit the rocky shore of Las Cruces, central Chile. Taking advantage of the presence of a marine reserve, we evaluated whether spatial and temporal variations in the composition and abundance of the avian assemblages are related to human activities. We did not assess the direct effect of humans on bird behavior, but instead examined the correlation between the presence of people and bird abundance and composition.

Methods

Study Site

Fieldwork was carried out along a 1.5-km rocky shore at Las Cruces (lat. 33°30′S, long. 71°38′W) on the central coast of Chile (Fig. 1). Las Cruces is a popular resort town less than 2 hours from Santiago, the capital of the country; consequently, it receives large numbers of weekend and summer (December–March) vacationers. At the center of this coastal stretch is a small marine reserve of approximately 500 m of seafront with an intertidal rocky shore area of about 4152 m^2, established by

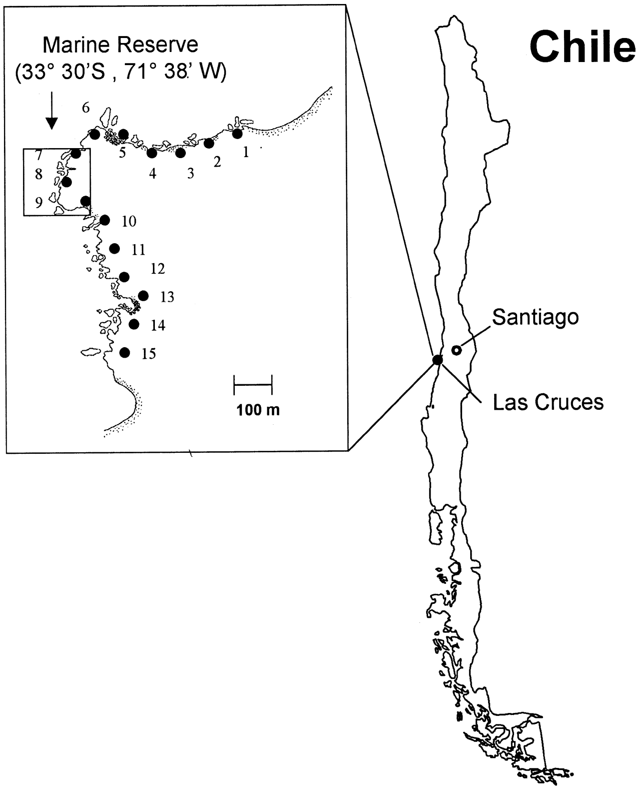

Figure 1. Location of the study site at Las Cruces on the central coast of Chile, and the position of the marine reserve of the Estación Costera de Investigaciones Marinas and the 15 observation points where bird surveys were conducted.

the Pontificia Universidad Católica de Chile, where no harvesting or recreational activities have occurred since December 1982.

Because only regulated research activities are allowed inside the reserve, we predicted that human interference on birds would be low along this 500-m stretch of shoreline, in sharp contrast to the immediately adjacent rocky shore areas, where fishing (Castilla & Durán 1985; Castilla & Bustamante 1989; Durán & Castilla 1989) and, particularly, recreational activities are common. Consequently, we predicted that bird abundance would be higher and composition would be different inside the marine reserve.

Shoreline Surveys

To evaluate the effect of human activity, we conducted two different types of bird surveys. First, to assess whether the presence of the marine reserve changed the spatial pattern of composition and abundance of the bird assemblage along the shore, we carried out monthly bird surveys of all species observed on the rocky intertidal and supralittoral zones along the 1.5-km coastline from June 1998 through May 1999. Second, to evaluate whether temporal variation in the number of people on the shore changed the abundance of shore and seabirds inside the reserve, a daily bird count was carried out in the reserve from November 1997 through November 1999.

We chose 15 consecutive, approximately equally spaced observation points along the upper part of the supralittoral zone. Observation points 7, 8, and 9 were inside the marine reserve (Fig. 1). From each observation point, a fixed stretch of 100 m of coastline was visually delimited and surveyed. Each sampling point covered similar areas from the low-water mark to approximately the line of coastal vegetation. We spent 10 minutes at each survey area, which according to our preliminary surveys was enough time to correctly identify and count all birds on the survey area present at the moment of our arrival at the observation point.

We conducted monthly bird surveys during 3–4 days of spring tides. Two bird surveys were conducted each day, one between 1 hour before and after the lowest low tide and another between 1 hour before and after the highest high tide. Surveys were conducted during daylight. We recorded all bird species observed foraging or roosting on the rocky intertidal or supralittoral zones. Birds observed flying over the survey area were not included. We also recorded the number of people observed on either the intertidal or supralittoral zones at each observation point. Differences in type of human activity were not recorded. Determining whether people were recreating or collecting organisms at each observation point was too time consuming to allow us to finish the survey within a low- or high-tide period, but previous studies (Durán et al. 1987) and our own observations showed that recreational activities are far more frequent and involve a larger number of people (approximately 90% of all people observed in the study area).

Bird Surveys inside Marine Reserve

Each day at 1300 hours and again at 1700 hours, we counted the total number of birds roosting and/or foraging inside the marine reserve from fixed observation points on a 40-m-high cliff. Because a daily survey identifying and counting all species found on the rocky shore was not possible with available resources, and because it would disturb the birds, we identified and counted only abundant and conspicuous species. These included the Olivaceous, Guanay, and Red-legged Cormorants, Peruvian Booby, Chilean Pelican, Kelp Gull, White Snow Egret, and Huairavo (see Table 1 for scientific names). These species represent 42% of all bird species observed in the area and approximately 75% of the total number of birds.

Data Analysis

Coastal birds belong to two distinctive guilds in terms of diet and use of the rocky shore. Some birds are mostly

Table 1. Coastal bird species observed roosting and/or foraging along the rocky shore of Las Cruces, central Chile, 1998–1999.

Family	*Scientific name*	*Common name*	*Residence status*[a]	*Use of intertidal zone*[b]
Sulidae	*Sula variegata*	Peruvian Booby	Re	R
Pelecanidae	*Pelecanus thagus*	Chilean Pelican	Re	R
Phalacrocoridae	*Phalacrocorax olivaceus*	Olivaceous Cormorant	Re	R
	Phalacrocorax bougainvillii	Guanay Cormorant	Re	R
	Phalacrocorax gaimardi	Red-legged Cormorant	Re	R
Ardeidae	*Egretta thula*	Snowy Egret	Re	F-R
	Nycticorax nycticorax	Black-crowned Night-Heron	Re	F-R
Haematopodidae	*Haematopus palliatus*	American Oystercatcher	Re	F-R
Scolopacidae	*Numenius phaeopus*	Whimbrel	M	F-R
	Arenaria interpres	Ruddy Turnstone	M	F-R
	Aphriza virgata	Surfbird	M	F-R
	Calidris alba	Sanderling	M	F-R
Laridae	*Larus dominicanus*	Kelp Gull	Re	F-R
	Larus modestus	Garuma Gull	M	R
	Larus pipixcan	Franklin's Gull	M	R
	Larosterna inca	Inca Tern	M	R
Furnariidae	*Cinclodes patagonicus*	Dark-bellied Cinclodes	M_p	F-R
	Cinclodes nigrofumosus	Seaside Cinclodes	M_p	F-R
	Cinclodes oustaleti	Grey-flanked Cinclodes	M_p	F-R

[a] *Re, resident; M, migratory; M_p, partially migratory.*
[b] *R, roosting; F-R, foraging and roosting.*

fish eaters that forage in the ocean and roost on the shore ("seabirds"; sensu Harrison 1983). Other species feed mostly on invertebrates in the intertidal zone and roost in the supralittoral zone ("shorebirds"; sensu Hayman et al. 1986). Because these groups could be affected differentially by human activity, we conducted separate analyses for the intertidally foraging bird assemblage (hereafter "foraging assemblage") and the roosting-only bird assemblage (hereafter "roosting assemblage"; see Table 1 for classification). Even though the Kelp Gull is usually considered a seabird, we include this species in the foraging assemblage because of its frequent intertidal foraging behavior (Bahamondes & Castilla 1986; Navarrete & Castilla 1990). The Furnariidea and Ardeidae species were also included in the foraging assemblage because these species usually forage on intertidal rocks and pools (Fjeldsa & Krabbe 1990; de la Peña & Rumboll 1998).

To evaluate whether the presence of humans limits the maximum number of birds observed on the coast, we used quantile regressions to estimate the shape of the upper bound of the relationship between numbers of birds and people at each observation point (Cade et al. 1999). We present results for the 75% quantile, which give reasonably stable estimates of the upper-boundary slopes (Cade et al. 1999).

The proximity of the observation points along the shore did not guarantee the independence of our observations of birds and people at any given time, so they were not considered true replicates in statistical analyses. Instead, different days within months and seasons were used as estimates of variation for the bird assemblage. Because all observation points in the marine reserve are necessarily contiguous and not independent, we could not conduct statistical significance tests to compare the marine reserve with the two areas outside. Instead, we visually examined the spatial pattern of variation in bird abundance along the coast and discuss the potential effect of other confounding factors.

Results

We observed 19 species of coastal birds during the study. Of the total, 11 species were observed foraging and roosting on the shore (foraging assemblage), and 8 were only observed roosting (roosting assemblage) (Table 1). The Kelp Gull, Olivaceus Cormorant, and Dark-bellied Cinclodes were the most abundant species, accounting for 52% (summer) to 87% (winter) of all individuals recorded. In addition to these species, three migratory birds, the Whimbrel, Ruddy Turnstone, and Surfbird, become locally abundant during summer and fall.

For both pooled bird assemblages (foraging and roosting) and with the addition of all individuals observed along the entire study area, a two-way analysis of variance (ANOVA) with season and tidal height as factors revealed significant seasonal variation in the number of birds ($F_{3,68} = 22.33$; $p < 0.001$): significantly more birds were observed in summer and fall months. There were no differences in total numbers between high and low tide ($F_{1,68} = 0.066$; $p = 0.793$), and there was no interaction between seasons and tide ($F_{3,68} = 0.985$; $p = 0.407$). Separate analyses for foraging and roosting assemblages showed the same general pattern. There was a significant seasonal variation for roosting ($F_{3,68} = 7.007$;

$p < 0.001$) and foraging assemblages ($F_{3,68} = 24.799$; $p < 0.001$), but no differences between high and low tide and no interaction between season and tide (Fig. 2a & 2b). As expected for the foraging assemblage, a tidal effect was observed only when birds recorded on the intertidal zone at the time of the survey were considered (Fig. 2c). In this case, a significant tidal effect was detected (higher numbers at low tide, $F_{1,68} = 161.16$; $p < 0.001$), which did not change across seasons (no significant interaction with season).

The number of people observed along the study area during the bird surveys also showed seasonal variation. A two-way ANOVA with season and tidal height as factors revealed significant seasonal variation in the number of people found along the shore ($F_{3,68} = 10.39$; $p < 0.001$). There were no differences between total numbers observed at high and low tide ($F_{1,68} = 0.164$; $p = 0.690$), and there was no interaction between seasons and tide ($F_{3,68} = 0.544$; $p = 0.650$). The highest mean number of people was recorded in summer (55.7 ± 6.9/1.5 km of shoreline) and the lowest in winter (5.3 ± 6.2/1.5 km). The number of people per observation point was negatively correlated with the maximum number of birds observed at the same locations (Fig. 3). Quantile regressions gave highly negative estimates of the upper boundary slope of this relationship, particularly in summer (Table 2).

The highest numbers of birds of the roosting assemblage, recorded on either the intertidal or supralittoral zones, were consistently registered at observation points located inside the marine reserve (Fig. 4). The same general pattern was observed for birds belonging to the foraging assemblage when birds found on both the intertidal and supralittoral zones were considered (Fig. 5). When we considered only birds of the foraging assemblage actually feeding in the intertidal zone during the low tide, no trend was detected (Fig. 5). Thus, there were higher numbers of birds inside the reserve roosting in the supralittoral zone (Fig. 5).

We examined the possible association between the temporal variation in the number of birds inside the reserve and human activity outside the reserve. Significantly more people were observed during weekends than during weekdays outside the reserve, both during the high season for tourism (December–March) and during low season. The mean number of birds recorded in-

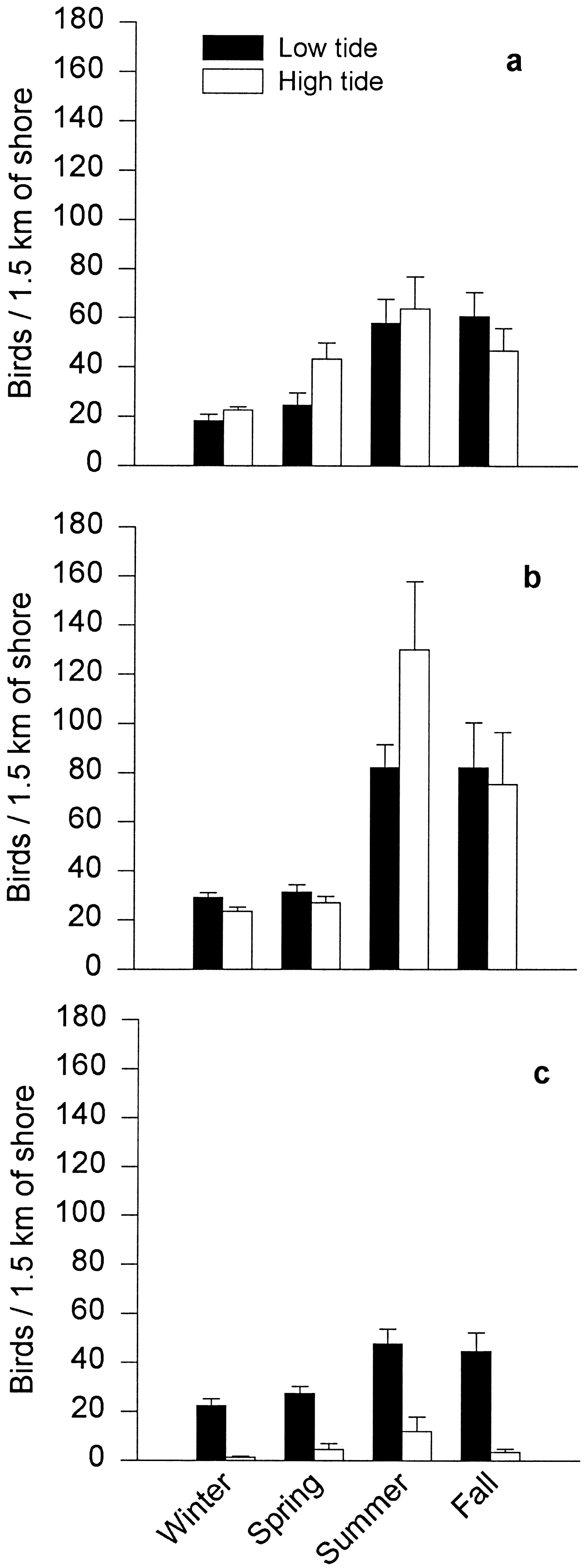

Figure 2. Mean number (±SE) of coastal marine birds recorded during low- and high-tide surveys in Las Cruces on different seasons for (a) roosting birds recorded in the intertidal and supralittoral zones, (b) foraging birds recorded in the intertidal and supralittoral zones, and (c) foraging birds recorded in the intertidal zone only.

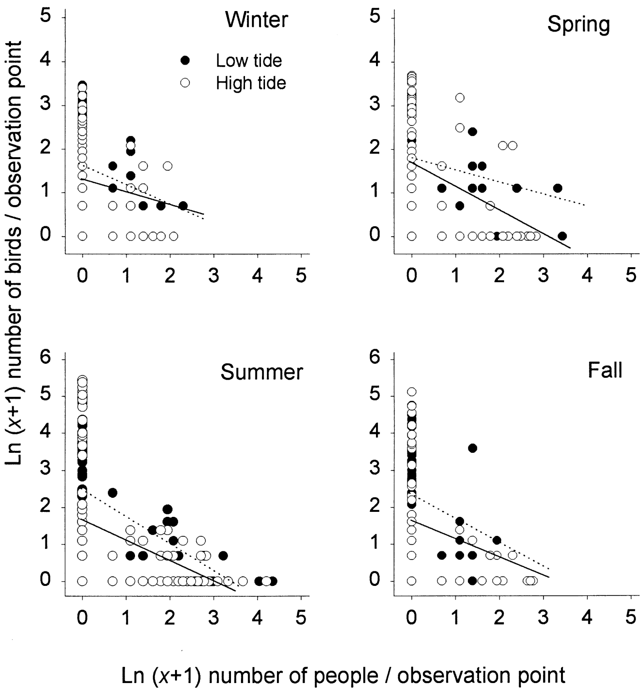

Figure 3. Number of coastal birds (birds of foraging and roosting assemblages pooled) versus number of people recorded at each observation point along the coast of Las Cruces in different seasons during low and high tides. Lines correspond to the upper-boundary slope from quantile regression during high tide (solid line) and low tide (dashed line).

side the reserve during weekends was significantly higher than that recorded on weekdays during low season (April–November: $F_{1,398} = 4.65$; $p = 0.031$). The mean number of birds recorded on weekends inside the reserve was 32.2 ± 2.6, whereas on weekdays it was 28.5 ± 1.9. During high season, no significant differences in bird numbers were observed between weekends and weekdays.

Discussion

Our results strongly suggest that the presence of humans on the coast interferes with the spatial and temporal abundance of shorebird and seabird species by reducing available roosting space on the supralittoral zone. We observed a marked seasonal pattern in the abundance of birds, with higher numbers overall during summer than the rest of the year. As expected, higher numbers of people were also recorded during summer, when vacationers visit the coast. Despite the seasonal variation in number of birds and people, a negative relationship between bird abundance and people along the rocky coastline was observed for all seasons. Further evidence of human effects on the spatial and temporal distribution of shorebirds and seabirds was the persistently higher number of birds recorded on observation points located inside the marine reserve and the increase in the number of birds inside the reserve on weekends, when more people visit the coast. Human interference appeared to be stronger and more evident for birds roosting on the supralittoral zone than for birds actively foraging on the intertidal zone.

The temporal variation in the abundance and composition of the coastal bird assemblage at Las Cruces was determined largely by the arrival to the Southern Hemisphere during summer months of large flocks of migratory species, such as *Aphriza*, *Arenaria*, and *Numenius* (Table 1). But resident species such as the Kelp Gull and cormorants also showed increases in abundance during summer. Seasonal changes in seabird abundance have been documented previously on other coasts, changes which have been associated mainly with seasonal variation in local oceanographic features and food supply (Schneider 1991; Ribic et al. 1997; Dinsmore et al. 1998) or with the proximity of breeding colonies (Norman 1992). It has been documented that some gull species of the genus *Larus* increase in abundance seasonally in response to human activities such as garbage dumping, which provides a new food source for gulls (King et al. 1992). Although some increase in sewage water and garbage dumping during summer does occur along the central coast of Chile, these activities are generally kept under regulation in the tourist areas. It is thus unlikely that seasonal increases in the abundance of seagulls and several other species (which do not forage opportunistically on wastes) could be produced by human subsidies of food. Most likely, seasonal bird responses are associ-

Table 2. Estimates of upper-boundary slope (*a*) and 95% confidence intervals using quantile regression for the relationships between number of people and observation point and between number of birds and observation point (foraging and roosting birds pooled).*

	Low tide			*High tide*		
Season	n	*slope*	*95% CI for* a	n	*slope*	*95% CI for* a
Winter	180	−0.40	−0.57–0.14	165	−0.26	−0.80–0.13
Spring	150	−0.30	−0.56–−0.22	135	−0.63	−0.74–0.12
Summer	135	−0.67	−0.97–−0.53	135	−0.47	−0.71–−0.27
Fall	120	−0.56	−1.23–1.03	120	−0.51	−0.55–−0.26

**The 75% quantile was used for the analysis. The* n *is total number of observations per season. Data were ln(*x *+ 1)-transformed.*

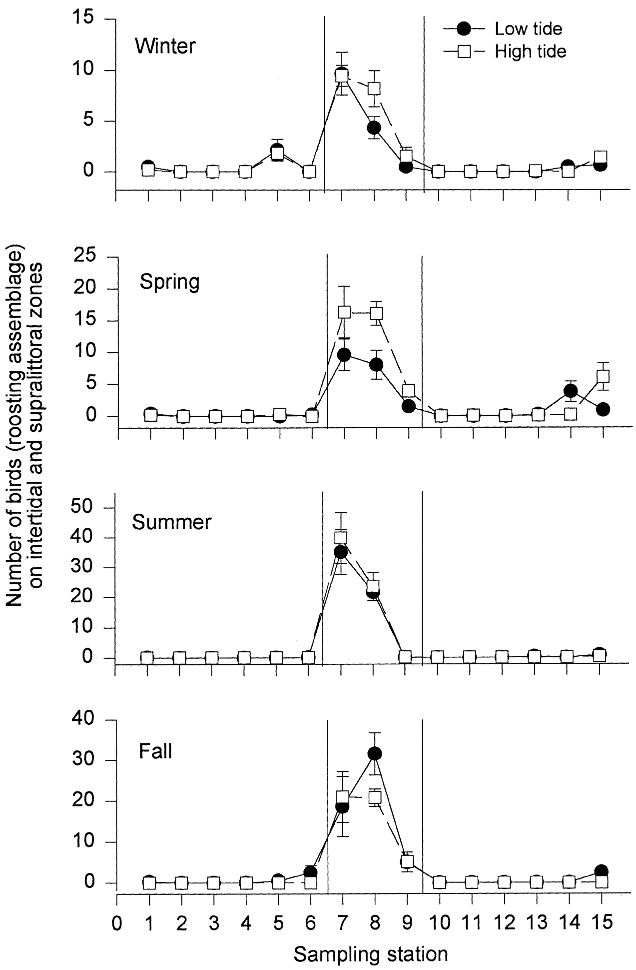

Figure 4. Mean number (±SE) of birds of roosting assemblage on each of the 15 observation points along the rocky shore of Las Cruces during low-tide and high-tide surveys. Birds found on intertidal or supralittoral zones were pooled. Observation points 7, 8, and 9 are inside the marine reserve (Fig. 1).

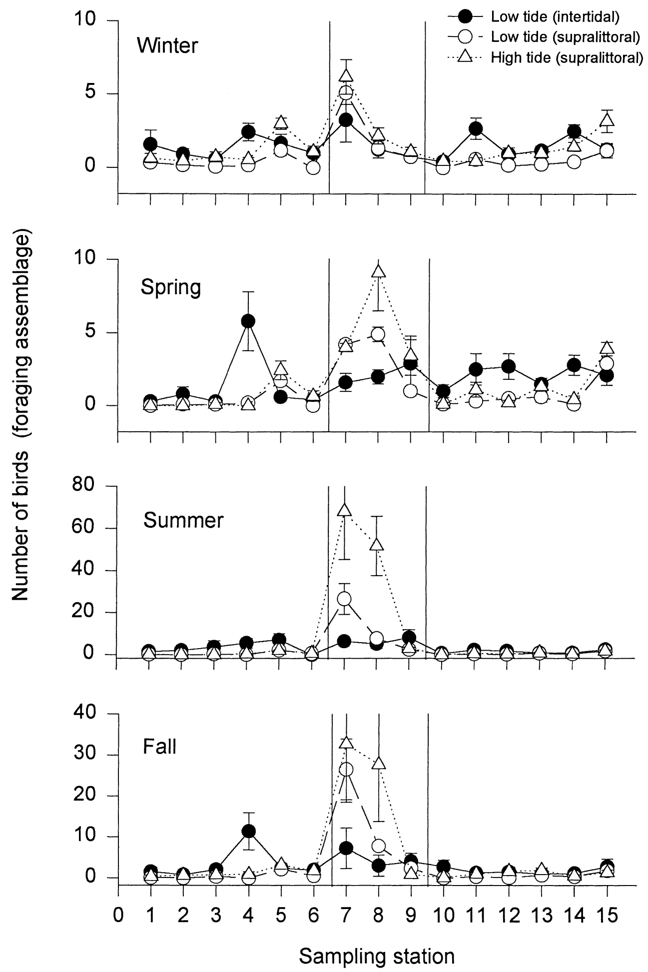

Figure 5. Mean number (±SE) of birds of foraging assemblage on the 15 observation points along the rocky shore of Las Cruces during low-tide surveys in the intertidal and supralittoral zones and during high-tide surveys in the supralittoral zone. Observation points 7, 8, and 9 are inside the marine reserve (Fig. 1).

ated with changes in overall environmental and oceanographic conditions. Whatever the mechanisms involved in seasonal patterns, the coincidence between the peaks in bird abundance and people activity on coastal areas maximizes the effects of human disturbance on the bird assemblage.

The negative relationship between the number of birds and the number of people recorded on the shore suggests that humans disturb coastal bird assemblages independently of season or tidal height. The abundance of birds observed along the coast was highly variable on a daily basis, regardless of the presence of people (i.e., on a given day and even in the absence of people there might be few birds on the shore), suggesting that other biotic or abiotic factors produce large fluctuations in bird abundance. It is not clear what other factors cause daily variability in bird numbers, but it is clear that the presence of people restricted the maximum number of birds observed on the shore.

The presence of humans in areas adjacent to the marine reserve appears to influence the spatial distribution of birds. Birds of the roosting and foraging assemblages, recorded on either the supralittoral or intertidal zones, were generally less abundant in observation points located outside the edges of the reserve than in those inside. But observation point number 9, located inside the southern edge of the reserve, showed consistently lower numbers of birds than observation points 7 and 8, located inside the reserve to the north. This is probably due to the presence of a small sandy beach (approximately 30 m long) right outside the southern border of the reserve, which is frequently visited by people.

We attribute the spatial pattern of bird abundance along the shore to the absence of humans within the reserve. It is possible, however, that human presence could be confounded with slight differences in the topographic characteristics of the rocky shore inside and outside the reserve, which could favor higher number of birds inside the reserve. Although this hypothesis cannot be completely ruled out due to the lack of appropriate replication of reserves, differences in topological characteristics cannot explain observed weekend increases in bird abundance within the reserve. Moreover, the reserve location on the coast was selected so as to be representative of wave-exposed habitats in central Chile (Castilla & Durán 1985), and therefore the intertidal habitat was not particularly unique. During our surveys we frequently observed birds flying away and concentrating within the reserve when people approached the shore. Thus, we are confident that the spatial and temporal patterns of bird abundance are a consequence of human disturbance.

When we considered the number of birds recorded on the intertidal and supralittoral zones, we found that the foraging and roosting bird assemblages were affected by human activity. To our surprise, however, when we considered only foraging birds on the intertidal zone, we found no differences in the number of birds observed inside and outside the reserve. This suggests that humans do not greatly interfere with birds while they are actively foraging in the intertidal zone, so bird foraging intensity inside the reserve can be expected to be roughly similar to that outside. This is probably due to the fact that the majority of people encountered along the shore are not food gatherers but visitors moving along the supralittoral zone, and that feeding birds may become habituated to humans passing along the supralittoral zone. Burger and Gochfeld (1991) reported that on sandy beaches, sanderlings did forage while humans were present, although the time of active feeding decreased. The apparent absence of human effects on foraging birds in our study should be interpreted with caution, however, because previous studies on other shores have shown that human interference has a strong and negative effect on shorebird foraging (Burger & Gochfeld 1991; Skagen et al. 1991; Boer & Longamane 1996; Lindberg et al. 1998). Our study was designed to determine whether there was a relationship between human presence and bird distribution and abundance along the coast, rather than to evaluate the effect of humans on bird feeding rates. Thus, further studies are required to evaluate the direct effects of human presence on the foraging behavior of shorebirds.

Our results strongly suggest that, along the coast of central Chile, disturbance by human recreational activities affects the selection of roosting sites by birds. For several bird species, especially cormorants and gulls, the presence of safe roosting sites is essential. After foraging and diving, these species need roosting time to fulfill physiological requirements such as thermoregulation, especially after diving in cold waters (Lustick et al. 1979; Lustick 1983; Guillemette 1998; Schmid et al. 1995; Grémillet et al. 1998). Moreover, most species that forage on the rocky intertidal zone roost on the supralittoral zone during high tides, sometimes in large flocks of more than 100 individuals (C.C., personal observation) until the tide is again low enough to permit foraging. The marine reserve of Las Cruces seems to play an important role in offering coastal birds safe roosting places with no human interference. Although the reserve served as a refuge for birds during weekends, when people crowded the shore, the daily bird temporal dynamics inside the reserve were directly influenced by the presence of people outside. This is likely a consequence of the small size of the reserve (only 500 m of seafront) and highlights the need for larger reserves to allow for a more natural pattern of bird dynamics. Our results emphasize the importance of establishing large marine reserves in which all human activities, not just harvesting, are regulated and monitored carefully. The situation is particularly critical for shorebird conservation in central Chile, because high levels of human pressure through recreational and harvesting activities are common and are expected to increase in the future.

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