HIGH BIRD DIVERSITY IN A SMALL COASTAL WETLAND OF CENTRAL PERU

Mónica A. Paredes,[1,2]* Héctor Aponte,[1,2] and Antony A. Apeño [2,3]

[1] Carrera de Biología Marina, Universidad Científica del Sur, Lima, Peru.
[2] COE-PERU (Coastal Ecosystem Researchers of Peru), Lima, Peru.
[3] CooperAcción, Huacho, Huaura, Lima, Peru.
E-mail: Mónica A. Paredes · Monni_Aoi@hotmail.com

Abstract · Small coastal wetlands fulfill essential roles in the prevalence of coastal ecosystems. However, they are threatened due to poor management and seemingly lack of importance. The loss of these ecosystems would reduce local biodiversity and threaten birds breeding and feeding habitats. Huacho-Hualmay-Carquin ("Huahualca") is a small (24 ha) threatened wetland located on Peru's central coast; while being widely unknown, it harbors the highest number of vascular plant species per hectare in the region. To census its bird fauna, 12 bird censuses consisting of two simultaneous transects (supralittoral and urban) were conducted between October 2019 and February 2021. Additionally, correlations with two thermal-related oceanic parameters of the South Pacific (Sea Surface Temperature and "Indice Costero El Niño") were calculated. Seventy-eight bird species were found. Species richness and abundance were higher in the supralitoral transect and during the warmer months when migrants arrived. Furthermore, we found a positive relation between monthly abundance and ICEN, suggesting that "El Niño" phenomenon positively affects coastal birds. Regardless of its small size, HHCW exhibits high bird diversity and highlights the importance of studying small wetlands to improve management and conservation strategies in the region.

Resumen · Alta diversidad ornitológica en un pequeño humedal costero en la costa del centro de Perú

Los pequeños humedales costeros cumplen funciones esenciales en la prevalencia de los ecosistemas costeros. Sin embargo, están amenazados como consecuencia de la mala gestión y la aparente falta de importancia. La pérdida de estos ecosistemas reduciría la biodiversidad local y amenaza los hábitats de reproducción y alimentación de las aves. Huacho-Hualmay-Carquin ("Huahualca") es un pequeño humedal amenazado (24 ha) ubicado en la costa central de Perú, aunque en su mayoría desconocido, alberga la mayor cantidad de especies de plantas vasculares por hectárea en la región. Con el objetivo de censar su avifauna, entre octubre de 2019 y febrero de 2021 se realizaron 12 censos de aves que consistieron de dos transectos simultáneos: "supralitoral" y "urbano". Adicionalmente, se realizaron calcularon correlaciones con dos parámetros oceánicos termales del Pacífico Sur (Temperatura Superficial del mar y el "Índice Costero El Niño"). Se encontraron 78 especies de aves.

La riqueza y abundancia de especies fue mayor en el transecto supralitoral y durante los meses más cálidos cuando llegan los migrantes. Encontramos una relación positiva entre la abundancia mensual y el ICEN, lo que sugiere que el fenómeno de “El Niño” trae efectos positivos para las aves costeras. Independientemente de su pequeño tamaño, HHCW exhibe una gran diversidad de aves y destaca la importancia de estudiar los humedales pequeños como medio para mejorar las estrategias de manejo y conservación en la región.

Key words: El Niño Southern Oscillation, El Niño Coastal Index, Sea surface temperature, Peru, Vagrant.

INTRODUCTION

Small coastal wetlands exist worldwide, largely due to long-term fragmentation of the coastal landscape by anthropogenic activity (Davidson et al. 2018). Usually found as narrow vegetation patches and lagoons along the coast, their small scale has proven to be a factor in underestimating their biological role; consequently, their study has been limited (Blackwell & Pilgrim 2011, Gibbs 1993, Tomaselli et al. 2011). Nonetheless, small wetlands near urban areas can provide natural recreation and opportunities for education, conveying awareness of the importance of their conservation (Ibrahim et al. 2012, Sinthumule 2021). In addition, these ecosystems provide coastal protection, act as biodiversity hotspots and are efficient carbon sinkers (Erwin 2009; Mitra et al. 2005). More than a third of all North American bird species depend, partially or entirely, on wetlands to fulfill their biological cycle (Nadeau & Conway 2015, Steward 2016). Nevertheless, wetlands are still globally threatened by urbanization and degradation, which risk their prevalence (Brinson & Malvarez, 2002, Xu et al. 2019).

Wetlands, being highly elastic and ever-changing ecosystems, have a strong relationship with environmental parameters like total rainfall, average temperature, salinity of bodies of water, among others which determine their habitats and biotas (Brock et al. 2005, Jiang et al. 2012). In addition, coastal wetlands are influenced by their coast's parameters such as sea surface temperature (SST), winds, and oceanic patterns like the ENSO ("El Niño Southern Oscillation"), which influence the local weather (Simionato et al. 2010, Thielen et al, 2020). This scenario makes them especially vulnerable to climate change, flooding, or loss of area due to rising sea levels (Goodman et al. 2018, Michener et al. 1997). Furthermore, in the face of loss of habitat, coastal and wetland birds with restrictive ranges could face local extinction (Osland et al. 2014, Şekercioğlu et al. 2012).

Peru encompasses at least 44 wetlands along its coast (Senner & Angulo 2014), with ten of these located in the Lima region, including the Huacho-Hualmay-Carquín coastal wetland (HHCW), a small (24 ha) site located on the edge of a developing city. HHCW is understudied, yet a previous study revealed that it possesses the highest richness of vascular plant species per hectare on the Lima coast (Aponte & Cano, 2018). Considering the vegetation as a proxy for higher trophic levels of diversity (Ferger et al. 2014, Woldemariam et al. 2018, Zellweger et al. 2016), we predicted high bird species richness and diversity despite the small size of the site (Kalwij et al. 2019). The ENSO phenomenon strongly determines Peru's coastal weather, bringing about abrupt changes in SST and total rainfall; the ENSO influences the whole food chain, changing species composition and abundance in oceanic and coastal ecosystems (Jaksic 2001, Wang & Fiedler 2006). Consequently, we expected to find an influence of these variables in the bird communities present in coastal wetlands.

The main objective was to describe the bird species composition, diversity and abundance in HHCW through the years 2019-2021, considering their temporal variance and association with SST and the El Niño Coastal Index (ICEN).

METHODS

Study area · HHCW is located in the Huaura province of Peru's central coast. It has approximately 24 hectares, formed by narrow patches of vegetation and interconnected ponds shaped by runoffs (*chorrillos*) from the subterranean aquifers found in the surrounding cliffs adjacent to the seashore. HHCW is situated between two other recognized wetlands ("Laguna El Paraíso" and "Albuferas de Medio Mundo").

Due to the small size of the wetland, different habitats merge within a short distance. However, the most significant difference occurs between the urban and supralittoral areas of the wetland (Figure 1). The urban area encompassed the east margin of the wetland, where most of the vegetation and species richness was found and includes perennial and temporal lakes and other bodies of water. This area is closest to the city, at places less than 20 m from the nearest streets; hence this area presented anthropic influence. The supralittoral area occupied the western margin of the wetland; it was mainly composed of patches of desert saltgrass (*Distichlis spicata*) and sandy shores. In this area, small lakes and runoffs are formed temporarily and rapidly change shape in response to rainfall and temperature. The supralittoral area possessed less anthropogenic influence, as it was primarily used as a recreational place for exercise and beach-going.

Bird censuses · We conducted 12 monthly censuses from October 2019 to February 2021, except on months when activity was restricted due to the COVID-19 pandemic. The censuses were initiated in the early morning (0600 h – 0700 h PST) and lasted 90 minutes. Each census consisted of two simultaneous banded transects run by two observers. To avoid recounting individuals, only the birds found between 80 m left and 5 m right of each observer were counted. The transects were parallel to the coast and named after the area they represented ("urban" for the eastern sector and "supralittoral" for the western one). Both transects had a length of 2.8 km and were separated by a distance variable from 90 to 120 m. We used 8 x 45mm binoculars and cameras with 300 mm lenses to avoid disturbing the birds, following the recommendations of Gregory et al. (2004). The birds were identified using the "Birds of Peru" identification guide (Schulenberg et al. 2010) and were counted individually or by grouping when the flock surpassed an estimated 300 individuals; in the case of mixed flocks, the less abundant species were counted first. All birds were counted, including those resting, feeding and in flight; in this last case, only the birds flying opposite the observer were counted to avoid recounting previous individuals. Birds heard but not seen (i.e., *Phleocryptes melanops* and *Anthus peruvianus*) were also counted. When possible, each species was photographed in order to provide further confirmation of its presence.

Data analysis · Species richness and abundance for each transect were determined monthly. Then, the Chao-2 estimator (Chao, 1987) was used to calculate the total bird species richness for the entire wetland (gamma diversity). For this purpose, a matrix was created using the total species richness found for each month in both transects; then, we used this equation:

$$Chao2 = Sobs + \frac{Q1^2}{2Q2}$$

Where "Sobs" is the overall observed number of species, "Q1" is the number of uniques (# of species that occurred only once in the whole evaluation) and, "Q2" is the number of duplicates (# of species that occurred only twice in the whole evaluation). Contrasting the Chao-2 estimate with the total species richness at the end of the 12 censuses gave us the percentage of completion of the evaluation.

We obtained the monthly average sea surface temperature (SST) values through the Marine Institute of Peru (*Instituto del Mar del Perú* - IMARPE - http://satelite.imarpe.gob.pe/uprsig/sst_prov.html). Meanwhile, the El Niño Coastal Index (ICEN), which measures the temperature anomalies on the coasts of Peru using a three-month running mean, was obtained through the Geophysical Institute of Peru (*Instituto Geofísico del Perú* – IGP - www.met.igp.gob.pe/datos/icen.txt).

The Spearman's rank correlation coefficient was used to test the possible correlation between species richness and abundance and the thermal-related oceanic parameters of the South Pacific (SST and ICEN). All analyses were conducted using the PAST C.4.3 statistical program (Hammer et al. 2001).

RESULTS

We recorded 78 species belonging to 30 families and 13 orders. The families better represented were Laridae (gulls and terns) and Scolopacidae (sandpipers) with 12 species each; members of these families also had the highest total abundances (Table1). Sixty-five percent of the species recorded were breeding residents, 30% boreal migrants, 4% austral migrants, and 1% were introduced species (*Passer domesticus* and *Columba livia*). Five species have a conservation status of "Near Threatened": *Calidris pusilla*, *Larosterna inca*, *Thalasseus elegans*, *Pelecanus thagus* and *Phalacrocorax bougainvillii* (IUCN, 2022). In addition, photographed sightings of two rare vagrant species (*Oressochen melanopterus* and *Sarkidiornis sylvicola*) were reported to the CRALEC (Lima and El Callao Bird Records Committee), where the observation of three individuals of *S. sylvicola* were accepted as one of the first ten recorded sightings in the region.

Species richness and abundance varied across season and transect (Fig. 2a-b). In all monthly censuses, supralitoral transects showed the highest species richness and abundance. The highest supralitoral monthly values being 43 species in November 2019 and 19,234 individuals in December 2019. In contrast, the urban transects had noticeably fewer species and abundance, with maximum monthly values of 34 species in February 2020 and 383 individuals in September 2020. Out of the 78 species found on the wetland, 25 were only seen in the supralitoral transect, while 14 were only found on the urban one (Table 1). The most abundant species in the urban transect was *Nycticorax nycticorax,* while, in the supralitoral transect, it was *Leucophaeus pipixcan.* In the supralitoral transect, the highest species richness and abundance were found in the summer months (December through March) and the lowest in the winter months (June through August). Chao-2 index (79.24) indicates that the completeness of our census was 98.7%.

No correlation was found between monthly species richness and the oceanic parameters evaluated: TSM (p-value: 0.17) and ICEN (p-value: 0.08), nor between monthly abundance and TSM (p-value: 0.125). However, we found a positive correlation between monthly bird abundance and ICEN (p-value: 0.03, SI: 0.64).

DISCUSSION

Peru's central coastal wetlands have a historical record of 211 species (Pulido, 2018); including species recorded during unusual environmental phenomena (Pulido & Bermudez 2018). The usual species richness for these ecosystems in the region is around 82 species, with temporal variations related to seasonal migrants (Alvarez & Iannacone 2008, Cruz et al. 2007, Podestá & Cotillo 2016, Quiñonez & Hernandez 2017). Considering this, HHCW harbors approximately 95% of the species found in the region. Additionally, when comparing the values for species richness per unit of area, HHCW was placed well above all other Lima wetlands, with 3.25 species/ha, followed by "Poza de la Arenilla" and "Humedal Santa Rosa", with 2.36 species/ha and 1.22 species/ha, respectively (Podestá & Cotillo 2016). However, some "usual" coastal wetland species were not found in HHCW (i.e., members of the Podecipedidae). The reason could be the repurposing of deep-water lakes for recreational use and the usage of the water resource for personal use (Lorenzón et al. 2016).

Although in HHCW, only 34% of recorded species were classified as migrants; the most abundant and diverse families were comprised primarily of migrant species (Table 1). This suggests that the wetland is being used as part of a flyway followed by waterbirds from their breeding colonies to their feeding grounds (Brown et al. 2017, Runge et al. 2015, Yang et al. 2017). Furthermore, while no seasonal analysis was possible due to the limitations imposed by the covid-19 pandemic, we observed that the highest species richness and abundance were found during the summer months (Nov-Feb) during the peak of arrival of the austral migrants following the Eastern Pacific Flyway (Mendez et al. 2018). The same seasonal pattern has been observed in other Peruvian coastal wetlands, such as the "San Pedro de Vice" mangroves and the "Pantanos de Villa" wildlife refuge, where the abundance of migratory birds on lakes and coastal zones surpassed the abundance of resident birds (García-Olaechea et al. 2018, Pulido & Bermudez 2018, Pulido et al. 2020).

We observed marked species composition and abundance differences between transects of the same census as an effect of the natural gradient, which provided different vegetation structures (Chawaka et al. 2018, Żmihorski et al. 2016). The level of human-related disturbance could also affect bird preference for different habitats (Lu et al. 2009). The closest border of a natural environment to an urban area acts as a buffer zone, where reduced native vegetation and loss of habitable space become more common (McKinney 2008, Rodrigues et al. 2018).

This study showed a positive correlation between total bird abundance and the ICEN, suggesting that in HHCW a higher abundance of birds was found during warm "El Niño" periods. Furthermore, the onset of "El Niño" phenomenon could be related to an increase in the abundance of migrating shorebirds (O'Hara et al. 2007), as ENSO years usually exhibit higher humidity and precipitation, which are beneficial to most wetland-dependent species like egrets, gallinules, ducks and other waders that rely on freshwater bodies (Romano et al. 2005, Vilina & Cofre 2000).

If adequately managed, HHCW could become a suitable environment for birdwatching as it possesses high bird diversity in a relatively small area. This situation could further improve the economic value of the wetland, bringing about not only environmental conservation but also education (Glowinski 2008). In addition, studies on migratory bird resting places and rare plant assemblages have shown that small wetlands are critical areas for the continued existence of both groups (McCulloch et al. 2003, Richardson et al. 2015), thus providing further evidence for the conservation of these ecosystems.

This study is the first step towards a verified bird species list for HHCW and demonstrates that even highly disturbed small wetlands can have high bird diversity. It also demonstrates the importance of conservating this ecosystem as it is not only a place of residency for numerous bird species but also serves as a stopover for migrants. Therefore, decision-making authorities should focus on management plans that prevent habitat loss while encouraging the participation of the community and including this vital wetland in the surrounding urban landscape.

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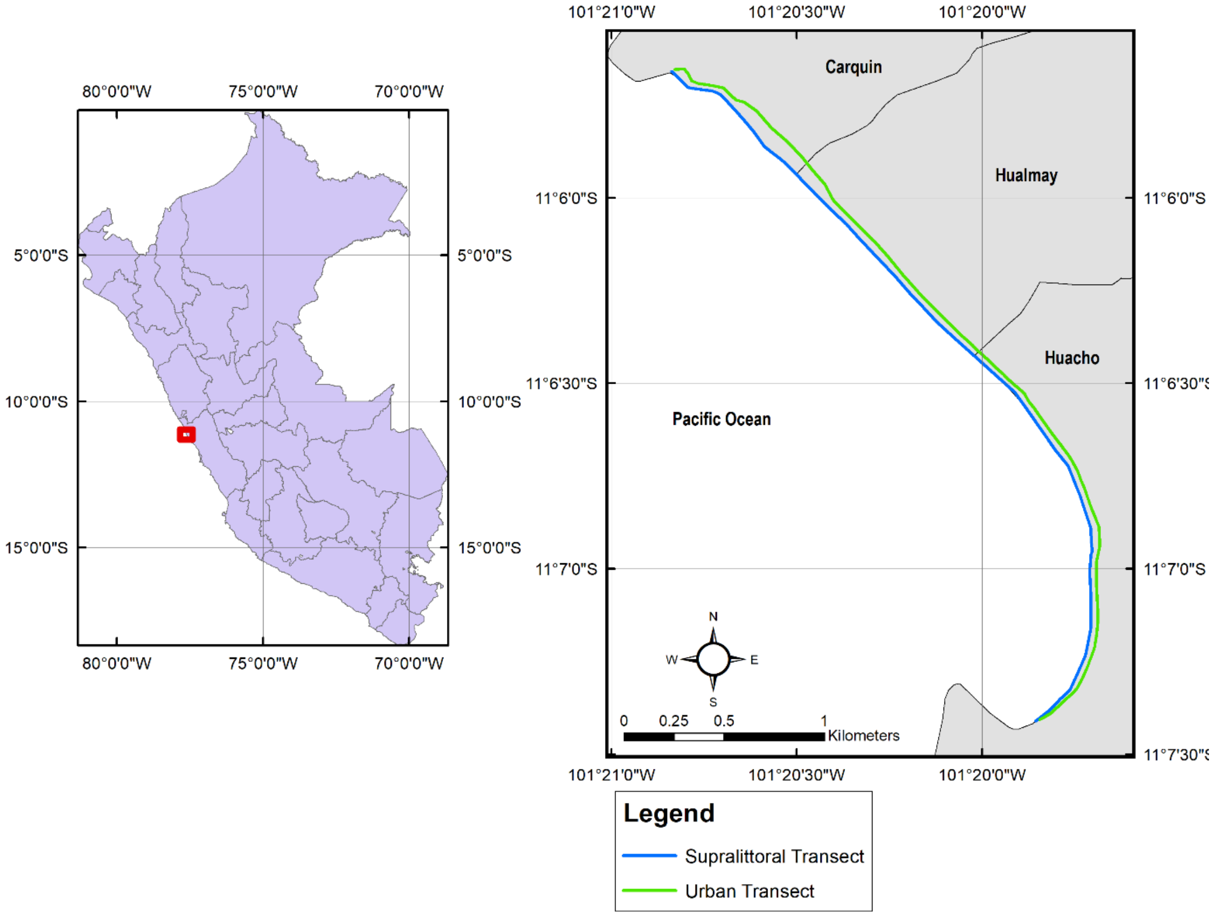
Figures legend

Figure 1. Location of the Huahualca wetland and location of the study area of study, black lines indicate the political division of the wetland; the green line follows the urban transect and the blue the littoral one.

Figure 2. Comparison between the supralitoral and urban monthly transects of A. Species richness, and B. Log10 of monthly bird abundance. The figures show higher monthly species richness and abundance on the littoral transect; note a marked decrease of richness abundance during southern winter months.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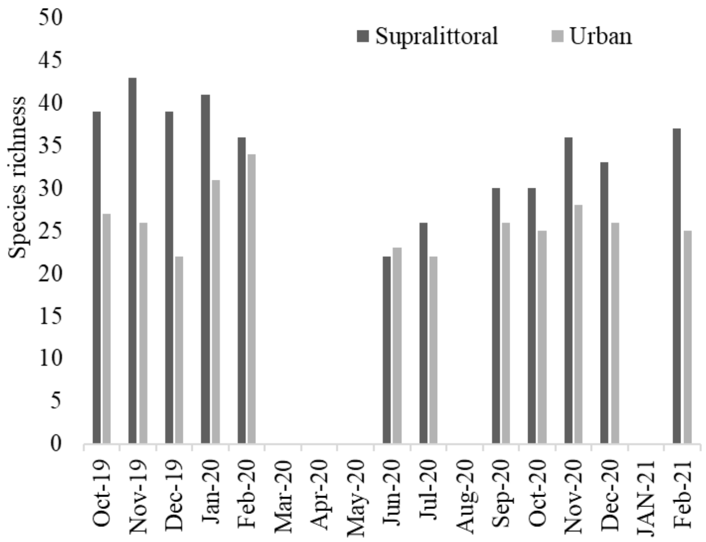
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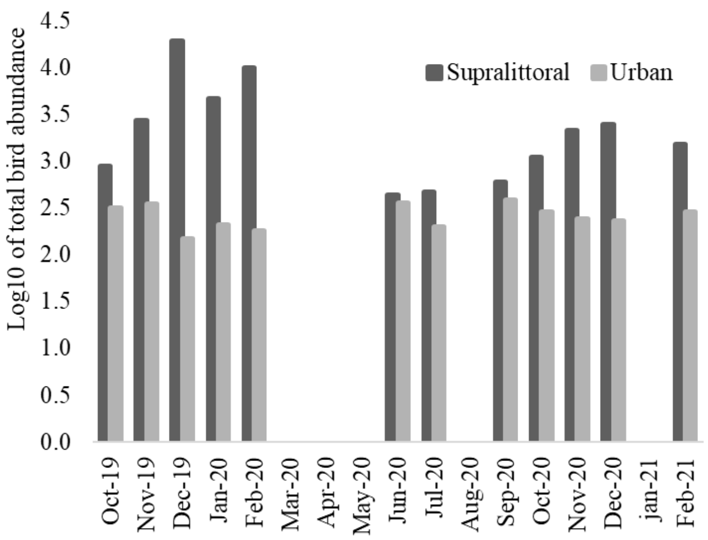
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
JAN-21
Feb-21


Log10 of total bird abundance
Supralittoral
Urban
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
jan-21
Feb-21

Tables lenged

Table 1. Bird species found on the HHCW. Indicating Migrant conditions: R – Resident, NB – Non-breeding, IN – Introduced (Plenge 2022) and conservation status according to the IUCN (2022). Total abundance is the sum of all monthly counts.

#	Order	Family	Species	Migrant Condition	Conservation Status	Total abundance Urban	Littoral
1	Accipitriformes	*Accipitridae*	*Parabuteo unicinctus*	R	LC	3	-
2	Anseriformes	*Anatidae*	*Anas bahamensis*	R	LC	8	-
3			*Oressochen melanopterus*	R	LC	-	1
4			*Spatula cyanoptera*	R	LC	90	16
5			*Spatula discors*	NB	LC	1	2
6			*Sarkidiornis sylvicola*	R	LC	-	3
7	Apodiformes	*Trochilidae*	*Amazilis amazilia*	R	LC	6	-
8			*Rhodopis vesper*	R	LC	1	-
9	Cathartiformes	*Cathartidae*	*Cathartes aura*	R	LC	62	88
10			*Coragyps atratus*	R	LC	66	51
11	Charadriiformes	*Burhinidae*	*Burhinus superciliaris*	R	LC	10	35
12		*Charadriidae*	*Charadrius semipalmatus*	NB	LC	-	184
13			*Charadrius vociferus*	R	LC	21	74
14			*Pluvialis squatarola*	NB	LC	-	286
15		*Haematopodidae*	*Haematopus ater*	R	LC	1	16
16			*Haematopus palliatus*	R	LC	2	325
17		*Laridae*	*Chroicocephalus cirrocephalus*	R	LC	32	436
18			*Chroicocephalus serranus*	R	LC	-	2
19			*Larosterna inca*	R	**NT**	-	32
20			*Larus belcheri*	R	LC	194	792
21			*Larus dominicanus*	R	LC	61	524
22			*Leucophaeus atricilla*	NB	LC	-	1
23			*Leucophaeus modestus*	NB	LC	-	128
24			*Leucophaeus pipixcan*	NB	LC	116	34 446
25			*Sterna hirundo*	NB	LC	-	6
26			*Thalasseus elegans*	NB	**NT**	-	17
27			*Thalasseus maximus*	NB	LC	-	16
28			*Thalasseus sandvicensis*	NB	LC	-	27
29		*Recurvirostridae*	*Himantopus mexicanus*	R	LC	3	0
30		*Rynchopidae*	*Rynchops niger*	R	LC	-	1806
31		*Scolopacidae*	*Actitis macularius*	NB	LC	18	75
32			*Arenaria interpres*	NB	LC	-	42
33			*Calidris alba*	NB	LC	-	301
34			*Calidris himantopus*	NB	LC	-	4
35			*Calidris mauri*	NB	LC	-	15
36			*Calidris melanotos*	NB	LC	-	1
37			*Calidris minutilla*	NB	LC	6	27
38			*Calidris pusilla*	NB	**NT**	2	32
39			*Numenius phaeopus*	NB	LC	2	3457
40			*Tringa flavipes*	NB	LC	3	4
41			*Tringa melanoleuca*	NB	LC	11	1
42			*Tringa semipalmata*	NB	LC	-	1
43	Columbiformes	*Columbidae*	*Columba livia*	IN	LC	203	151
44			*Columbina cruziana*	R	LC	4	-
45			*Zenaida auriculata*	R	LC	2	-
46			*Zenaida meloda*	R	LC	41	-
47	Cuculiformes	*Cuculidae*	*Crotophaga sulcirostris*	R	LC	50	16
48	Falconiformes	*Falconidae*	*Falco peregrinus*	R	LC	3	-
49			*Falco sparverius*	R	LC	6	1
50	Gruiformes	*Rallidae*	*Fulica ardesiaca*	R	LC	1	-
51			*Gallinula galeata*	R	LC	348	71
52			*Pardirallus sanguinolentus*	R	LC	4	8
53	Passeriformes	*Furnaridae*	*Phleocryptes melanops*	R	LC	36	30
54		*Hirundinidae*	*Hirundo rustica*	NB	LC	-	2
55			*Pygochelidon cyanoleuca*	R	LC	156	95
56			*Riparia riparia*	NB	LC	-	1
57		*Icteridae*	*Leistes bellicosus*	R	LC	13	13
58		*Mimidae*	*Mimus longicaudatus*	R	LC	6	-
59		*Motacillidae*	*Anthus peruvianus*	R	LC	26	50
60		*Passeridae*	*Passer domesticus*	IN	LC	46	40
61		*Thraupidae*	*Sporophila telasco*	R	LC	2	-
62			*Volatinia jacarina*	R	LC	-	1
63		*Troglodytidae*	*Troglodytes aedon*	R	LC	2	-
64		*Tyrannidae*	*Myiophobus fasciatus*	R	LC	1	-
65	Pelecaniformes	*Ardeidae*	*Ardea alba*	R	LC	26	30
66			*Bubulcus ibis*	R	LC	59	4
67			*Butorides striata*	R	LC	11	4
68			*Egretta caerulea*	R	LC	259	152
69			*Egretta thula*	R	LC	273	236
70			*Nyctanassa violacea*	R	LC	1	2
71			*Nycticorax nycticorax*	R	LC	469	89
72	Pelecaniformes	*Pelecanidae*	*Pelecanus thagus*	R	**NT**	-	99
73		*Threskiornithidae*	*Plegadis ridgwayi*	R	LC	108	36
74	Strigiformes	*Strigidae*	*Athene cunicularia*	R	LC	32	-
75	Suliformes	*Phalacrocoracidae*	*Phalacrocorax bougainvillii*	R	**NT**	-	11

76		*Phalacrocorax brasilianus*	R	LC	16	89
77	*Sulidae*	*Sula nebouxii*	R	LC	-	11
78		*Sula variegata*	R	LC	-	194
				Total abundance	**2923**	**44 710**