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Spatio-temporal composition of aquatic birds community in Juluapan Lagoon, Colima, Mexican Central Pacific

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ABSTRACT

Introduction: Aquatic birds (AB) are usually associated with wetlands, which provide refuge, food, and/or nesting sites for resident and migratory species. Despite their ecological importance, there is little knowledge on AB in some tropical environments, such as those found on the Colima coast.

Objective: To investigate the spatial and temporal composition of the AB community in Juluapan Lagoon, Colima, Central Mexican Pacific.

Methods: Monthly counts were conducted between June 2017 and May 2018 during low-tide conditions to record habitat use by AB. Species richness and bird counts were obtained to compare sampling areas; mean richness and number of individuals were compared between seasons.

Results: We detected 53 species and 5 750 individuals. The highest species richness and relative abundance values were obtained in winter at the lagoon area farthest from the connection with the marine system, where anthropogenic activity is lower. Diversity was greater in zones 2 and 3 in spring, summer, and fall. Muddy flats were the most used environment, and the most frequent activity was resting. Nesting activity was only recorded in the middle of the lagoon at the mangrove during spring. "Shorebirds" and "waders" were the most dominant groups in the bird community of the Juluapan lagoon.

Conclusions: This coastal wetland is a site of great biological importance for aquatic birds; thus, conservation measures should be implemented, and there should be a continuous study of the effects of anthropogenic pressure.

Key words: avifauna structure; coastal lagoon; ecological aspects; substrates; ecosystem use.

RESUMEN

Composición espacio-temporal de las aves acuáticas en la laguna Juluapan, Colima, en el Pacífico Central Mexicano

Introducción: Las aves acuáticas (AA) son usualmente relacionadas a los humedales debido a que éstos funcionan como sitios de refugio, alimentación y anidación de diferentes especies residentes y migratorias. Sin embargo, el conocimiento sobre las aves acuáticas en algunos humedales es nulo.
Objetivo: Investigar la composición espacio-temporal de la comunidad de AA en la laguna Juluapan, Colima, en el Pacífico Central Mexicano.
Métodos: Entre junio de 2017 y mayo de 2018 se llevaron a cabo conteos mensuales en condiciones de marea baja para registrar el uso de hábitat de las AA. Se obtuvieron valores de riqueza de especies y número de individuos para realizar comparaciones entre zonas de muestreo, así como el promedio del número de especies y número de individuos para comparaciones entre temporadas.
Resultados: Se registraron un total de 53 especies y 5 750 individuos. Los valores de riqueza de especies y densidad de individuos fueron más altos durante invierno, en la zona más alejada al ambiente marino, donde la actividad antropogénica es menor. La diversidad tuvo valores más altos en la zona 2 y 3, durante primavera, verano y otoño. El ambiente más explotado por las aves fueron las planicies lodosas; y el descanso fue la actividad más frecuente. Asimismo, la actividad de anidación sólo se registró en el manglar de la zona media durante primavera. Las "aves playeras" y "aves zancudas" fueron los grupos más predominantes en la comunidad de aves de la laguna Juluapan.
Conclusiones: Este humedal costero es un sitio de gran importancia biológica para aves acuáticas, por lo que resulta necesario la implementación de medidas de conservación, así como el estudio de los efectos por la presión antropogénica.

Palabras clave: estructura de avifauna; laguna costera; aspectos ecológicos; sustratos; uso del ecosistema.

INTRODUCTION

Wetlands are among the most productive ecosystems on the planet due to the physical, biological, and chemical processes that arise from interactions between the continent and ocean (Mitsch & Gosselink, 2007). Aquatic birds are usually associated with wetland ecosystems, where they obtain a number of resources that allow them to fulfill their life cycle; they find food, resting areas, and some species use certain habitats to nest (Batzer & Shartitz, 2007). This group of birds presents morphological and physiological adaptations and feeding strategies that allow them to inhabit these ecosystems and make good use of the resources available in wetlands. Adaptations include long necks, legs, and bills (herons, ibis, and storks), webbed feet (ducks and seabirds), semi-webbed feet (sandpipers and plovers), lobed feet (coots), and relatively small feet with webbing adapted for diving, swimming, or floating on the surface of the water (Shealer, 2001). In addition, many of these environments function as important stopover areas during annual migrations (Batzer & Shartitz, 2007; Kushlan et al., 2002), where birds can feed, rest, and store energy to continue their migration (Howes & Bakewell, 1989; Palacios et al., 1991).

Several studies have been undertaken on aquatic bird ecology in coastal wetlands of the Mexican Central Pacific (MCP); in particular for the state of Colima, general studies such as that by Vega-Rivera et al. (2016) reported 441 resident and migratory species, of which only 26 % (115 species) were associated with coastal or continental wetlands. There is more information on aquatic birds present in Cuyutlán Lagoon (7 200 ha), one of the largest coastal wetlands in the MCP (Mellink & Riojas-López, 2009), than for smaller adjacent wetlands (Verdugo-Munguía & Gómez-del Castillo, 2012). Some studies have focused on the reproduction of some aquatic bird species (Mellink & Riojas-López, 2006; Mellink & Riojas-López, 2008; Mellink et al., 2007; Mellink et al., 2009a; Riojas-López & Mellink, 2016), or described the richness, abundance, and distribution of aquatic birds (Mellink & de la Riva, 2005). Some studies analyzed changes in bird abundance with respect to physical modifications of the lagoon system (Mellink et al., 2009b), or provided information on anthropogenic activities and their effects on bird conservation (Mellink & Riojas-López, 2009). However, all these studies have been undertaken in Cuyutlán Lagoon, which is also located in the state of Colima and is considered one of the largest coastal wetlands in the MCP (Vega-Rivera et al., 2016), whereas there is scarce knowledge of aquatic birds in smaller adjacent wetlands.

There is no information on the birds present in Juluapan coastal lagoon, a small wetland (98 hectares) near Cuyutlán Lagoon. Currently, this coastal lagoon is affected by anthropogenic activities (tourism development, residual water discharge, badly planned urban development, and the addition of nutrients from agricultural activities) (Liñán-Cabello et al., 2016); it is therefore essential to establish the ecological importance of this site for birds. The objective of this study was to analyze the richness and abundance (considering all birds in general and by bird groups) of aquatic birds in Juluapan Lagoon. We also described their spatial (by zone) and temporal (by season of the year) distribution and the activities they carried out on the different lagoon substrates. This research is the first to describe ecological aspects of waterfowl in Juluapan Lagoon and will provide a baseline for future studies focused on the conservation and sustainable management of habitats and birds.

MATERIALS AND METHODS

Study area: Juluapan Lagoon is a small wetland that is permanently linked to the ocean through a 20 m wide by 75 m long artificial canal. It is located on the Mexican Central Pacific coast (19°06’ - 19°07’ N & 104°23’ - 104°24’ W), West of Santiago de Manzanillo Bay, Colima (Fig. 1). It has an approximate surface of 98 ha and ranges between 0.2 m and 5 m in depth (Liñán-Cabello et al., 2016). To the North of the lagoon, there are muddy substrates that are exposed during low tides, whereas

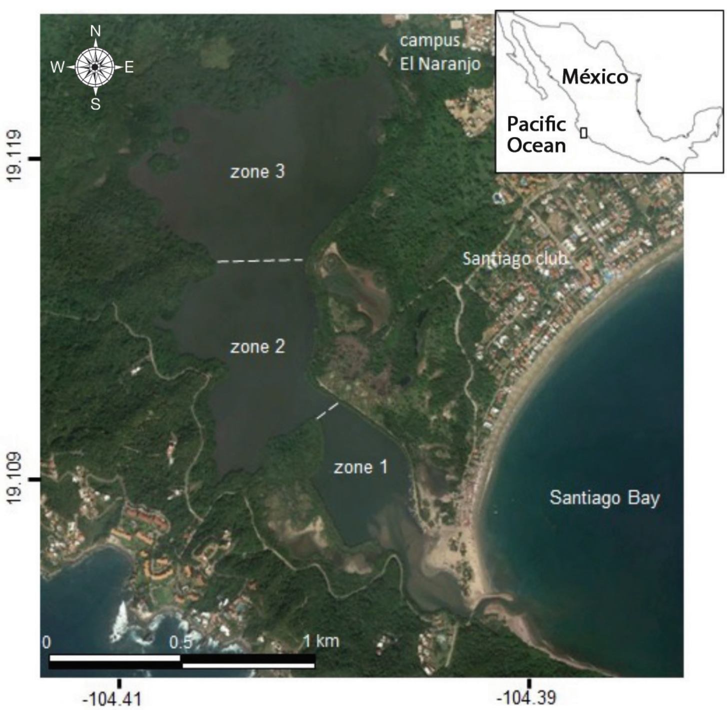

Fig. 1. Geographical location of Juluapan Lagoon, indicating the three sampling zones (Map adapted from Google Earth Pro).

to the South there are sand banks (Luna & Zepeda, 1980). The margins of this wetland are covered mainly by red mangrove (*Rhizophora mangle*) and white mangrove (*Laguncularia racemosa*) (Jiménez-Quiroz & González-Orozco, 1996). The bottom of the lagoon is made up of fine alternating stratifications of silt, clay, and sand (Luna & Zepeda, 1980). The zone closest to the beach and where there is communication with the sea (labelled zone 1 in this study) is dominated by small plains of sandy substrate that are exposed at low tide. This area is where the influence of tourism and fishing activities is greatest. The center of the lagoon (zone 2) is surrounded by mangroves and small muddy areas, and is the area least affected by anthropogenic activities. The northernmost part (zone 3) is dominated by mangroves, as well as by large areas of soft sediments that have been exposed by human activities. There is marked coastal urban growth in the northeast area, where the El Naranjo campus of the University of Colima and the Club Santiago residential development are located (zones 3 and 2, Fig. 1); there are rural shellfish restaurants in the Southeast, as well as tourism influence and a dock for smaller vessels (zone 1, Fig. 1); whereas anthropogenic impact is minimal or null in the Northern (zone 3) and Western (zones 2 and 3) areas. The Miramar stream is located in the extreme Northeast; this stream presents an important fluvial contribution from agricultural and urban areas in the rainy season (summer) that can modify littoral morphology during the tropical cyclone season (Lancin & Carranza, 1976; Liñán-Cabello et al., 2016).

Bird surveys: Monthly visits to Juluapan Lagoon were undertaken from June 2017 to May 2018. Bird counts were performed during the lowest monthly tide in order to detect the greatest number of birds in the different environments. The lagoon was divided into three zones (1, 2, and 3, described in study area). The same route was followed in each zone (30 m from the inner edge of the lagoon) during each monthly visit; approximately 1.5 hours were required to survey each zone. A 3-m long aluminum boat with a 5-hp outboard motor was used at a navigation speed of less than 3 knots. Birds were counted along a transect parallel to the inside edge of the lagoon, covering a 25-m wide band on each side of the transect. The observation area was 9.0 ha in zone 1 (transect length: 1 811 m; width: 50 m), 9.2 ha in zone 2 (transect length: 1 842 m; width: 50 m); and 8.9 ha in zone 3 (transect length: 1 779 m; width: 50 m). Information on the number of species and individuals was obtained during counts, as well as on the type of substrate where birds were found (body of water, sand flat, mud flat, or mangrove); the activity undertaken by birds was also documented as feeding, resting, or nesting.

The identified aquatic bird species were separated into four functional groups, considering their morphological characteristics and ecological affinity; seabirds (including the following families: Pelecanidae, Laridae, Fregatidae, and Phalacrocoracidae) (Mellink & de la Riva, 2005; Schreiber & Burger, 2001), ducks and rails (Anatidae and Rallidae) (Hernández-Vázquez, 2005a; Mellink & de la Riva, 2005), shorebirds (Charadriidae, Recurvirostridae, Scolopacidae, and Haematopodidae) (Alonzo-Parra, 2009; Mellink & de la Riva, 2005; Warnock et al., 2001), and waders (Ardeidae, Threskiornithidiae, and Ciconiidae) (Frederick, 2001, Mellink & de la Riva, 2005). A fifth group called "others" was created for this study; it included birds that did not belong to the previous groups (Anhingidae, Pandionidae, and Cerylidae).

Bird identification was performed using 10 x 50 binoculars and field guides by Hernández-Vázquez and Esparza-Salas (2008), and by the National Geographic Society (Dunn & Alderfer, 2017). Common names and scientific nomenclature were based on the American Ornithological Society (AOS; Chesser et al., 2021). Risk categories were determined according to the Official Mexican Norm NOM-059-SEMARNAT-2019 (DOF, 2019) and the International Union for Conservation of Nature (IUCN, 2021).

Data analysis: The density of species and individuals was calculated to compare among sampling zones (1, 2, and 3), according to (Mandujano-Rodríguez, 2011):

$$D = n/2wL, \qquad \text{(Eq. 1)}$$

where D is density, n is the number of species or individuals counted, L is transect length, and w is transect width on each side of the center line.

The average number of species and number of individuals for each season (summer: June-August 2017, fall: September-November 2017, winter: December 2017-February 2018, and spring: March-May 2018) was obtained to compare between seasons. Fewer than 50 data points were obtained, so tests of normality were performed; Shapiro-Wilks (W) and Bartlett tests were used to determine homogeneity of variances. Nonparametric statistical tests were used when data were not normal ($P < 0.05$), and parametric statistical tests were used when the normality assumption was met ($P > 0.05$).

A nonparametric Kruskal-Wallis (K-W) test was used to evaluate possible differences among zones (1, 2, and 3) in the number of species and number of individuals per group. A one-way Analysis of Variance (ANOVA: F) was used to evaluate total bird density (considering all groups), as data were normal ($P > 0.05$). A Kruskal-Wallis test was used to evaluate differences in activity (feeding or resting) among zones, for all bird groups and for each group separately. A one-way ANOVA was used to analyze seasonal differences in the total number of species and individuals (including all groups), and a Kruskal-Wallis test was used to perform the analysis for each group. A Mann-Whitney (U) test was used to compare seasonal activities (feeding vs. resting) for the number of species and individuals (Zar, 2010). Statistical analyses were undertaken using the STATISTICA program (v. 10, StatSoft, Inc., 2011), considering a 0.05 significance level.

The Shannon-Weaver (H') proportional diversity index (Shannon & Weaver, 1949) was used to calculate total diversity (for the entire lagoon and all birds), as well as for study areas and seasons of the year, as follows:

$$H' = -\sum_{i-1}^{k} (pi)\left(\log^2\right)(pi) \qquad \text{(Eq. 2)}$$

where H' is the Shannon diversity index, k is the number of species, and pi is the proportion of species i in the sample. Differences in diversity values were obtained with Hutcheson's "t" test (Hutcheson, 1970).

RESULTS

Total richness and abundance: A total of 53 species were identified, 5 750 individuals were recorded (considering all seasons and zones), and a total alpha diversity of H'= 3.10 was obtained. Of all recorded species, three are included in the IUCN Red List (IUCN, 2021) as Near Threatened (*Egretta rufescens, Larus heermanni,* and *Thalasseus elegans*). Six species are included under a protection category according to the Mexican Official Norm NOM-059-SEMARNAT-2019 (DOF, 2019); two are threatened (*Calidris mauri* and *Limosa fedoa*), three are under special protection (*L. heermanni, T. elegans,* and *Mycteria americana*), and one is in danger of extinction (*E. rufescens*) (MS1).

The three species with highest number of birds were: the black-bellied whistling duck (*Dendrocygna autumnalis*) (1 184 individuals; 20.59 % of the total), the white ibis (*Eudocimus albus*) (457 individuals; 7.95 % of the total), and the elegant tern (*T. elegans*) (371 individuals; 6.45 % of the total). The number of species per group ranged between 5 and 16; it was greater in shorebirds (16 species, 30.2 % of the total) and waders (14 species, 26.4 % of the total). All groups, excepting "others", showed similar abundances; the most abundant group were waders (1 531 individuals, 26.6 %) and ducks and rails (1 470 individuals, 25.6 %) (Table 1). The most abundant waders were *E. albus*, *Nyctanassa violacea*, and *Egretta caerulea*, which together comprised 59 % of all individual records in this group. *Dendrocygna autumnalis* represented 81 % of individuals in the ducks and rails group (MS1).

Table 1
Number of species and individuals of aquatic birds recorded in Juluapan Lagoon

Functional group	Species		Individuals	
	Number	%	Number	%
Seabirds	10	18.9	1 306	22.7
Shorebirds	16	30.2	1 352	23.5
Waders	14	26.4	1 531	26.6
Ducks and rails	8	15.1	1 470	25.6
Others	5	9.4	91	1.6
Total	53		5 750	

Distribution by zone: Based on the general analysis (including all groups), there were significant differences in species richness among zones (standardized by area; K-W = 7.03, df = 2, P < 0.05); species richness was greater in zone 3 (Fig. 2A). There were also significant differences in diversity between zones: zone 1 (H' = 2.58) vs. zone 2 (H' = 2.78) (t = 3.87, df = 553, P < 0.05), zone 1 vs. zone 3 (H'= 2.72) (t = 3.95, df = 333, P < 0.05), but not zone 2 vs. zone 3 (t =1.29, df = 431, p = 0.19). However, comparisons by group showed a different pattern of species richness, with no significant differences among zones between seabirds and shorebirds (K-W = 3.92, df = 2, P = 0.14 and K-W = 2.93, df = 2, P = 0.23, respectively). There were differences in wader species richness among the three zones (K-W = 10.32, df =2, P = 0.005), with greater richness in zone 3. It should be noted that species belonging to the group of ducks and rails were only observed in zone 3 (Fig. 2A).

Bird density differed between the three zones ($F_{2, 156}$ = 5.40, P = 0.045); these differences were also observed for each group (seabirds K-W = 10.31, df = 2, P = 0.005; shorebirds K-W = 13.15, df = 2, P = 0.001; waders K-W = 10.32, df = 2, P = 0.005). There more birds in zone 3 for almost all groups, except for seabirds, which presented greater density in zone 1. Ducks and rails were only recorded in zone 3 (Fig. 2B).

There were greater diversity values in zone 2 (H' = 2.78) and 3 (H' = 2.72) compared with zone 1 (H' = 2.58) (Fig. 2C). The comparisons between pairs indicated significant differences between zone 1 vs zone 2 (t = 3.83, df = 553, P < 0.05) and 3 (t = 3.95, df = 3341, P < 0.05), while zones 2 vs 3 were similar (t = 1.29, df = 431, P = 0.19).

Activity by group and zone: Species richness was not associated with any particular activity in the three lagoon zones (feeding K-W = 3.96, df = 2, P = 0.13; resting K-W = 3.57, df = 2, P = 0.16); however, the analysis by

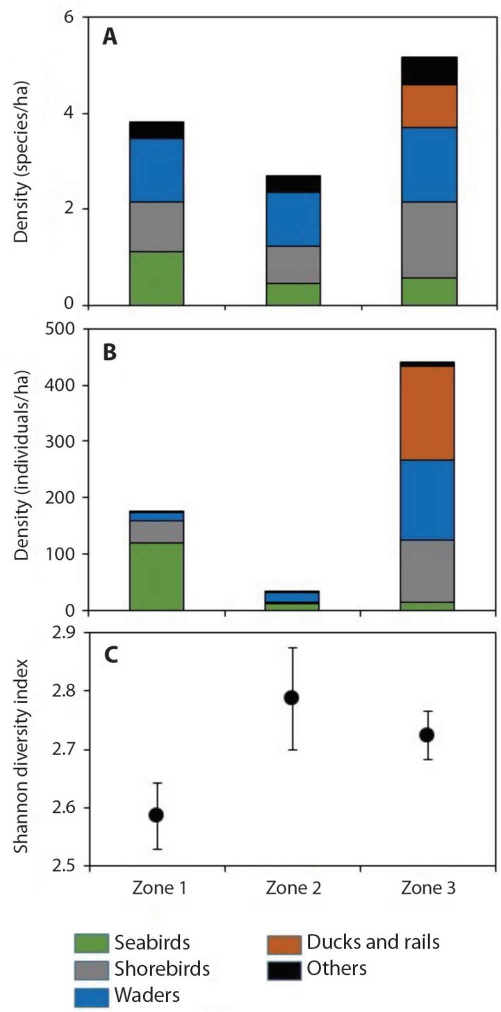

Fig. 2. A. Species density, **B.** density of individuals, and **C.** Shannon diversity index with confidence intervals of aquatic bird groups in the three sampling zones in Juluapan Lagoon.

group showed that certain zones were used for particular activities. For example, there were more seabirds resting on the sandy substrates and shallow areas of the water body in zone 1. Shorebirds and waders used all substrates for feeding and resting, although shorebirds were present in zone 2 to feed. Ducks and rails only used zone 3, where they fed and rested mainly in muddy areas (Fig. 3A). There was also greater seabird density in zone 1, where birds used sandy substrates to rest. There was greater bird density of other groups in zone 3, on muddy substrates and shallow areas of the water body that birds used to feed and to rest, to a lesser extent. Ducks and rails used the muddy areas of zone 3 mainly to rest (Fig. 3B).

Seasonal abundance and activity: The total number of species (considering all groups) was similar among the four seasons ($F_{3,16}$ = 0.90, P = 0.90). Average species richness fluctuated between 11.3 species in summer and 14.7 species in winter; the groups with most species were shorebirds and waders. This dominance was observed during the four seasons of the year (Fig. 4A). However, there were significant differences among seasons in the average number of birds ($F_{3,16}$=3.46, P=0.04), with greater abundance in winter (= 1 245 individuals) and spring (= 561 records). The comparison by group also detected significant differences in bird abundance among seasons; seabirds (K-W = 8.15, df = 3, P = 0.042), ducks and rails (K-W = 8.57, df = 3, P = 0.03), and shorebirds (K-W = 14.18, df = 3, P = 0.002). In all cases, there were more birds in winter (= 265.5 seabirds, 351.5 shorebirds, and 225.7 ducks and rails) and spring (= 118.2 seabirds and = 119.7 ducks and rails), whereas the number of waders was not significantly different among seasons (K-W = 2.63, df = 3, P = 0.45) (Fig. 4B).

There were no significant differences in the number of species between the two activities (feeding vs. resting) for ducks and rails (U = 122.00, P = 0.82) and waders (U = 86.00, P = 0.11), whereas there were significant

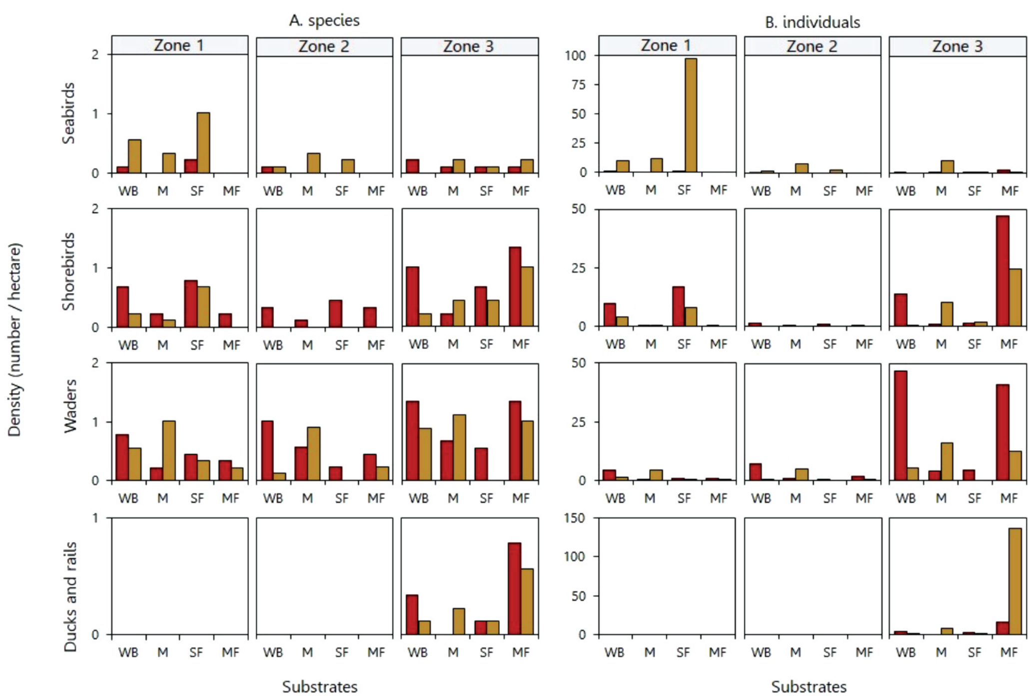

Fig. 3. A. Density of species and **B.** individuals, classified by zones, activity, and substrates. Red bar: feeding; orange bar; resting. WB= Water Body, M= Mangrove, SF= Sand Flat, MF= Mud Flat.

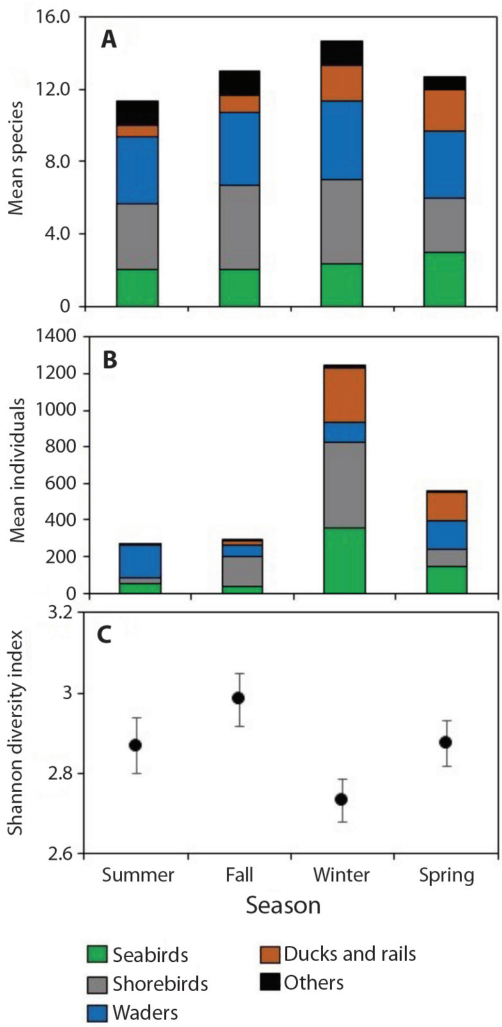

Fig. 4. A. Average number of species, **B.** individuals **C.** and Shannon diversity index with confidence intervals of aquatic bird groups during the four sampling seasons in Juluapan Lagoon.

differences for seabirds and shorebirds (U = 44.00, P = 0.001; U = 50.50, P = 0.003, respectively). In the case of seabirds, there were more species resting on all substrates; a similar pattern was detected during all seasons. Shorebirds used substrates to feed, mainly on muddy, sandy substrates, and shallow waters of the lagoon; this activity was more common in fall and winter (Fig. 5A). There was a similar pattern for the number of birds, with no significant differences between activities for shorebirds (U = 96.5, P = 0.23), ducks and rails (U = 125.5, P = 0.92), and waders (U = 86.0, P = 0.11), except for seabirds (U = 56.0, P = 0.006). Most birds used Juluapan Lagoon to rest; this activity was more common on muddy substrates during winter and spring (Fig. 5B).

Diversity obtained by season of the year varied from H'= 2.73 in winter to H'= 2.94 in autumn, with significant differences between seasons (Summer vs. Autumn, t = 2.41, df = 1678, P = 0.01; Summer vs. Winter, t = 3.07, df = 1848, P = 0.002; Fall vs. Winter, t = 5.92, df = 2144, P < 0.05; Fall vs. Spring, t = 2.58, df = 2089, P = 0.01; Winter vs. Spring, t = 3.66, df = 3874, P < 0.05), except between Spring and Summer (t = 0.16, df = 1835, P = 0.87) (Fig. 4C).

DISCUSSION

Although Juluapan Lagoon is relatively small, its richness is comparable to that of larger coastal wetlands, and its diversity is greater than that of several wetlands in the Mexican Central Pacific (Table 2). An example is Cuyután Lagoon, which has an area of 7 200 ha (73 times larger than Juluapan) and 57 aquatic bird species during the non-reproductive season (Mellink & de la Riva, 2005), which indicates that Juluapan contributes importantly to aquatic bird richness and diversity on the Colima coast. Shorebirds and waders were the most representative groups by number of species in Juluapan, which corresponds to a common pattern observed in nearby wetlands, such as the Agua Dulce Lagoon, El Ermitaño Estuary (Hernández-Vázquez, 2005a), and Barra de Navidad Lagoon (Hernández-Vázquez et al., 2022). These wetlands present similar characteristics in terms of the availability of soft substrates exposed at low tides, dense vegetation, and mangroves in the surrounding area, which favors the presence of more birds, mainly shorebirds and waders.

Although the number individuals recorded in the lagoon was not as high as that reported for nearby wetlands (Table 2), there was an important number of migratory species

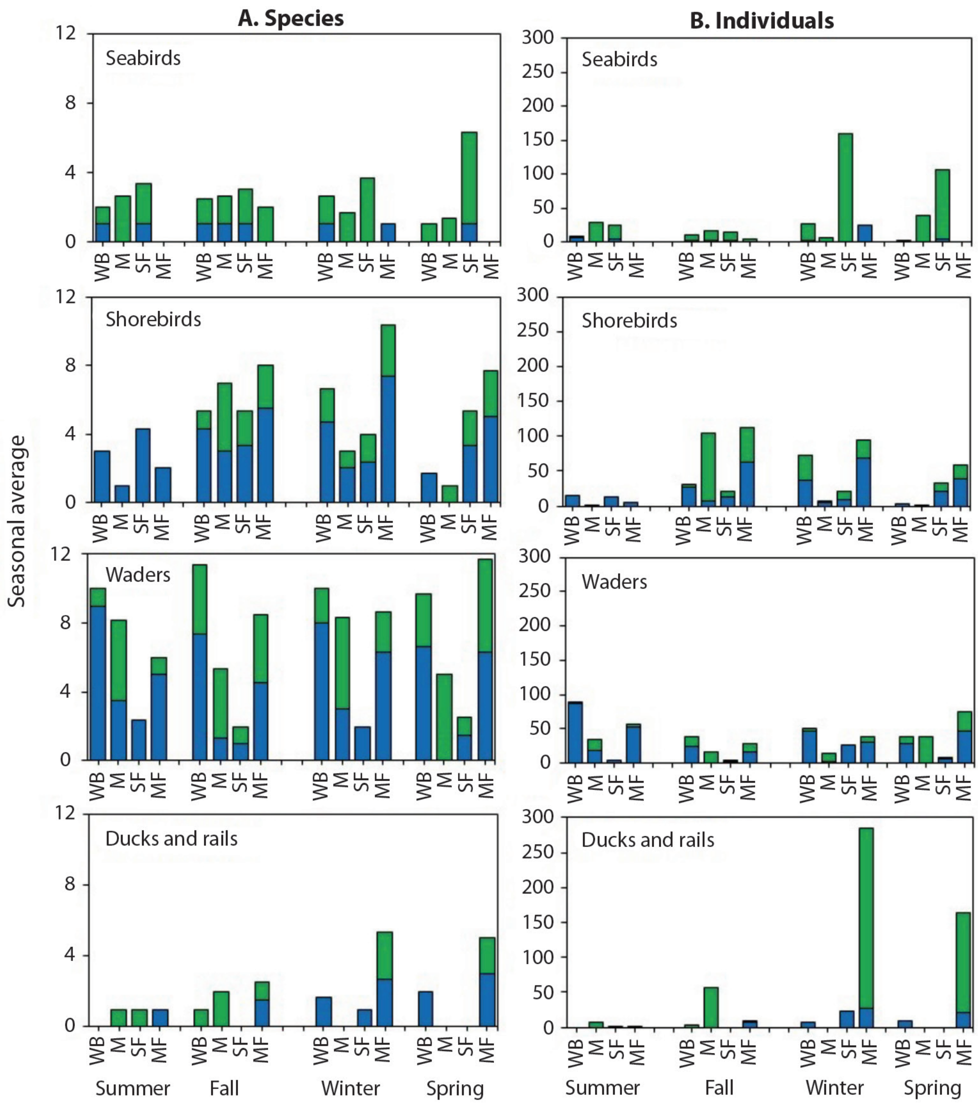

Fig. 5. A. Average number of species and **B.** individuals, classified by bird groups, seasons, substrates, and activity; green bars: resting; blue bars: feeding. WB= Water Body; M= Mangrove, SF= Sand Flat, MF= Mud Flat.

in winter (31 species, MS1) that used this lagoon as a resting and feeding place during their migratory journey to the North and South of the continent. The shorebirds *Tringa semipalmata* and *C. mauri*, and some seabirds such as *T. elegans* were among the most abundant migratory species. *D. autumnalis* is considered a resident species and presented the greatest abundance, with 1 184 records (MS1). Hernández-Vázquez (2005a) pointed out that this species concentrates in coastal wetlands when the reproductive season is over in Agua Dulce Lagoon and El Ermitaño Estuary.

Species richness, density, and diversity of most bird groups were greater in zone 3, although diversity was also high in zone 2. This zone presented shallow environments with a large surface area of exposed mud flats during low tide and reduced impacts from tourism or fishermen due to the difficult access. These

Table 2
Number of aquatic bird species, individuals, and diversity recorded in coastal wetlands in the Mexican Central Pacific

Wetlands	Area (ha)	Species	Records of individuals	Diversity H´	Source of information
Barra de Navidad	375.98	68	16 469	3.351*	Hernández-Vázquez et al., 2023,
Agua Dulce	696	78	66 976	2.601*	Hernández-Vázquez, 2005a
Ermitaño	318	73	112 832	1.886*	Hernández-Vázquez, 2005a
Chalacatepec	808	59	22 252	2.156*	Hernández-Vázquez et al., 2010, Hernández-Vázquez et al., 2014
Xola-Paraman	622	66	96 564	1.927*	Hernández-Vázquez et al., 2010, Hernández-Vázquez et al., 2014
Cuyutlán Lagoon	7 200	57	54 370	-	Mellink & de la Riva, 2005
Juluapan Lagoon	98	53	5 750	3.10	This study

*Diversity calculated from the Hernandez-Vázquez (2005b) data for purposes of comparison with this work.

conditions influenced the fact that some individuals aggregated to rest and/or feed, as prey capture is more effective in shallower areas (David, 1994). In some Jalisco wetlands, such as La Manzanilla Estuary, Barra de Navidad Lagoon, and Agua Dulce Lagoon, as well as Cuyutlán Lagoon in Colima, the number of species, number of individuals, and diversity were influenced by variations in water levels caused by tide changes, and the existence of substrates suitable for foraging (Hernández-Vázquez, 2000: Hernández-Vázquez, 2005a; Hernández-Vázquez, 2005b; Hernández-Vázquez et al., 2012; Mellink & de la Riva, 2005).

The alpha-diversity composition of waterbird species fluctuated not only due to annual changes in water levels (time), but also to wetland specificities (space), reinforcing habitat selection Neotropical aquatic birds species (Lima et al., 2021; Ronchi-Virgolini et al., 2009). The expanse of soft substrates was low in zone 2 due to the presence of a dense strip of mangrove in its margin. This substrate was used for the construction of four *N. violacea* nests and one *Butorides virescens* nest. During later visits (eight visits from May to August 2018), approximately 64 nests of three wader species (*N. violacea*, *B. virescens,* and *Cochlearius cochlearius*) were recorded (Hernández-Vázquez et al., 2022); these data represent the first reports of nesting in this lagoon. In addition to nesting, mangroves in zone 2 also provided refuge and protection for several marine species, as was observed mainly for *Fregata magnificens, P. occidentalis,* and *Nannopterum brasilianum*, and several wader species. These results highlight the functional importance of mangroves for the life cycle of some species (Flores-Verdugo, 1989).

The low species richness and individual density values (zone 1 and 2) and diversity values (zone 1) could be related to the characteristics of their habitat, because soft substrata (sandy and muddy) for resting or feeding are scarce, and there was also more frequent contact with human activity, due to the proximity of sandbanks where tourist activities are carried out. There is evidence of the negative effects of human presence on the feeding and resting activities of aquatic birds (Burger, 1981; Burger, 1994; Burger & Gochfeld, 1998), as it leads to a decrease in feeding efficiency and resting time, resulting in greater energy spent to constantly escape humans (Burger, 1986). A similar pattern was observed in Barra de Navidad Lagoon, Jalisco, where bird richness and abundance were affected in areas with greater anthropogenic activity (presence of tourists and boat traffic), which was more evident in the shorebird group (Hernández-Vázquez et al., 2022).

There is a common pattern of greater species and individual richness in winter in coastal wetlands of the Mexican Pacific. Several migratory species arrive to rest and feed during this time of year, mainly on substrates that have been exposed by the decrease in water levels.

For example, shorebirds were found mainly on sandy substrates and mud flats, whereas ducks and rails chose open areas with submerged vegetation and shallow areas with weak circulation and low salinity (Hernández-Vázquez, 2000; Hernández-Vázquez, 2005a; Hernández-Vázquez & Mellink, 2001; Hernández-Vázquez et al., 2010; Ysebaert et al., 2000). This coincides with the characteristics of substrates used by shorebirds and ducks and rails during the cold season. This trend is a result of the migratory movements of some bird species from the Northern part of the continent; these species move towards wetlands located in Mexico and to the South of the continent to winter (Recher, 1966). This study shows that *C. mauri, Himantopus mexicanus, T. semipalmata* (shorebirds), *Spatula clypeata,* and *S. discors* (ducks and rails) were among the most representative migratory species that arrived in winter to Juluapan Lagoon.

The presence of more migratory than resident species, mainly in winter, is similar to what was observed in Las Garzas Lagoon (Verdugo-Munguía & Gómez-del Castillo, 2012) and in Cuyutlán Lagoon (Mellink & Riojas-López, 2008). The opposite occurred in the estuaries of La Manzanilla, El Salado, and Rancho Bueno (Amador et al., 2006; Cupul-Magaña, 2000; Hernández-Vázquez, 2000), where there were more resident species reported. Low diversity values were caused by differences in the number of individuals of migratory and resident species during winter, since the Shannon-Weaver index combines the number of species and the relative abundance. The difference between migratory and resident species could be related to the particular characteristics of each wetland; it has been documented that there are natural (local climate, lagoon surface, variations in physical parameters, and productivity) and anthropogenic (perturbations due to agriculture, residual discharge, deforestation, silting, and tourism) factors that affect species richness and abundance (Hernández-Vázquez et al., 2012; Mellink & Riojas-López, 2009; Sánchez-Bon et al., 2010). Given the above, it is evident that Juluapan Lagoon functions as a place for resting, feeding, and reproduction for resident birds. For migratory birds, it is a stopping place to feed and rest during their migration to the North or South.

The present study showed that aquatic birds used Juluapan Lagoon for different ecological activities, with greater use of the Northern part of the lagoon, mainly in winter. We also provide basic information that reveals the importance of the different substrates that constitute this wetland, specifically mud flats and sand flats that are exposed during low tides. Therefore, we present evidence of the relevance of this body of water as a fundamental site for feeding and resting birds. It should be noted that the species are migratory and that some are greatly vulnerable. The presence of some species that are included under a protection category in Mexico (six species) and internationally (3 species), evidences the need to apply conservation measures to this lagoon, and to the species that live in it.

Ethical statement: the authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgments section. A signed document has been filed in the journal archives.

See supplementary material a03v72n1-MS1

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