

Bird diversity of the mangrove in an UMA of the Mexican tropics

Sol-Sánchez, Ángel; Cornelio-Torres, Guadalupe del C.; Hernández-Melchor, Gloria I*.

¹ Colegio de Posgraduados, Campus Tabasco, Periférico Carlos A. Molina S/N km.3, Ranchería Rio Seco y Montaña, Heroica Cárdenas, Tabasco, México, C.P. 86500.

² Universidad Autónoma de Chiapas, Facultad Maya de Estudios Agropecuarios, Carretera Catazajá Palenque, Km. 4, Catazajá, Chiapas México, C. P. 29980

* Correspondence: gloria.hernandez@unach.mx

ABSTRACT

Objective: To identifying bird species present in three mangrove sites at different stages of conservation: conserved, under development, and undergoing reforestation.

Design/Methodology/Approach: Monitoring methods included direct and indirect observation, and the analysis of species richness, relative abundance, diversity, and dominance, using statistical tools such as the Shannon-Wiener diversity index and Simpson's dominance index. Fieldwork was conducted at three sampling sites with distinct ecological characteristics. The first site, characterized by mature mangrove, maintained consistent connectivity with water, contributing to ecosystem stability. The second site was undergoing eutrophication, while the third site was in the process of reforestation. Each site included three observation points spaced 50 meters apart, allowing for the recording of both resident and migratory birds through visual sightings and vocalizations.

Results: A total of 514 individuals representing 51 species, 12 orders, and 32 families were recorded. The Shannon-Wiener index indicated greater species evenness in the developing mangrove ($H' = 3.018$), suggesting a more balanced community. Simpson's dominance index confirmed the presence of dominant species across all three sites, with *Quiscalus mexicanus* and *Rostrhamus sociabilis* being the most abundant.

Findings/Conclusions: The Jaccard similarity coefficient showed moderate similarity between the conserved and reforested sites ($CJ = 0.68$), while the altered site exhibited lower similarity to the others.

Keywords: birds, mangroves, diversity index

Citation: Sol-Sánchez, Á., Cornelio-Torres, G. del C., Hernández-Melchor, G. I. (2025). Bird diversity of the mangrove in an UMA of the Mexican tropics. *Agro Productividad*. <https://doi.org/286kj916>

Academic Editor: Jorge Cadena Iñiguez

Associate Editor: Dra. Lucero del Mar Ruiz Posadas

Guest Editor: Daniel Alejandro Cadena Zamudio

Received: January 11, 2025.

Accepted: April 13, 2025.

Published on-line: June XX, 2025.

Agro Productividad, 18(5). May. 2025. pp: 31-44.

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0 International license.



INTRODUCTION

The diversity of goods and services provided by mangroves and their surrounding areas makes them a unique environment, offering both tangible and intangible benefits to nearby human populations and the associated fauna (Guerra, 2017). Due to their continued presence in the area, certain bird species are considered indicators of disturbed habitats, whether caused by anthropogenic or natural activity. It has been observed that areas lacking mangroves function only as occasional perches for birds and, over time, see a decline in avian presence, as the ecosystem continuum is lost, along with all biological interactions. However, birds are often observed moving from one conserved area to another (Ortiz, 2017). Mexico has over 905,000 hectares of mangroves distributed across the country, with

Tabasco being one of the few states showing a consistent increase in mangrove coverage (CONABIO, 2022). As a consequence of this increase, wildlife populations, particularly birds, have also grown. Birds play a vital role in mangrove ecosystems, occupying various levels of the food chain (Rodríguez, 2019). Mangroves are highly diverse coastal ecosystems that provide critical habitats for a wide range of species, from aquatic birds and fish to crustaceans and marine mammals (CONABIO, 2020). Their complex networks of roots and waterways create ideal environments for reproduction, feeding, and shelter, significantly contributing to marine, coastal, and inland lagoon biodiversity. The interaction between mangroves and their associated fauna is essential for maintaining the ecological balance of these unique ecosystems (Ortiz *et al.*, 2018). Birds are widely recognized as key bioindicators of potential biodiversity disturbances due to their ease of observation and monitoring (Valdez-Leal *et al.*, 2015). Their diversity within ecosystems is influenced by both spatial and temporal factors. Vegetation structure plays a crucial role in their distribution, as it provides essential resources such as food, shelter, protection from predators, and suitable nesting sites (Valdez-Leal *et al.*, 2015). Amphibians and certain reptile species are highly sensitive to significant ecological changes that alter their natural habitats (Enríquez, 2004; Mora *et al.*, 2020). These species are critical in regulating populations of rats, mice, insects, and other pests (Mora *et al.*, 2020). They also serve as a food source for a wide variety of organisms within the same habitat (Enríquez, 2004; Mora *et al.*, 2020). Any substantial decline in their populations could negatively impact the ecological balance of the system. The aim of the present study is to analyze the behavior of bird communities across three vegetation types with varying degrees of conservation. This analysis focuses on assessing species turnover over time and establishing a relationship with the growth and development processes in a reforested area, offering deeper insights into the ecological dynamics of these environments.

MATERIALS AND METHODS

Study area

The study area is located in the ejido La Solución Somos Todos in Paraíso, Tabasco. Three sampling sites were delineated, each characterized by the presence of tree or shrub vegetation at different successional stages: one conserved site, one under development, and one undergoing restoration. All three are in contact with or in proximity to local water bodies (Figure 1). Site one is located at the confluence of the Cuxcuxapa and González Rivers and the Mecoacán Lagoon (18° 20' 14.08" N, 93° 06' 18.22" W). Site two is situated in former hydrocarbon extraction areas of PEMEX and is considered an altered site, as the watershed road altered the hydrological regime at the time (18° 22' 50.70" N, 93° 03' 53.90" W). Site three, undergoing reforestation, is located across from the area known as La Isla (18° 22' 18.84" N, 93° 05' 58.02" W). Site one is dominated by physiologically and sexually mature white mangrove (*Laguncularia racemosa* L. (A.) Gaertn), though it is not a climax site, as it is used for resource extraction. The site has continuous water inflow and outflow from the Mecoacán Lagoon, maintaining ecosystem stability due to water currents in the area. Site two was once dominated by degraded white mangrove, with stagnant waters and low regeneration activity. The site shows widespread areas of stagnant

water undergoing eutrophication. Occasionally, a few black mangrove trees (*Avicennia germinans* L.) can be observed. Site three features all three mangrove species red, white, and black mangrove and is considered a climax site where resource extraction is selective and infrequent, with a high rate of natural regeneration. It is located beside Playa del Ángel, in front of La Isla (Figure 1).

Fieldwork; monitoring

For the bird study, three permanent observation points, each 50 meters in length, were established at each site. Bird species were recorded through direct and indirect observations within a 10-minute observation window (González & Pérez, 2015). Each site included three sampling replicates, spaced 300 meters apart. Transportation to sites 1 and 3 was by water, while access to site 2 was by land (Pérez, 2015). Surveys were mainly conducted in the morning; as afternoon observations were limited by wave activity. During fieldwork, local guides assisted in identifying birds by their common names. Species-level identification was carried out through direct observation, involving visual detection of birds either with the naked eye or using 12×50 mm binoculars, depending on distance and sun position. Identification was aided by Peterson's (2022) bird field guides. Indirect identification was done through bird vocalizations. To determine territorial status, several fundamental categories were applied. The process began with identifying the species' primary residency and, if applicable, an additional category was assigned (Berlanga *et al.*, 2015):

- Residents (R): Species that live in the same region year-round and perform all life functions there, including feeding and reproduction.
- Winter Migrants (WM): Species that breed in the northern part of the continent and spend winter in Mexico or further south, typically between September and April.



Figure 1. Location of sampling sites.

- Summer Migrants (SM): Species that are present in Mexico only during the summer breeding season, generally from March to September.
- Transitory (T): Species that pass through Mexico during migration, heading south in the fall or north in the spring.
- Accidental (A): Species that are rare or irregular in Mexico, often observed outside their normal range, potentially due to weather events like hurricanes or storms.
- Oceanic (O): Species of pelagic birds that spend most of their time in open sea and typically breed on islands. Although not a residency category, this highlights their regular offshore presence throughout most of the year.

Bird community analysis

Specific wealth

Species richness refers to the number of species recorded per unit area studied (Nagelkerken, 2020). The simplest way to measure species richness is by directly counting the total number of species (S) obtained from the list of individuals recorded either by direct sightings or indirect methods.

Relative abundance

Relative abundance is the proportion of a species or taxon in relation to all species or taxa recorded at a site (Baker, 2020). It is a component of biodiversity and refers to how common or rare a species is compared to other species present at the monitoring site (Ellison, 2022).

To compare the abundances of fauna among the sampling units, rank-abundance curves, also known as Whittaker curves, were created. These curves are constructed by arranging species from the most dominant to the least abundant and representing them on a logarithmic scale (Kumar, 2020). This approach allows for the identification of changes in community composition patterns, evenness, and dominance (González, 2015).

Diversity

Diversity refers to the various species present in a given area and their characteristics (Lee, 2021). It is estimated using diversity indices (Macdonald, 2021). For this study, the calculation was performed using the Shannon-Wiener diversity index, which measures the information content per individual in randomly obtained samples from a 'large' community where the total number of species S is known (Pérez, 2015).

$$H' = -\sum p_i \ln p_i$$

where: p_i is the relative proportion (area) of each community within the landscape.

$$p_i = \frac{n_i}{N}$$

where: n_i =number of individuals of species i ; N =total number of individuals for all S species in the community.

Dominance

This expresses the extent to which a taxon is more numerous or has greater biomass than its competitors in an ecological community (Osland, 2019). Simpson's dominance index indicates the probability of finding two individuals of different species in two successive random "draws" without replacement (Rivera, 2020). This index gives greater weight to abundant species while underestimating rare ones, ranging from '0' to '1', where zero indicates low dominance and one represents maximum dominance (Brower *et al.*, 2020).

The formula used was:

$$D = \frac{\sum_{i=1}^S n_i (n_i - 1)}{N(N - 1)}$$

where: n_i =number of individuals of species i ; N =total number of individuals for all S species in the community.

Similarity

Similarity between populations refers to the degree of specific similarity between two or more studied communities. Qualitative or incidence-based indices are measures that allow us to evaluate similarity based on species presence-absence. Similarity can be assessed using indices such as Sørensen, Jaccard, and Simpson. In this case, to determine the similarity of the bird community among sampling units, the Jaccard coefficient (CJ) was used. This coefficient ranges from 0 to 1.0, where 0 indicates no shared species between samples and 1.0 indicates identical species composition in both samples (Thorne, 2023). For community structure analyses including richness and abundance, sampling effort, and comparisons among sampling units the software Past version 3 (Paleontological Statistics) was used.

Conservation status

To identify the degree of vulnerability of the species, a review of current environmental regulations was conducted: NOM-059-SEMARNAT-2010, which classifies vulnerable species into four categories: Probably extinct in the wild (E), endangered (P), threatened (A), and subject to special protection (Pr). At the international level, the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN) was consulted, which classifies species into nine categories: Extinct (EX), extinct in the wild (EW), critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), least concern (LC), data deficient (DD), and not evaluated (NE).

RESULTS AND DISCUSSION

The monitoring points were established at the following sites:

Site 1: Mature Mangrove Ecosystem

This environment is composed entirely of trees averaging 25 meters in height, primarily white mangrove, with a few red and black mangrove trees.

In this site, 31 bird species and 302 individuals were recorded. The most represented family was Ardeidae with five species. Regarding their residency status, 19 species were classified as residents; one as resident and summer migratory; four as resident and winter migratory; six as winter migratory and resident; and *Setophaga petechia* exhibited four categories: winter migratory, summer migratory, transient, and resident (Annex I).

Birds in this site were observed using trees for resting, perching, hunting, and feeding. They generally did not show fear of human presence. Bird activity peaked from 5:45 a.m. to around 10:50 a.m., and again from 4:30 p.m. until dusk.

Site 2: Young Mangrove Ecosystem

This ecosystem features young trees in the sapling and pole stages, with a certain degree of disturbance due to access roads and paths used for mangrove wood extraction. This has negatively impacted the fauna, making it easy to spot birds during rest or movement. Despite the presence of tree cover, the vegetation is less dense than in the mature mangrove, leading birds to use it mainly as a temporary perching site and to retreat upon human presence.

Species richness in this site was also 31 species, with 95 individuals recorded. The most represented family was Icteridae with four species, followed by Columbidae with three species (Annex I). In terms of residency, 22 species were residents; four were resident-winter migratory; four were winter migratory; and *Setophaga petechia* again exhibited all four residency categories (Table 1).

Site 3: Reforestation Mangrove Area

This area is undergoing reforestation, as the original tree species were harvested and the site is currently in recovery. Scattered trees were occasionally observed. The bird group in this environment was represented by 22 species and 117 individuals. The most represented family was Icteridae with three species, followed by Accipitridae, Cathartidae, Tyrannidae, and Ardeidae, each with two species (Table 1).

In terms of residency status, 15 species were residents; one was resident and summer migratory; three were resident and winter migratory; one was winter migratory; one was migratory and resident; and *Setophaga petechia* again exhibited all four categories (Table 1). Most species were observed feeding in the isolated trees.

The taxonomic composition of the bird community across the study sites included 56 species, representing 11.4% of the total bird species reported for the state of Tabasco (490 species) (Chablé-Santos *et al.*, 2005).

The most represented family was Ardeidae, typically found in swamps or near lakes (Peterson, 2018). Observations of this family were made in the mature mangrove site, two

Table 1. Richness and abundance by environment.

Place	Atmosphere	Wealth	Abundance	Shannon-Wiener diversity index
1	Mature mangrove	31	302	2.416
2	Mangrove under development	31	95	3.018
3	Reforestation area	22	117	2.184

in the reforestation area, and one in the developing mangrove. Overall, these species are often spotted in open habitats, where species like *Tyrannus melancholicus*, *Pitangus sulphuratus*, and *Myiozetetes similis* benefit from an unobstructed field of vision to detect flying insects, which are a major part of their diet (Cárdenas, 2022).

Richness and abundance per sampling unit

Table 1 shows that in general a richness of 57 species was obtained with 514 individual species distributed as follows.

The most well-represented families were Ardeidae and Tyrannidae, each with five species. The most abundant species was *Quiscalus mexicanus*, with 81 individuals recorded, followed by *Phalacrocorax brasilianus* with 73, *Stelgidopteryx serripennis* with 51, and *Rostrhamus sociabilis* with 50 individuals. The remaining species were less represented. The best-represented sampling unit was the mature mangrove, with 31 species and 302 individuals. This is likely due to it being the least disturbed site, thus maintaining the comfort conditions required by birds. The site with developing mangrove also had 31 species but only 95 individuals. Although its species richness is similar to the mature mangrove, the number of individuals was reduced to one-third, likely due to frequent human traffic from people extracting mangrove wood. On the other hand, the reforestation site showed the lowest richness, with 22 species and 117 individuals observed. Although this area is in the process of ecological recovery, the bird species richness and abundance suggest that the ecosystem is gradually regenerating.

Relative abundance per sampling unit

According to the rank-abundance analysis, the bird community was abundant across all three sampling units, each displaying distinct patterns.

In the mature mangrove, the species *Quiscalus mexicanus*, *Phalacrocorax brasilianus*, and *Rostrhamus sociabilis* stood out, showing the highest number of individuals and being exclusive to this site. In the young mangrove, a similar pattern was observed, with *Pitangus sulphuratus*, *Setophaga petechia*, and *Butorides virescens* being the most represented, while the rest of the species appeared more evenly distributed, with the least abundant species considered rare. In the reforestation site, only *Stelgidopteryx serripennis* was classified as abundant, while 50% (13 species) were considered rare. Most birds were observed in transit (in flight), and to a lesser extent, using the area as a perch. However, *Rostrhamus sociabilis* was noted to use the area as a roosting site, with a specific location identified as a dormitory area. In the young mangrove and reforestation area, the most abundant species were those commonly found in environments with some degree of disturbance.

Diversity

The bird diversity index was considered high at Site 2 and moderate at Sites 1 and 3. The highest diversity value was recorded in the developing mangrove with $H' = 3.018$, followed by the mature mangrove ($H' = 2.416$). The reforestation site was the least diverse, with $H' = 2.184$ (Figure 2).

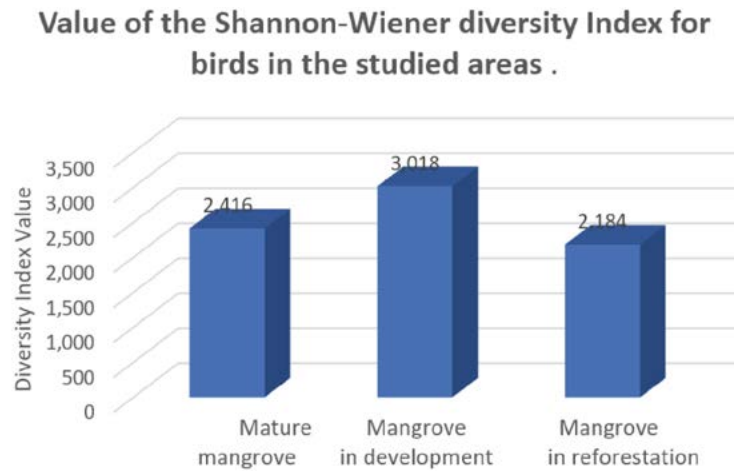


Figure 2. Diversity index by sampling environment.

According to field data, some bird species are generalists in terms of habitat, meaning they can inhabit various environments as long as food sources and shelter are available. This pattern is especially evident in families such as Accipitridae, Icteridae, and Ardeidae, which are connected to multiple habitats but are more concentrated in the mature mangrove (Figure 3). This graph illustrates the degree of species hierarchy across the three habitats. This pattern suggests that the habitat provides resources and favorable conditions that support greater bird diversity and abundance. Habitats such as the young mangrove

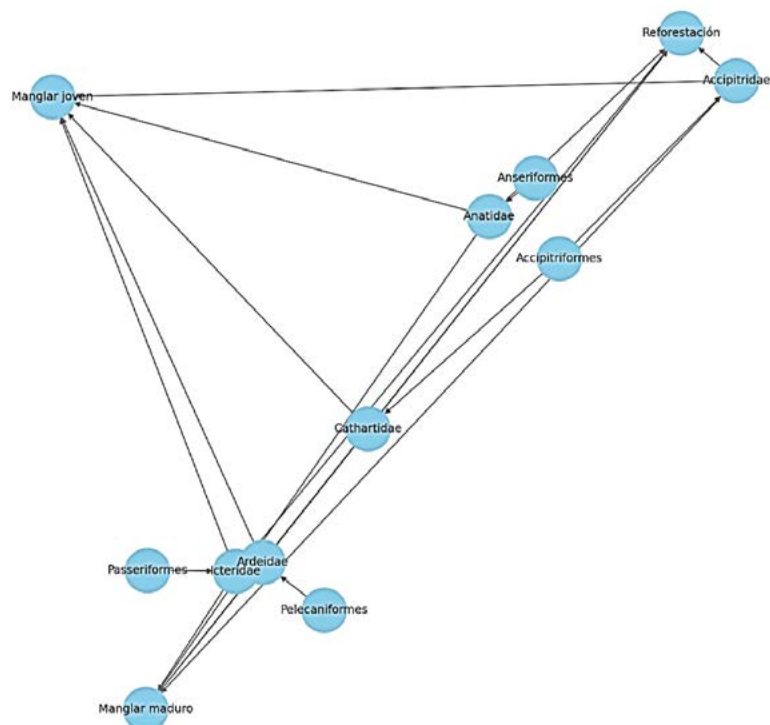


Figure 3. Network diagram, showing the hierarchical relationships between orders, families and habitats (mature mangrove, young mangrove and reforestation).

exhibit fewer connections and lower individual abundance; however, given that wildlife is dynamic, this behavior is likely transitory or less attractive for most resident species. Species in reforested habitats appear to be more specific, with fewer connections, which may be linked to the limited ecological functionality of the ecosystem compared to more developed habitats.

Each habitat plays an essential role in maintaining the avian diversity of the mangrove area. However, mature mangroves are particularly important due to the multifunctional services they provide to birds, including shelter, perching sites, feeding grounds, resting areas, and hunting zones, all supported by their high primary productivity (Ramadamhi *et al.*, 2022). Well-developed mangroves offer habitats that support a higher bird carrying capacity per unit area. This is evident, as the vertical structure of the trees provides more surface area for the dispersion of organisms compared to altered sites, where a single tree might sustain an exaggerated bird density, leading to competition and conflict over space (Nagelkerken *et al.*, 2020). Young mangroves tend to harbor lower diversity due to limited vegetation cover and less developed structure, which aligns with the patterns of limited connections observed in Figure 2 (Duke *et al.*, 2022). Reforested areas show ecological recovery potential. However, their effectiveness as bird habitats will depend on the management strategy and the time elapsed since reforestation began. The data indicate that these areas have not yet fully replaced the ecosystem services provided by mature mangroves (Osland *et al.*, 2019).

Simpson's Dominance Index

The value of Simpson's dominance index was $D=0.852$ for Site 1, $D=0.932$ for Site 2, and $D=0.780$ for Site 3. Since values closer to zero indicate higher diversity, and these values are close to 1, the diversity according to Simpson's index is considered low. (Table 2).

Since the value is low, the probability of obtaining two individuals from different species in two successive random extractions without replacement is also low. This index gives greater weight to abundant species and underestimates or excludes rare or scarce ones, with values ranging from 0 to a maximum of 1 (Figure 4).

Similarity Index

The similarity values show that the greatest species association occurred between the developing mangrove and the reforested mangrove, with a similarity of 3.25. The lowest similarity was found between the mature mangrove and the reforested mangrove, with a value of 2.5, while the mature mangrove and the developing mangrove presented an intermediate similarity (Table 3).

The mature and reforested mangroves are located on the margins of the Mecoacán Lagoon and the Manatí-Tilapa-Jícara lagoon complex, respectively.

Table 2. Simpson dominance index values for birds in the La Solución somos todos ejido, Paraíso Tabasco.

Mature mangrove	Mangrove in development	Area in reforestation
0,852	0,932	0,780

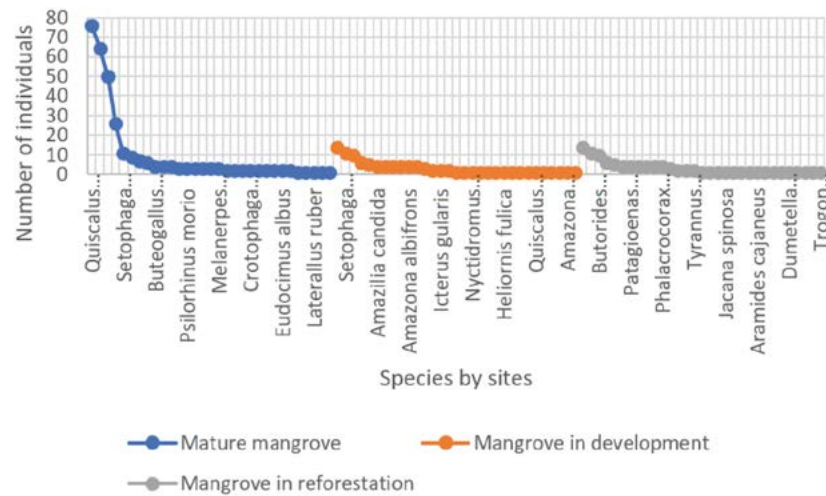


Figure 4. Abundance diversity curve by sampling environment, in the La Solución Somos Todos ejido, Paraíso, Tabasco.

Table 3. Jaccar similarity index values between the sites worked on.

Mature mangrove - developing mangrove. Sites 1-2	Mature mangrove forest - mangrove forest under reforestation. Sites 1-3	Mangroves under development - mangroves under reforestation. Sites 2-3
2.75	2.5	3.25

Conservation status

Regarding the species listed under a protection category by NOM-059-SEMARNAT-2010, a total of 11 species were recorded: *Aramus guarauna* was classified as Threatened (A), while the following were categorized as Subject to Special Protection (Pr): *Lithobates brownorum*, *Busarellus nigricollis*, *Buteogallus anthracinus*, *Rostrhamus sociabilis*, *Cathartes burrovianus*, *Heliornis fulica*, *Amazona albifrons*, and *Eupsittula nana* (Annex I). Additionally, 94.11% of the species are listed under the Least Concern (LC) category according to the International Union for Conservation of Nature (IUCN) Red List (Annex I).

CONCLUSION

The bird diversity in the study area is high compared to other forested areas in the tropics. The reason for the presence of these organisms is the availability of fish and other food species in the area’s shallow and deep water bodies. This condition favors the presence of birds throughout the year. Although this study was conducted for one season of the year, it is advisable to conduct the study throughout the year to understand the full diversity.

REFERENCES

Barragán-Vázquez, M. R., Torrez-Pérez, M. A., & Ríos-Rodas, L. (2015). Registros recientes de especies de anfibios y reptiles para Tabasco, México. *Mesoamericana, edición especial*, 19(1), 132.

Berlanga, H., Gómez de Silva, H., Vargas-Canales, V. M., Rodríguez-Contreras, V., Sánchez-González, L. A., Ortega-Álvarez, R., & Calderón-Parra, R. (2015). Aves de México: Lista actualizada de especies y nombres comunes. CONABIO, México D.F., 122.

- Baker, R., & Connolly, R. M. (2020). The role of mangroves in supporting fish and bird biodiversity. *Science Advances*, 6(23), eaba8329.
- Cárdenas, G., Harvey, C. A., Ibrahim, M., & Finegan, B. (2022). Diversidad y riqueza de aves en diferentes hábitats en un paisaje fragmentado en cañas, Costa Rica. *Agroforestería en las Américas*, 10, 39-40.
- Chablé-Santos, J. B., Escalante-Pliego, P., & López-Santiago, G. (2005). Aves (pp. 261-282). En J. Bueno, J. Álvarez, & S. Santiago (Eds.), *Biodiversidad del Estado de Tabasco* (Capítulo 12). México, DF: Comisión Nacional para el Conocimiento y Uso de Biodiversidad (CONABIO) e Instituto de Biología de la Universidad Nacional Autónoma de México (IBUNAM).
- Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). (2020). Manglares. Recuperado de <https://www.biodiversidad.gob.mx/ecosistemas/manglares>
- Conabio 2022. Extensión y distribución de manglares. Sistema de Monitoreo de Manglares de México. <https://www.biodiversidad.gob.mx/monitoreo/smmm/extensionDist>
- Crump, L. M., & Scott, N. J. (2001). Relevamientos por encuentros visuales. En *Medición y monitoreo de la Diversidad Biológica: Métodos* Press. España, 79-87.
- Domínguez-Domínguez, M., Zavala-Cruz, J., & Martínez-Zurimendi, P. (2011). Manejo forestal sustentable de los manglares de Tabasco. Secretaría de Recursos Naturales y Protección Ambiental, Colegio de Postgraduados, Villahermosa, Tabasco, México.
- Duke, N. C., Schmitt, K., & Anthony, E. J. (2022). Mangroves: Ecology, Biodiversity, and Conservation. *Annual Review of Environment and Resources*, 47, 1-30.
- Enríquez, P. L. (2004). Ecología y conservación de las aves de México. Sociedad para el Estudio y Conservación de las Aves en México.
- Enríquez-Cisneros, V. E. (2004). Propuesta de un sistema de monitoreo de especies indicadoras: anfibios y reptiles en sector Los Andes del complejo Los Volcanes, Departamento de Santa Ana, El Salvador. Tesis de licenciatura, Facultad de Ciencias Naturales y Matemáticas, Escuela de Biología, Universidad de El Salvador, Centroamérica.
- Ellison, A. M., Farnsworth, E. J., & Merkt, R. E. (2022). Mangrove biodiversity and its role in ecosystem function. *Marine Ecology Progress Series*, 693, 1-12. <https://doi.org/10.3354/meps14174>
- González, M. A., & Pérez, J. L. (2015). Comparación de métodos de conteo por puntos y de bioacústica para el monitoreo de aves. *Revista de Ecología y Biodiversidad*, 12(1), 45-58.
- González-García, F., & Gómez de Silva Garza, H. (2015). Patrones de diversidad de aves a lo largo de un gradiente latitudinal en la Sierra Madre Oriental, México. *Revista Mexicana de Biodiversidad*, 86(2), 419-430.
- Guerra, M. A., & Méndez Linares, A. (2017). Servicios ecosistémicos y estrategias de conservación en el manglar de la Isla de Salamanca, Colombia. *Revista Iberoamericana de Ciencias*, 3(4), 427-441. Recuperado de https://www.scielo.org.mx/scielo.php?pid=S1870-54722017000300427&script=sci_arttext
- Hammer, O. H., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. 4(1), 9 pp.
- Howell, N. G., & Webb, S. (1995). *The birds of Mexico and Northern Central America*. Oxford University Press.
- IUCN. (2016). International Union for Conservation of Nature and Natural Resources. Recuperado de <http://www.iucnredlist.org/>
- Magurran, A. E. (1989). *Diversidad Ecológica y su Medición*. Ediciones Vedral.
- Magurran, A. E. (2004). *Measuring biological diversity*. Blackwell Publishing.
- Mora, J. M., García, G., & Soto, R. A. (2020). Rol ecológico de anfibios y reptiles en ecosistemas tropicales. *Revista de Biodiversidad y Conservación*, 12(3), 45-59.
- Moreno, C. E. (2001). *Métodos para medir la biodiversidad*. M&T-Manuales y Tesis SEA.
- Martínez, E., & Ruiz, J. (2020). The mangrove ecosystem of the Gulf of Mexico: Biodiversity, conservation, and restoration perspectives. *Marine and Freshwater Research*, 71(8), 1034-1045. <https://doi.org/10.1071/MF19068>
- Nagelkerken, I., Sheaves, M., Baker, R., & Connolly, R. M. (2020). The role of mangroves in supporting fish and bird biodiversity. *Science Advances*, 6(23), eaba8329.
- NOM-059-SEMARNAT-2010. Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo.
- Nagelkerken, I., & Connolly, R. M. (2021). Mangrove ecosystems and their role in supporting coastal biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 31(1), 3-17. <https://doi.org/10.1002/aqc.3596>
- Hossain, M. S., & Kundu, A. (2021). Mangrove ecosystems and their roles in enhancing biodiversity in coastal zones: Implications for ecosystem-based management. *Global Ecology and Biodiversity*, 30(4), 597-612. <https://doi.org/10.1111/geb.13293>

- Ortiz-Pulido, R., Gómez de Silva, H., González-García, F., & Álvarez, A. (1995). Avifauna del centro de investigaciones costeras La Mancha Veracruz, México. *Acta zoológica mexicana*, 66, 87-118.
- Ortiz Reyes, A., Robles López, K., Urrego Giraldo, L. E., & Romero Tabarez, M. (2018). Diversidad e interacciones biológicas en el ecosistema de manglar. *Revista de Ciencias*, 22(2), 111-127.
- Osland, M. J., & Feher, L. C. (2019). Mangrove biodiversity in the Americas: Roles in tropical coastal ecosystems. *Biological Conservation*, 238, 108238. <https://doi.org/10.1016/j.biocon.2019.108238>
- Pérez, J. L. (2015). Comparación de métodos de conteo por puntos y de bioacústica para el monitoreo de aves. *Revista Mexicana de Biodiversidad*, 86(1), 123-134. Recuperado de https://www.scielo.org.mx/scielo.php?pid=S1870-34532015000100123&script=sci_arttext
- Pérez, J. L. (2015). Comparación de métodos de conteo por puntos y de bioacústica para el monitoreo de aves. *Revista de Ecología y Biodiversidad*, 12(1), 45-58.
- Peterson, R. T. (2022). A field guide to the birds of North America. Houghton Mifflin Harcourt.
- Ralph, C. J., Geupel, G. R., Pyle, P., Martín, T. F. D. F., Desante, D. Y., & Mila, B. (1996). Manual de métodos de campo para el monitoreo de aves terrestres. General Technical Report, Pacific Southwest Research Station, USDA Forest Service.
- Ramadhani A., Ambarwati R., Satriyo G.R. 2022. Diversity and abundance of water birds in the mangrove area of south coast of Bangkalan, Madura Island, Indonesia. *Biodiversitas* Vol 23, Num. 6 Pages: 3277-3284 E-ISSN: 2085-4722.
- Rivera-Monroy, V. H., & McKee, K. L. (2020). Mangrove ecosystems and their biodiversity value: A review of ecological functions and ecosystem services. *Oceanography and Marine Biology: An Annual Review*, 58, 139-183. <https://doi.org/10.1201/9780429279391-5>
- Valdez-Leal, J. D., Ortega-Rodríguez, J. M., & Ávila-Monroy, M. E. (2015). Aves como bioindicadores de la calidad ambiental en ecosistemas reforestados. *Revista Mexicana de Ecología y Biodiversidad*, 86(4), 857-865.
- Valdez-Leal, J. D. D., Pacheco-Figueroa, C. J., Méndez-López, E., Rangel-Ruiz, L. J., Moguel-Ordoñez, E. J., Arriga-Weiss, S. L., Mata-Zayas, E. E., Gama-Campillo, L. M., Gordillo-Chávez, E. J., García-Morales, R., & Luna-Ruiz, R. D. C. (2015). La comunidad de las aves en tres hábitats de la planicie de Tabasco, México. *Agro Productividad*, 69-73.
- Zimmerman, L. B. (2001). Transectos de bandas auditivas. En: Medición y monitoreo de la Diversidad Biológica: Métodos estandarizados para Anfibios. Universidad Nacional de la Patagonia, Smithsonian Institution Press, España, 87-93.
- Kumar, R., Singh, R. K., & Yadav, S. (2020). Mangrove ecosystems and their role in biodiversity conservation in the Indian Sundarbans. *Environmental Monitoring and Assessment*, 192(11), 672. <https://doi.org/10.1007/s10661-020-08596-0>
- Lee, S. Y., & Stoklosa, R. (2021). The importance of mangroves for maintaining biodiversity and ecosystem services. *Ecological Applications*, 31(6), e02257. <https://doi.org/10.1002/eap.2257>
- MacDonald, C. A., & Raventós, J. (2021). Mangroves as biodiversity hotspots: Linking ecosystem structure and function in a tropical coastal ecosystem. *Journal of Coastal Research*, 37(3), 594-603. <https://doi.org/10.2112/JCOASTRES-D-21-00011.1>
- Thorne, M. A., & Cochran, K. A. (2023). Biodiversity conservation in mangrove ecosystems: A synthesis of ecosystem functions and species interactions. *Environmental Conservation*, 50(1), 29-43. <https://doi.org/10.1017/S0376892922000104>

Annex 1.

Family	Species	Nom 059 and IUCN	Residency categories	Mature mangrove	Young mangrove	Reforestation	Grand total
Accipitridae	<i>Busarellus nigricollis</i>	Pr LC	Re	0	1	0	1
	<i>Buteogallus anthracinus</i>	Pr LC	Re, MV	4	0	1	5
	<i>Rostrhamus sociabilis</i>	Pr LC	Re	50	0	0	50
	<i>Rupornis magnirostris</i>	LC	Re	0	0	1	1
Cathartidae	<i>Cathartes burrovianus</i>	Pr LC	Re	0	0	1	1
	<i>Coragyps atratus</i>	LC	Re	2	0	1	3
Anatidae	<i>Dendrocygna autumnalis</i>	LC	Re	2	1	12	15
Trochilidae	<i>Amazilia candida</i>	LC	Re, MI	0	4	0	4
Caprimulgidae	<i>Nyctidromus albicollis</i>	LC	Re	0	1	0	1
Jacaniidae	<i>Jacana spinosa</i>	LC	Re	0	1	0	1
Laridae	<i>Hydroprogne caspia</i>	LC	MI, Re	2	0	0	2
Scolopacidae	<i>Actitis macularius</i>	LC	MI	0	1	0	1
Columbidae	<i>Leptotila verreauxi</i>	LC	Re	1	1	0	2
	<i>Patagioenas flavirostris</i>	LC	Re	0	4	0	4
	<i>Zenaida asiatica</i>	LC	Re, MI	0	2	0	2
Alcedinidae	<i>Chloroceryle americana</i>	LC	Re	1	5	0	6
	<i>Megaceryle torquata</i>	LC	Re	9	0	0	9
Cuculidae	<i>Crotophaga sulcirostris</i>	LC	Re	2	0	1	3
Aramidae	<i>Aramus guarauna</i>	A LC	Re	3	0	0	3
Heliornithidae	<i>Heliornis fulica</i>	Pr LC	Re	0	1	0	1
Rallidae	<i>Aramides cajaneus</i>	LC	Re	0	1	0	1
	<i>Laterallus ruber</i>	LC	Re	1	1	3	5
Corvidae	<i>Psilorhinus morio</i>	LC	Re	3	0	0	3
Hirundinidae	<i>Stelgidopteryx serripennis</i>	LC	Re, MI	0	0	51	51
Icteridae	<i>Agelaius phoeniceus</i>	LC	Re, MI	0	4	9	13
	<i>Icterus galbula</i>	LC	MI	0	1	0	1
	<i>Icterus gularis</i>	LC	Re	0	2	1	3
	<i>Quiscalus mexicanus</i>	LC	Re	76	1	4	81
Mimidae	<i>Dumetella carolinensis</i>	LC	MI	0	1	1	2
Parulidae	<i>Geothlypis trichas</i>	LC	MI, Re	3	0	0	3
	<i>Mniotilta varia</i>	LC	MI	0	3	0	3
	<i>Setophaga petechia</i>	LC	MI, MV, T, Re	11	11	6	28
Poliopitidae	<i>Poliopitila caerulea</i>	LC	MI, Re	2	0	0	2
Thraupidae	<i>Sporophila torqueola</i>	LC	Re	0	0	1	1
Tityridae	<i>Pachyrhamphus aglaiae</i>	LC	Re	0	1	0	1
Troglodytidae	<i>Campylorhynchus zonatus</i>	LC	Re	3	4	0	7
	<i>Pheugopedius maculipectus</i>	LC	Re	0	1	1	2

Annex 1.

Family	Species	Nom 059 and IUCN	Residency categories	Mature mangrove	Young mangrove	Reforestation	Grand total
Tyrannidae	<i>Contopus cinereus</i>	LC	Re	1	0	0	1
	<i>Megarynchus pitangua</i>	LC	Re	4	0	0	4
	<i>Myiozetetes similis</i>	LC	Re	0	0	1	1
	<i>Pitangus sulphuratus</i>	LC	Re	6	14	7	27
	<i>Tyrannus melancholicus</i>	LC	Re	0	2	4	6
Ardeidae	<i>Ardea alba</i>	LC	MI, Re	26	0	2	28
	<i>Ardea herodias</i>	LC	MI, Re	2	0	0	2
	<i>Bubulcus ibis</i>	LC	Re, MI	3	0	0	3
	<i>Butorides virescens</i>	LC	Re, MI	4	10	3	17
	<i>Egretta caerulea</i>	LC	MI, Re	7	0	0	7
Pelecanidae	<i>Pelecanus occidentalis</i>	LC	Re, MI	2	0	0	2
Threskiornithidae	<i>Eudocimus albus</i>	LC	Re, MI	2	0	0	2
Picidae	<i>Melanerpes aurifrons</i>	LC	Re	3	6	1	10
Psittacidae	<i>Amazona albifrons</i>	Pr LC	Re	0	4	0	4
	<i>Amazona autumnalis</i>	LC	Re	0	1	0	1
	<i>Eupsittula nana</i>	Pr LC	Re	2	0	0	2
Strigidae	<i>Ciccaba virgata</i>	LC	Re	1	0	0	1
Phalacrocoracidae	<i>Phalacrocorax brasilianus</i>	LC	Re	64	4	5	73
Trogonidae	<i>Trogon melanocephalus</i>	LC	Re	0	1	0	1
	Total number of organisms			302	95	117	514

Re=Residents; WM=Winter Migrants; SM=Summer Migrants; T=Transitory; A=Accidental; O=Oceanic; Pr=Protection.

Resident (Re) species live year-round in the same region, fulfilling key functions such as feeding and reproduction within that area.

Winter Migrant (WM) species breed in the northern part of the continent and spend the winter in Mexico and further south, generally between September and April.

Summer Migrant (SM) species are present in Mexico only during the summer breeding season, typically from March to September.

Transient (T) species migrate through Mexico on their way to overwintering grounds in the south during autumn or to breeding areas in the north during spring.

Accidental (A) species occur rarely or irregularly in Mexico, often as a result of dispersion outside their usual range or due to extreme weather events such as hurricanes or storms.

Oceanic (O) species are pelagic birds that spend most of their time in open ocean environments and typically breed on islands. Although not a formal residency category, this designation highlights their regular presence offshore for most of the year.