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Tropical forest remnants as shelters of avian diversity within a tourism development matrix in Yucatan Peninsula, Mexico

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Abstract: Tropical forests have undergone extensive transformation because of increasing tourism development, in addition to historic clearing for agricultural and cattle grazing activities. Altogether, these activities have had an important effect on bird diversity, reducing the habitat available to many species. In this study, the role of tropical forest remnants located between different land use types was evaluated for species diversity, composition, and distribution of the bird community at Akumal region in Quintana Roo, Mexico. Point counts were used to quantify the avifauna by habitat, and Shannon´s and Simpson´s diversity index were used to determine bird diversity. Additionally, bird species were classified according to seasonality and trophic guild by type of habitat. A total of 160 species and 50 families was recorded, of which 100 species were permanent residents, 47 winter visitors and 11 transients. Mature tropical forest and tropical forest remnants had higher species richness than those of modified environments. This study supports the importance of tropical forest remnants as shelters for bird species in landscapes with tourism developments, and the relevance of these remnants to maintaining high bird diversity. Rev. Biol. Trop. 66(2): 799-813. Epub 2018 June 01.

Key words: avian community; conservation; species richness; fragmentation; Akumal; Quintana Roo.

Tourism development is an important driver of forest fragmentation in some countries in tropical areas, in addition to the historic clearing for cattle and agriculture (Bierregaard & Stouffer, 1997; Lambin, Geist, & Lepers, 2003). Construction of tourism developments and associated infrastructure (golf courses, residential zones, recreational parks, roads, etc.) result in fragmentation of forest habitats (Fahrig, 1997; Christ, Hillel, Matus, & Sweeting, 2003; White et al., 2012), leaving many different shapes and sizes of forest remnants. Further, selective extraction of native vegetation and introduction of exotic species to increase the value of tourism complexes (Chettri, Chandra, Sharma, & Jackson, 2005; Schlaepfer, Sax, & Olden, 2011), modify plant species composition, and forest structure and complexity (vertical stratification and plant species composition). Altogether, these environmental modifications reduce the availability of habitats with suitable attributes (e.g., food resources and shelter) to forest-dependent wild fauna, including bird communities (McGarigal & McComb, 1995; Newsome, Moore, & Dowling, 2002; Buckley, 2004).

In addition, if the number of remnants increases, distance between them increases and the exposed edge becomes larger (Fahrig, 1997; Sodhi, 2002; Sekercioglu, 2007), resulting as plausible scenario a higher mortality of bird species by high nest predation as well lower food availability near to the edge of remnants with respect to their interior (e.g., Whyte, Didham, & Briskie, 2005; Newmark & Stanley, 2011). However, these effects depend

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on the attributes of avian community such as: migratory status, feeding guilds, species richness, and abundance (Stouffer & Bierregaard, 1995; Bierregaard & Stouffer, 1997); as well as forest type and the local threats facing each of them. Nevertheless, some bird species are able to use forest remnants surrounded by secondary growth, in a matrix with pasture and crops and other land uses, with stable population sizes and even experiencing significant increases in their populations (Hughes, Daily, & Ehrlich, 2002; Sekercioglu, Loarie, Oviedo, Ehrlich, & Daily 2007). Thus, this biodiversity corresponds to species generalists or species associated with anthropogenic activities (Krauss et al., 2010). Forest-interior bird species (i.e., specialist species) abilities to use the matrix of modified habitats surrounding forest fragments may affect their vulnerability in fragmented landscapes i.e. species that avoid the matrix tend to decline or disappear in fragments, while those (i.e., generalist bird species) that tolerate or exploit the matrix often remain stable or increase. However, it is not known what happens in a tourism development where forest remnants are interspersed by residential buildings and tourism activities, which are increasing across the tropical forest in Latin American.

During the period 2000-2010, world tropical forest deforestation was 62 % (Keenan et al., 2015), resulting in 6.5 million hectares lost per year. However, in Mexico showed the largest deforestation rates, with 197 651 hectares lost from the 2001 to 2015 period (see details in http://www.globalforestwatch.org/country/MEX). Tropical forest originally covered about 8 % of the country, being considered a world "hotspot" because of its high biodiversity and endemism (Myers, Mittermeier, Mittermeier, Da Fonseca, & Kent, 2000). Unfortunately, this ecosystem has experienced high deforestation rates, particularly since the early 1970´s, because of conversion to pastures and crops, and the establishment of tourism development. Nonetheless, it is still possible to find considerable amount of tropical forest in the Yucatan Peninsula. However, these tropical forest area consist of forest remnants surrounded by mosaics of agricultural land, tourism development and secondary growth. Therefore, it is very important to know the characteristics and extension of these remnants of tropical forest and evaluate if it possible to conserve bird diversity and richness compared to other areas with different land uses. In order to know if the tropical forest remnants are functioning as bird diversity shelters within a matrix dominated by tourism development in one of the most important tourism area in Mexico, our goal was to better understand differences in bird species richness among natural and modified habitats in Akumal region in Quintana Roo, Mexico. In addition, to investigate the role of the different habitat types in a matrix dominated by tourism development. This study aims to provide a general understanding of how bird communities are affected by tourism development. We expected to find a lower species richness and a distinctive bird species composition in modified environments compared with natural environments (mature tropical forest and tropical forest remnants).

MATERIALS AND METHODS

Study area: The present study was carried out in Akumal, an area with several tourism developments (covering approximately 143 km^2) located in the Yucatan Peninsula between 20°30' N - 87°12' W & 20°10' N - 87°26' W (Fig. 1), at the municipality of Tulum in Quintana Roo, Mexico. This site ranges in elevation from 0 to 20 masl, climate of warm subhumid type with abundant rainfalls in summer. Annual average temperature ranges from 25 to 28 °C, and annual precipitation between 1 300 and 1 500 mm. Dominant natural vegetation in the area is tropical semideciduous forest, tropical deciduous forest, and tropical flooded forest associated with secondary growth; as well as relicts of dunes coast vegetation and mangrove. Common tree species in the study area included *Brosimum alicastrum, Bursera simaruba, Manilkara zapota, Talisia olivaeformis, Metopium brownei, Caesalpinia gaumeri, Thrinax radiata, Coccothrinax readi* and

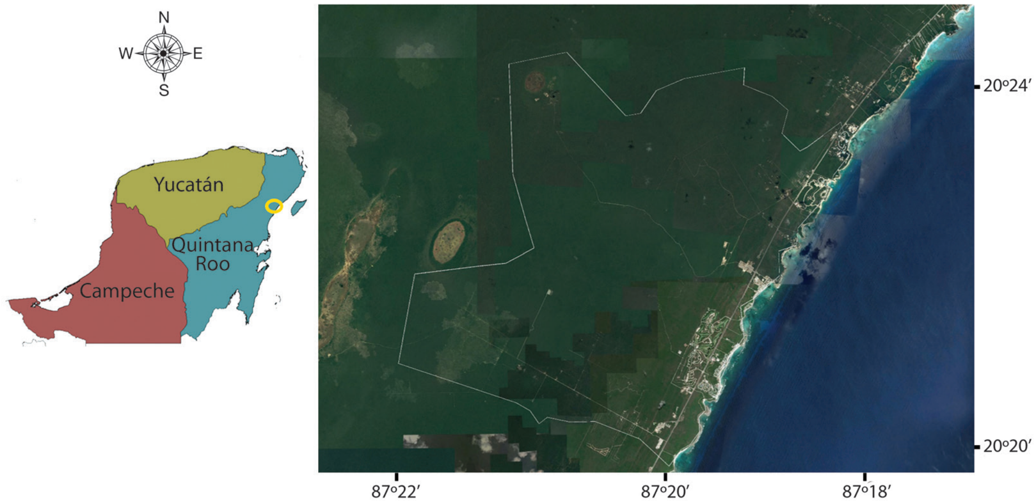

Fig. 1. Map show the location of study area in Yucatan Peninsula, Mexico. The location of study area is found in the eastern Yucatan Peninsula, and it's delimited by a square that it's shown in detail in the right panel.

Pseudophoenix sargentü. The mangrove relicts founded are dominated by *Rhizophora mangle* and *Laguncularia racemose*. From the tide line, where the sand accumulates and the soil is very unstable plants, are established *Sesuvium portulacastrum,* trailblazers like *Ambrosia hispida, Salicornia* and *Hymenocallis littoralis bigelavii*. This vegetation is the limit to stable dunes where there is a thicket forming shrub species complex as *Cocoloba uvifera, Ipomoea pescaprae, Camavelia rosea, Sophora tomentosa,* and *Ernodea littoralis,* among others (Miranda, 1959; Rzedowski, 1978).

Habitat classification: Habitat classification was based on main vegetation cover, land uses, and the pattern of utilization by settlements as follow: (a) mature tropical forest: tropical semideciduous and tropical deciduous forest >2 ha with mature trees >10 years with canopy height 8 to 15 m and, diameters >20 cm; (b) tropical forest remnants: tropical semideciduous and tropical deciduous forest remnants <2 ha with mature trees <10 years, with canopy height 4 to 8 m and, diameters <20 cm within golf courses and residential zones; (c) modified environments by tourism developments, that include golf course and artificial water bodies in golf course; hotels zones and residential with natural and introduced vegetation; (e) modified environments by urban developments, crops and livestock, that include urban zone with natural and introduced vegetation, cattle pastures and agricultural fields; (f) coast dunes, beach zone and small remnants mangrove.

Bird surveys: Point counts surveys were conducted along transects in the different habitat types (see above; Hutto, Pletschet, & Hendricks, 1986) from April 2009 to November 2010, for a total of 412 point counts in 96 days. Points were randomly selected to represent different types of natural vegetation and land uses in the area (107 km^2). Distance between sampling points were at least 250 m to avoid double-counting of highly local species (Hutto et al., 1986; Ralph, Saber, & Droege, 1995). Observation time by point was 20 min, as proposed for tropical environments (Vielliard, 2000). Points were located in both edge and interior of the forest remnants. Sampling was conducted monthly mostly in the morning (06:00 to 11:30 h) and in the afternoon (15:30 to 20:00 h), additional to nocturnal observations. Birds were identified by sight and sound (mostly), excluding birds that overflew the sampling points. Sampling was avoided on rainy days. Species richness was expressed as the total number of species recorded in each habitat, because effort was approximately equal at all habitats (21 days of sampling effort per habitat, with exception of coast dunes, beach zone and small remnants mangrove, which was 12 days). For species identification, Peterson and Chalif (1989), and Howell and Webb (1995) guides were used, and nomenclature and taxonomic status followed AOU (2017), as well as some supplements.

Bird attributes: Birds were categorized as resident or migratory species according to their presence during the study period and complemented with Howell and Webb (1995). Feeding habits were categorized according to which the species was feeding most frequently, which was complemented with literature sources (Peterson & Chalif, 1989; Howell & Webb, 1995) and field observations: omnivores, nectarivores, carnivores, frugivores, granivores, and insectivores (included aquatic invertebrates as well as bark insectivores, aerial insectivores, trunk insectivores, generalist insectivores, ground insectivores, and leaf insectivores). Habitat use preferences were categorized based on Blair (1996), and based on main cover vegetation of the land uses (see above).

Statistical analyses: Species richness was calculated as the cumulative number of species observed in the study area. EstimateS v.9 was used to compute species accumulation curves for the species detected by survey (number of sampling days) (Colwell, 2013). Species accumulation curves estimate the number of species expected in the study area and to compare qualitatively avian richness among habitat types, based on randomized re-sampling from all pooled samples. Asymptote from species accumulation curves was constructed by Michaelis-Menton species richness estimation function using EstimateS v.9 (Colwell & Coddington, 1994). This method estimates of total species richness based on successively larger numbers of samples from the data set. Non-parametric estimator Jackknife 2 was selected based for having the slightest bias in the accuracy data (Walther & Moore, 2005; Hortal, Borges, & Gaspar, 2006). The Shannon diversity index (H´) and Simpson´s index (*D*) were obtained to estimate diversity among habitats (Krebs, 2000). Point Abundance Index (PAI) was calculated by dividing the number of detections for each species by the total number of point's sampled (Blondel, Ferry, & Frochot, 1970). To understand how community composition differs, and what species are present and how the habitats differ in the mix of species they have, we conducted a hybrid multidimensional scaling ordination (HMDS), using the Bray-Curtis dissimilarity index on untransformed species abundance. The hybrid MDS was introduced by Faith, Michin and Belbin (1987) and combines both the PCoA (principal coordinate analysis or classical MDS) and the non-metric MDS (NMDS). It has the advantage of assuming a linear relationship between the ecological distances obtained by the ordination and the dissimilarity measures where it is most often straight (the PCoA part), and only monotonicity where ecological distances (in the ordination space) are too high to be accurately measured (the NMDS part; Faith et al., 1987). Differences between natural environments and modified environments (see above) were tested using a permutation multivariate analysis of variance (PERMANOVA; Anderson, 2005). Data of the coast dunes, beach zone and mangrove were not included given the low number of sampling points made in those areas. All analyses were conducted using Minitab (see details http://www.minitab.com/).

RESULTS

We recorded a total of 1 914 bird sightings during the study period, with a bird density of 54.3 individuals/observation-hour. A total of 160 species and 50 families was recorded, from which only five species are considered endemic, and 10 species were most frequently recorded (Appendix). Accumulation curves for sampling by census reached an asymptote

(Fig. 2A) in the value of 170 species. In this context, Jackknife´s 2 estimator resulted in a value of 177 species, indicating that the probability of encountering more species increasing sampling effort is very low (Fig. 2B). From all detected bird species, 99 were permanent residents, 47 were winter visitors, 11 were transients, and three introduced (Appendix). The avian community in the study have a predominance of insectivore species (N= 97, see Appendix).

Bird community attributes by habitats: A total of 96 species were found in mature tropical forest, 92 in tropical forest remnants, 79 in modified environments by tourism developments and, 40 in modified environments by urban developments, crops and livestock (Appendix). Accumulation curves showed that the expected species richness present in mature tropical forest had the highest bird richness (Jackknife 2 = 114), followed by tropical forest remnants with expected species (Jackknife 2 = 110), modified environments by tourism developments (Jackknife 2 = 91), and (Jackknife 2 = 57; Fig. 2B). Only 17 species were exclusively found in mature tropical forest, three in tropical forest remnants, and the rest

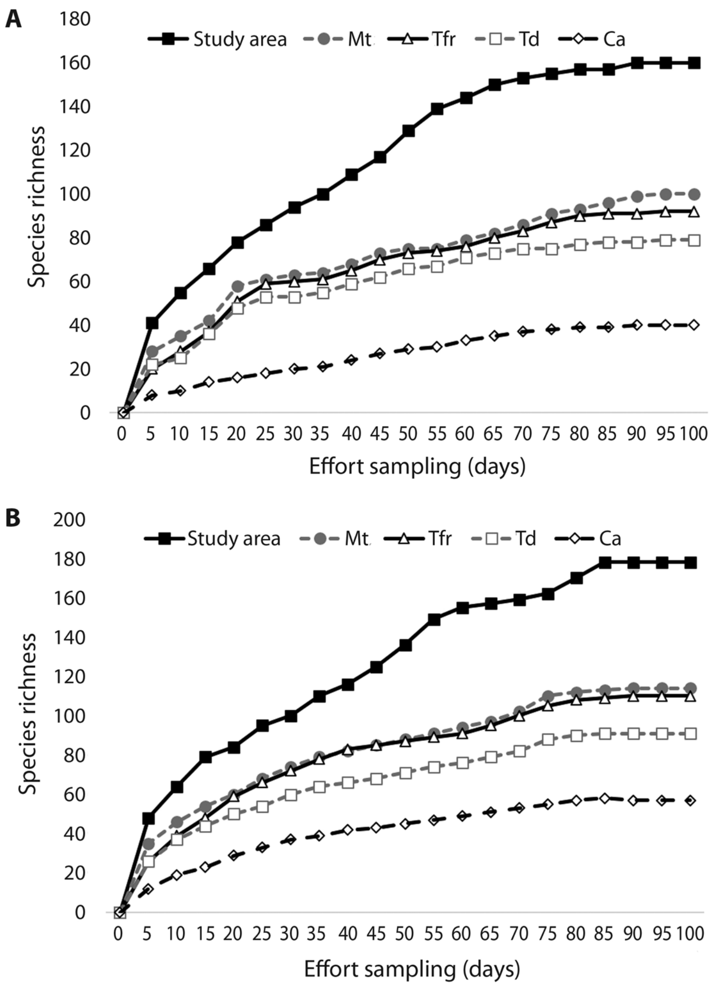

Fig. 2. Species accumulation curve for birds sampled by census in the study area. Observed species richness (a) and expected (b) in the study area and habitat type: Mature tropical forest (Mt), Tropical forest remnants (Tfr), Modified environments by tourism developments (Td), and Modified environments by urban developments, crops and livestock (Ca).

was shared, and four in modified environments by tourism developments and two in modified environments by urban development, crops and livestock, while the rest were found in two to four habitat types (Appendix). The species richness and diversity values were highest in mature tropical forest (96 species, H‘ = 3.78±0.006, D= 0.93±0.010) and tropical forest remnants (94 species, H‘= 3.32±0.008, D= 0.90±0.010); while, modified environments by tourism developments (72 species, H‘= 2.89±0.014, D= 0.73±0.030), and modified environments by urban developments, crops and livestock (40 species, H‘= 2.73±0.012, D= 0.69±0.029) presented the lowest species richness and diversity values (Fig. 3). Bird species richness and diversity values (H‘, D) varied significantly among habitats (Fig. 3; P< 0.001), with few species detected in modified environments compared with mature tropical forest and tropical forest remnants. This was supported also by the HMDS ordination explained 55 % of the variation in species composition among habitats. Clear gradients in community composition were observed along both axes, with the centroids for mature tropical forest sites and tropical forest remnants having negative values on both axes and the centroids for modified environments (by tourism developments and by urban developments, crops and livestock) having positive values (Fig. 4). Mature tropical forest and tropical forest remnants sites were

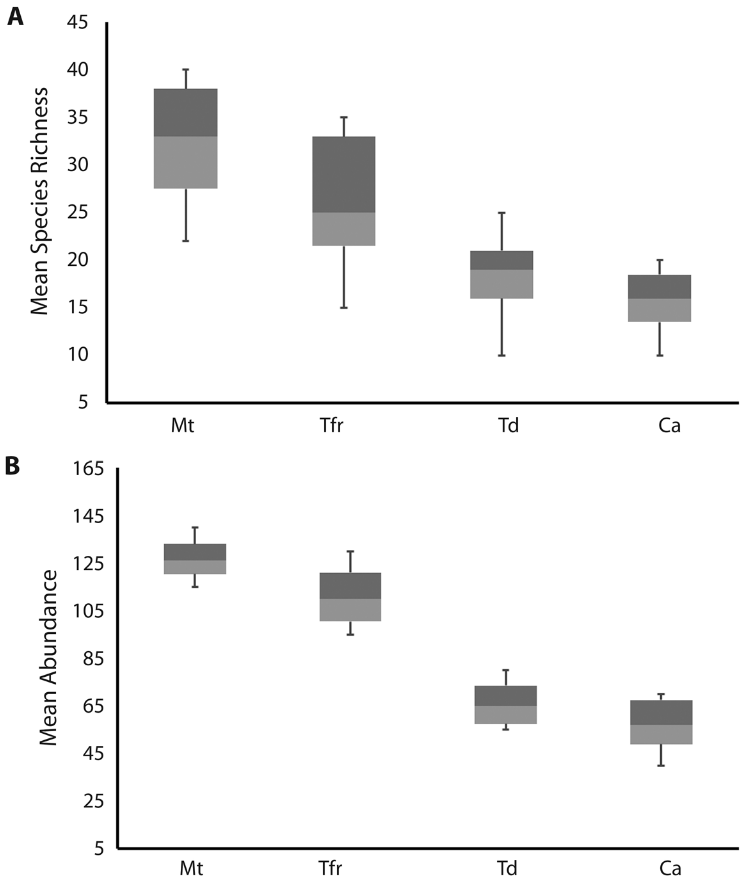

Fig. 3. Boxplots of mean species richness (a), mean abundance (b), (c) Shannon diversity index, and (d) Simpson´s diversity index of bird species at Akumal region, Quintana Roo, Mexico: Mature tropical forest (Mt), Tropical forest remnants (Tfr), Modified environments by tourism developments (Td), and Modified environments by urban developments, crops and livestock (Ca). Lines represent minimum, first quartile, median, third quartile, and maximum.

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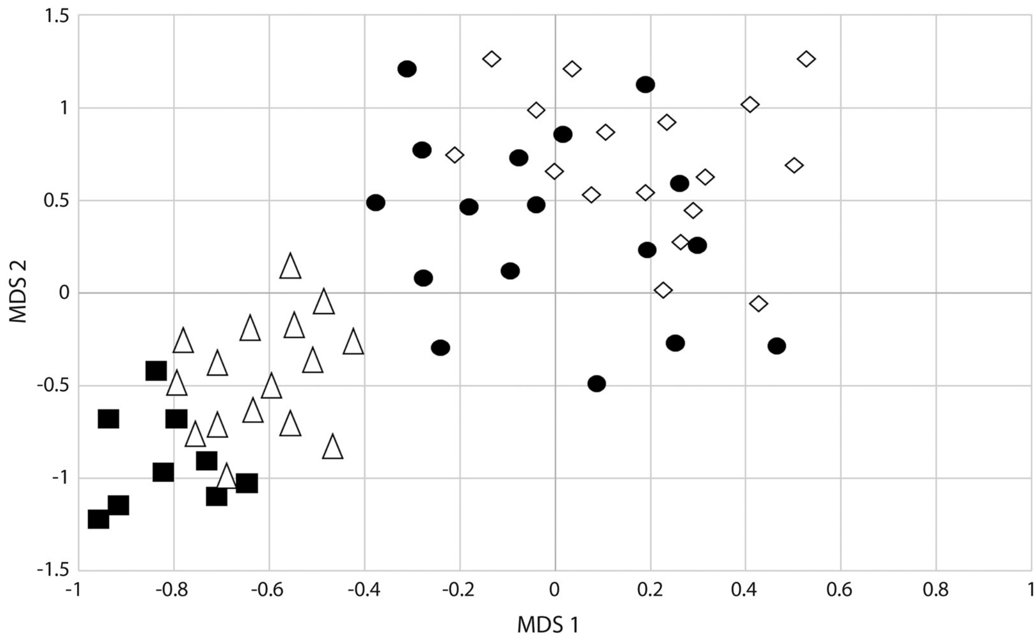

Fig. 4. Ordination plot of HMDS axes showing gradients in bird composition in mature tropical forest (■), tropical forest remnants (Δ), modified environments by tourism developments (●) and modified environments by urban developments, crops and livestock (◊).

clearly separated from modified environments, and grouping of same land-use sites was significant (F_2 = 28.632, R^2 = 0.412, P< 0.05) showing that bird richness differ significantly between the four analyzed habitats (Fig. 4). Similarly, with migratory status, the highest species richness of resident and migratory species was recorded in mature tropical forest (69 resident species and 26 migratory species) and tropical forest remnants (62 resident species and 35 migratory species) while modified environments by tourism developments (45 resident species, 26 migratory species, and one introduced species) and modified environments by urban developments, crops and livestock (30 resident species, eight migratory species, and two introduced species) recorded the lowest species richness; but not significant difference depending on migratory status, both migratory and resident species respond the same way. Insectivore species were better represented in the mature tropical forest, and tropical forest remnants (>16). Frugivores and nectarivores species were slightly higher and abundant in mature tropical forest and, tropical forest remnants (with six species in each habitat). Carnivores (18), granivores (10) and omnivores (10) species were better represented in modified environments (particularly in cattle pastures and agricultural fields), and insectivore species were better represented in mature tropical forest (65 species) and, tropical forest remnants (59; Appendix). Results in this study are consistent with respect to that modified environments (i.e., agricultural and livestock areas) had a higher proportion of carnivores and granivores species in comparison with tropical forest.

DISCUSSION

Our study revealed that mature and tropical forest remnants in Akumal region had higher bird species diversity that the modified environments, which is expected because modified environments lack suitable vegetative remnants, shrubs and canopy cover that limits food density and diversity, nest placement, and predator avoidance. Above mentioned reveals the importance of tropical forest remnants for bird diversity conservation in a tourism area, as an important shelters to the bird community. According with our results, Bennet and Saunders (2010) mentioned that the forest remnants are very important in terms of shelter, feeding and nesting areas, particularly to birds that depend on native vegetation.

Bird species recorded accounted for 32 % of all species reported for Quintana Roo by Correa and MacKinnon (2011), being the order Passeriformes the most representatives with 52 % (83 species) from the total recorded. Abundance index values (PAI) showed a large number of species with low PAI, as well as few species with intermediate to high PAI compared to the pattern observed in other surveys (Aleixo & Vielliard, 1995; Lyra-Neves, Martins, Mendes, Rodrigues, & Lacerda, 2004). Bird species richness in the study was similar to other tropical forest areas with a predominance of insectivore species (e.g., Estrada, Coates-Estrada, & Meritt, 1997; Blake & Loiselle, 2001). Omnivore species abundance can be directly related to the variety of available resources for change in land use and declining native resources like fruits. However, the presence of frugivore species, also some bark insectivore species indicate that the study area is relatively well conserved (Blake & Loiselle, 2015). Others signs of relative adequate habitat conditions included the occurrence of mixed-species flocks (Stotz, Fitzpatrick, Parker, & Moskovits, 1996), and trunk insectivores. Frequency and structure of mixed-species flocks also suggests habitat conditions at the study area were adequate for many common in tropical forest bird species according to Stotz et al. (1996). Most bird species recorded in this study were dependent on forest edge, these results suggest that the sensitivities of bird species to vegetation are associated with their dependence of food resources as availability of native fruit (Hasiu, Gomes, & Silva, 2007).

The differences in the species richness and diversity found in this study indicated that the mature tropical forest and tropical forest remnants present greater diversity and richness compared with modified environments. This accords with other studies in tropical environments, and indicates that the loss of original habitats directly influences the presence, abundance and persistence of species (Kattan, Álvarez-López, & Giraldo, 1994; Laurance & Bierregaard, 1997; Rocha, Virtanen, & Cabeza, 2015). The higher avian diversity found in tropical forest may be due to high numbers of individuals and mature vegetation that provide many different microhabitats, which promote varieties of bird species compared with habitats with different land covers (e.g., with human infrastructure or tourism development). However, others studies have found highest richness in modified environments than natural environments (Petit, Petit, Christian, & Powell, 1999; Martin, Viano, Ratsimisetra, Laloë, & Carrière, 2012), but this may be due to the environmental heterogeneity that can get to present the area.

Tropical forest remnants had a significant contribution to the bird species richness and diversity in the study area which is consistent with those reported by Estrada et al. (1997) in Los Tuxtlas region in Veracruz, Mexico. On the other hand, bird composition in terms of the feeding guilds is related to vegetation structure (Laurance & Bierregaard, 1997). Different groups of bird species were found that respond differently to the conversion of forest to modified environments. Not surprisingly, tropical forest assemblages were characterized by a high proportion of forest-associated species, whereas modified habitats were dominated by generalists and open habitat specialists. However, modified environments by urban developments, crops and livestock are very important to a lot of carnivores, granivores and insectivores species because of temporarily or permanently provide such resources depending on their phenology and seasonality (Loiselle & Blake, 1994).

In general, the tropical forest remnants that presents the study area appears to contribute to the relatively high species richness, especially considering the number of species occurring in mature tropical forest. Results of this study showed evidence that tropical forest remnants are significantly important in tourism zones as an available habitat for birds. The continuing expansion of tourism complex, particularly large-scale, will likely result in the simplification and loss of bird diversity. That is particularly important in tourism zones from Quintana Roo because these remnants representing shelters, feeding or nesting areas for birds dependent from natural environments; as well as responsible for maintaining an important proportion of regional avian diversity. The importance of tropical forest remnants provides important habitats for many species of resident and migrant birds in Yucatan Peninsula. Our results confirm the great need for conservation (preserved areas), restoration with native vegetation, and ecological studies of tropical forests remnants, because represent the first step to take actions for conservation of regional avian diversity in the Yucatan Peninsula subjected to anthropogenic activities. An added potential value to this tourist area to attract other tourism type (as birdwatchers) as an alternative to preserve and promote ecological tourism. Furthermore, create incentives for protection and preservation on natural areas and, native biota, which allow preserve these tropical forest remnants.

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RESUMEN

Remanentes de bosque tropical como refugios de la diversidad de aves dentro de una matriz de desarrollo turístico en la Península de Yucatán, México. Los bosques tropicales han sufrido una transformación extensa debido al aumento de los desarrollos turísticos, además de la compensación histórica de las actividades agrícolas y de pastoreo del ganado. En conjunto, estas actividades han tenido un efecto importante en la diversidad de aves, reduciendo el hábitat disponible para muchas especies. En este estudio, se evaluó el papel de los remanentes de bosque tropical para la diversidad de especies y composición de la comunidad de aves ubicados en diferentes tipos de uso de suelo en la región de Akumal en Quintana Roo, México. Se utilizaron puntos de conteo para caracterizar la avifauna por hábitat, y se utilizó el índice de diversidad de Shannon y Simpson para determinar la diversidad de aves. Además, las especies de aves se clasificaron según la estacionalidad y el gremio alimenticio. Se registraron 160 especies, distribuidas entre 50 familias; 100 especies fueron residentes permanentes, 47 visitantes de invierno y 11 transitorias. El bosque tropical maduro y remanentes de bosque tropical tuvieron una mayor riqueza de especies y valores de diversidad que los ambientes modificados. La composición de las especies de aves de los remanentes de bosque tropical fue similar a la del bosque tropical maduro, pero mayor que los ambientes modificados. Este estudio demuestra la importancia de los remanentes forestales tropicales como refugios y corredores biológicos en paisajes con desarrollos turísticos, y la relevancia de estos remanentes en el mantenimiento de una alta diversidad de aves.

Palabras clave: comunidad de aves; conservación; riqueza de especies; fragmentación; Akumal; Quintana Roo.

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APPENDIX

Bird species recorded were classified according to their migratory status and feeding habits in each habitat type in Akumal region, Quintana Roo, Mexico

Species	Migratory status	Feeding habits*	PAI	Habitat use preferences**
Dendrocygna autumnalis	Resident	I	0.9856	**Td** (Gc)
Anas discors	Winter visitor	I	0.6312	**Td** (Gc)
Nomonyx dominicus	Resident	I	0.9856	**Td** (Gc)
Ortalis vetula	Resident	Fr	1.8874	**Td** (Gc), **Cbm**
Phoenicopterus ruber	Resident	I	0.1322	**Cbm**
Podilymbus podiceps	Winter visitor	I	0.6312	**Td** (Gc), **Cbm**
Columba livia	Introduced	Om	2.2480	**Ca** (Us)
Patagioenas flavirostris	Resident	Fr	0.8523	**Mt**
Streptopelia decaocto	Introduced	Om	0.8523	**Td** (Rh), **Ca** (Us)
Columbina passerina	Resident	Gr	1.2340	**Tfr, Td** (Rh)
Zenaida asiatica	Resident	Gr	1.2340	**Mt, Tfr, Td** (Gc, Rh), **Ca** (Cp, Us)
Zenaida aurita	Resident	Gr	1.2003	**Td** (Rh), **Ca** (Cp, Us)
Coccyzus minor	Resident	Fr, I	0.0045	**Mt, Tfr**
Chordeiles acutipennis	Resident	I	0.0987	**Mt, Tfr, Td** (Gc)
Nyctidromus albicollis	Resident	I	0.0846	**Mt**
Chaetura vauxi	Resident	I	1.0084	**Mt, Tfr, Td** (Gc, Rh), **Ca** (Cp, Us)
Anthracothorax prevostii	Resident	Ne	0.0012	**Mt**
Archilochus colubris	Winter visitor	Ne	0.0458	**Mt, Tfr**
Chlorostilbon canivetii	Resident	Ne	0.0683	**Mt, Tfr**
Amazilia yucatanensis	Resident	Ne	0.0879	**Mt, Tfr**
Amazilia rutila	Resident	Ne	0.0879	**Mt, Tfr, Td** (Rh), **Ca** (Us)
Gallinula chloropus	Winter visitor	I	0.0875	**Td** (Gc), **Cbm**
Fulica americana	Winter visitor	I	0.0875	**Td** (Gc), **Cbm**
Himantopus mexicanus	Transient	I	0.0987	**Td** (Gc)
Pluvialis squatorola	Winter visitor	I	0.0784	**Cbm**
Pluvialis dominica	Transient	I	0.0012	**Td** (Gc), **Cbm**
Charadrius semipalmatus	Winter visitor	I	0.5489	**Cbm**
Charadrius vociferus	Winter visitor	I	0.6231	**Td** (Gc), **Cbm**
Jacana spinosa	Resident	I	0.0023	**Td** (Gc), **Cbm**
Actitis macularius	Winter visitor	I	0.0987	**Td** (Gc), **Cbm**
Tringa solitaria	Winter visitor	I	0.0846	**Td** (Gc), **Cbm**
Arenaria interpres	Winter visitor	I	0.0846	**Cbm**
Calidris minutilla	Winter visitor	I	0.0846	**Cbm**
Calidris pusilla	Transient	I	0.0784	**Cbm**
Leucophaeus atricilla	Winter visitor	Ca	0.0784	**Cbm**
Hydroprogne caspia	Winter visitor	Ca	0.0458	**Cbm**
Chlidonias niger	Transient	I, Ca	0.0030	**Cbm**
Thalasseus elegans	Winter visitor	Ca	0.0458	**Cbm**
Thalasseus maximus	Winter visitor	Ca	0.0458	**Cbm**
Fregata magnificens	Resident	Ca	0.6307	**Td** (Gc), **Cbm**
Sula leucogaster	Resident	Ca	0.5543	**Td** (Gc), **Cbm**
Phalacrocorax brasilianus	Resident	Ca	0.9936	**Td** (Gc), **Cbm**
Anhinga anhinga	Resident	Ca	0.9701	**Td** (Gc), **Cbm**
Pelecanus occidentalis	Resident	Ca	0.6111	**Td** (Gc), **Cbm**
Ardea herodias	Winter visitor	Ca	0.0224	**Td** (Gc), **Cbm**

Species	Migratory status	Feeding habits*	PAI	Habitat use preferences**
Ardea alba	Resident	Ca	0.0458	**Td** (Gc), **Cbm**
Egretta thula	Resident	I, Ca	0.1322	**Td** (Gc), **Cbm**
Egretta caerulea	Winter visitor	I, Ca	0.1322	**Td** (Gc), **Cbm**
Egretta tricolor	Winter visitor	I, Ca	0.0112	**Td** (Gc), **Cbm**
Bubulcus ibis	Resident	I	0.7789	**Ca** (Cp)
Butorides virescens	Resident	I, Ca	0.0112	**Td** (Gc), **Cbm**
Euducimus albus	Resident	I	0.6803	**Td** (Gc), **Cbm**
Coragyps atratus	Resident	Ca	1.9635	**Mt, Tfr, Td** (Gc, Rh), **Ca** (Cp, Us)
Cathartes aura	Resident	Ca	1.9648	**Mt, Tfr, Td** (Gc, Rh), **Ca** (Cp, Us)
Pandion haliaetus	Winter visitor	Ca	0.0112	**Cbm**
Buteogallus anthracinus	Resident	Ca	0.0157	**Tfr, Cbm**
Rupornis magnirostris	Resident	Ca	0.1002	**Mt, Tfr, Ca** (Cp, Us)
Buteo nitidus	Resident	Ca	0.0875	**Mt, Tfr, Ca** (Cp)
Tyto alba	Resident	Ca	0.0045	**Td** (Rh), **Ca** (Cp, Us)
Megascops guatemalae	Resident	Ca	0.0012	**Mt, Tfr**
Glaucidium brasilianum	Resident	Ca	0.0012	**Mt**
Trogon melanocephalus	Resident	Fr	0.0085	**Mt, Tfr**
Trogon caligatus	Resident	Fr	0.0088	**Mt,**
Momotus coeruliceps	Resident	Om	0.0654	**Mt**
Eumomota superciliosa	Resident	Om	0.0879	**Mt, Tfr**
Megaceryle alcyon	Winter visitor	Ca	0.0085	**Td** (Gc), **Cbm**
Chloroceryle americana	Resident	Ca	0.0084	**Td** (Gc), **Cbm**
Melanerpes pygmaeus	Resident	I	0.0879	**Mt, Tfr**
Melanerpes aurifrons	Resident	I	0.6321	**Mt, Tfr, Td** (Rh), **Ca** (Us)
Picoides scalaris	Resident	I	0.6004	**Tfr, Td** (Rh), **Ca** (Us)
Campephilus guatemalensis	Resident	I	0.0081	**Mt, Tfr**
Herpetotheres cachinans	Resident	Ca	0.0879	**Tfr, Ca** (Cp)
Falco sparverius	Winter visitor	Ca	0.0701	**Tfr, Ca** (Cp)
Falco columbarius	Winter visitor	Ca	0.0556	**Mt, Tfr, Td** (Gc), **Ca** (Cp)
Eupsittula nana	Resident	Fr	0.7540	**Mt, Tfr, Td** (Rh), **Ca** (Cp, Us)
Amazona xantholora	Resident	Fr	0.6412	**Mt**
Sittasomus griseicapillus	Resident	I	0.0683	**Mt**
Xiphorhynchus flavigaster	Resident	I	0.0023	**Mt**
Synallaxis erythrothorax	Resident	I	0.0023	**Mt**
Camptostoma imberbe	Resident	I	0.0023	**Mt, Tfr**
Myiopagis viridicata	Resident	I	0.0245	**Mt, Tfr**
Elaenia flavogaster	Resident	I	0.0023	**Mt, Tfr**
Oncostoma cinereigulare	Resident	I	0.0245	**Mt**
Todirostrum cinereum	Resident	I	0.0023	**Mt**
Rhynchocyclus brevirostris	Resident	I	0.0023	**Mt**
Contopus virens	Transient	I	0.0245	**Mt, Tfr**
Contopus cinereus	Resident	I	0.0335	**Mt, Tfr, Td** (Rh), **Ca** (Cp)
Attila spadiceus	Resident	I	0.0335	**Mt, Tfr**
Myiarchus yucatanensis	Resident	I	0.0335	**Tfr**
Myiarchus tuberculifer	Resident	I	0.0278	**Mt, Tfr, Td** (Rh), **Ca** (Cp, Us)
Myiarchus tyrannulus	Resident	I	0.1150	**Mt, Tfr, Td** (Rh), **Ca** (Cp, Us)
Pitangus sulphuratus	Resident	Om	0.2369	**Mt, Tfr, Td** (Rh, Gc), **Ca** (Us)
Myiozetetes similis	Resident	I	0.4481	**Mt, Tfr, Td** (Rh), **Ca** (Us)
Myiodynastes luteiventris	Resident	I	0.1150	**Mt, Tfr**

Species	Migratory status	Feeding habits*	PAI	Habitat use preferences**
Tyrannus melancholicus	Resident	I	0.2369	**Tfr, Td** (Gc, Rh), **Ca** (Cp, Us)
Tyrannus couchii	Resident	I	0.2369	**Mt, Tfr, Td** (Gc), **Ca** (Cp)
Tyrannus tyrannus	Transient	I	0.1150	**Mt, Tfr, Td** (Rh), **Ca** (Cp)
Tityra semifasciata	Resident	Fr, I	0.2369	**Mt, Tfr**
Pachyramphus aglaiae	Resident	I	0.1123	**Mt, Tfr**
Vireo pallens	Resident	I	0.2369	**Mt**
Vireo philadelphicus	Winter visitor	I	0.2369	**Mt, Tfr**
Vireo magister	Resident	I	0.1123	**Mt**
Psilorhinus morio	Resident	Om	1.0523	**Mt, Tfr, Td** (Rh), **Ca**(Cp)
Cyanocorax yucatanicus	Resident	Om	1.1238	**Mt, Tfr, Td** (Rh)
Stelgidopteryx serripennis	Winter visitor	I	1.0523	**Mt, Tfr, Td** (Gc, Rh), **Ca** (Cp, Us)
Riparia riparia	Transient	I	1.0035	**Td** (Gc), **Cbm**
Petrochelidon fulva	Resident	I	1.0523	**Td** (Gc), **Cbm, Ca** (Cp)
Hirundo rustica	Transient	I	1.0035	**Td** (Rh, Gc), **Ca** (Cp, Us)
Thryothorus maculipectus	Resident	I	0.1123	**Mt, Tfr**
Thryothorus ludovicianus	Resident	I	0.1122	**Mt, Tfr**
Uropsila leucogastra	Resident	I	0.2369	**Mt, Tfr**
Polioptila caerulea	Resident	I	0.2035	**Mt, Tfr, Td** (Rh), **Ca** (Us)
Catharus ustulatus	Transient	I	0.1122	**Mt, Tfr**
Turdus grayi	Resident	Om	0.2369	**Mt, Tfr, Td** (Rh)
Hylocichla mustelina	Winter visitor	I	0.1122	**Mt, Tfr**
Dumetella carolinensis	Resident	I	0.2369	**Mt, Tfr**
Melanoptila glabirostris	Resident	I	0.1123	**Mt, Tfr**
Mimus gilvus	Resident	Fr, I	0.2369	**Mt, Tfr, Td** (Rh), **Ca** (Us)
Arremonops rufivirgatus	Resident	Gr	0.1123	**Mt, Tfr**
Euphonia hirundinacea	Resident	Fr	0.2369	**Mt**
Dives dives	Resident	Om	0.9856	**Mt, Tfr, Td** (Gc, Rh), **Ca** (Us)
Quiscalus mexicanus	Resident	Om	3.4522	**Td** (Gc, Rh), **Ca** (Us)
Molothrus aeneus	Resident	Gr	0.9856	**Td** (Gc, Rh), **Ca** (Us)
Icterus prosthemelas	Resident	I	0.2369	**Mt, Tfr**
Icterus cucullatus	Resident	Om	0.2568	**Mt, Tfr, Td** (Rh)
Icterus chrysater	Resident	I	0.1148	**Mt, Tfr**
Icterus auratus	Resident	I	0.1148	**Mt, Tfr**
Icterus galbula	Winter visitor	Om	0.1148	**Tfr, Td** (Rh)
Seiurus aurocapilla	Winter visitor	I	0.1123	**Mt, Tfr**
Helmitheros vermivorum	Winter visitor	I	0.1123	**Mt, Tfr**
Parkesia noveboracensis	Winter visitor	I	1.0035	**Mt, Tfr**
Mniotilta varia	Winter visitor	I	0.1123	**Mt, Tfr, Td** (Rh)
Protonotaria citrea	Transient	I	0.0041	**Mt, Tfr**
Oreothlypis peregrina	Transient	I	0.0041	**Mt, Tfr**
Oreothlypis ruficapilla	Winter visitor	I	0.1148	**Mt, Tfr, Td** (Rh)
Geothlypis poliocephala	Resident	I	0.0245	**Mt, Tfr**
Geothlypis trichas	Winter visitor	I	0.0041	**Tfr**
Setophaga citrina	Winter visitor	I	0.0041	**Mt, Tfr**
Setophaga ruticilla	Winter visitor	I	0.0041	**Mt, Tfr**
Setophaga americana	Winter visitor	I	0.0041	**Mt, Tfr**
Setophaga magnolia	Winter visitor	I	0.1123	**Mt, Tfr**
Setophaga petechia	Winter visitor	I	0.1148	**Mt, Tfr, Td** (Rh)
Setophaga caerulescens	Winter visitor	I	0.0041	**Mt, Tfr**

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Species	Migratory status	Feeding habits*	PAI	Habitat use preferences**
Setophaga virens	Winter visitor	I	0.0041	**Mt, Tfr**
Cardellina canadensis	Winter visitor	I	0.0041	**Mt, Tfr**
Cardellina pusilla	Winter visitor	I	0.0245	**Tfr, Td** (Rh), **Ca** (Us)
Icteria virens	Winter visitor	I	0.0041	**Mt, Tfr, Td** (Rh)
Thraupis abbas	Resident	Fr, I	0.1148	**Mt, Tfr**
Piranga roseogularis	Resident	I	0.2035	**Mt**
Piranga rubra	Winter visitor	I	0.2369	**Mt, Tfr**
Cardinalis cardinalis	Resident	Gr	0.1148	**Tfr**
Pheucticus ludovicianus	Winter visitor	I, Gr	0.2035	**Mt, Tfr, Td** (Rh)
Cyanocompsa parellina	Resident	Gr	0.2369	**Mt, Tfr, Td** (Rh)
Passerina caerulea	Winter visitor	Gr	0.2568	**Tfr, Td** (Rh), **Ca** (Us, Cp)
Passerina cyanea	Winter visitor	Gr	0.1148	**Tfr, Ca** (Cp)
Volatinia jacarina	Resident	Gr	0.1123	**Tfr, Ca** (Cp)
Cyanerpes cyaneus	Resident	Ne	0.1123	**Mt, Tfr**
Sporophila torqueola	Resident	Gr	0.1148	**Tfr, Ca** (Cp)
Saltator atriceps	Resident	Gr	0.2035	**Mt, Tfr**
Saltator coerulescens	Resident	Gr	0.2369	**Mt, Tfr**

* Feeding habits: Omnivores (Om); Nectarivores (Ne); Carnivores (Ca); Frugivores (Fr); Granivores (Gr); Invertebrates (I, included aquatic invertebrates, bark insectivores aerial insectivores, trunk insectivores, generalist insectivores, ground insectivores, and leaf insectivores.

** Habitat use preferences: Mature tropical forest (**Mt**); Tropical forest remnants (**Tfr**), Modified environments by tourism developments (**Td**): Golf course and artificial water bodies in golf course (Gc), Hotel and residential zones with native and introduced vegetation (Rh); Modified environments by urban development, crops and livestock (**Ca**): Urban zone with native and introduced vegetation (Us), Cattle pastures and agricultural fields (Cp); and, Coast dunes, beach and mangrove zones (**Cbm**).