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Relationships Between Bird Species Richness and Natural and Modified Habitat in Southern Mexico

Jorge E. Ramírez-Albores[1,2] and Adolfo G. Navarro-Sigüenza[2]
[1]El Colegio de la Frontera Sur (ECOSUR). San Cristóbal de las Casas, Chiapas
[2]Museo de Zoología "Alfonso L. Herrera", Facultad de Ciencias, Universidad Nacional Autónoma de México
México

1. Introduction

Principles implicitly addressed in most landscape level investigations of bird communities focus mainly on the arrangement of habitat patches, corridors, and matrix elements within landscapes; and patch area and isolation effects on dispersal, colonization, and local extinction (Forman, 1995). Ecologists are increasingly examining ecological patterns and processes at a scale that makes easier to understand the distribution and abundance of organisms contained within the habitat patches that compose the landscape (Forman & Gordon, 1986, Flather & Sauer, 1996, Bolger et al., 1997). Species interactions may vary for species within patches that adjoin different patch types (i.e., edge effects; Paton, 1994); for species in habitat patches of similar composition, but of differing patch sizes or distributions (i.e., habitat fragmentation effects; Robinson et al., 1995); for species requiring source-sink dynamics among patches in a landscape (i.e., metapopulations; Pulliam, 1988); and for species in habitat patches of similar composition but located within different landscape matrices (Renjifo, 1999).
Many studies of the effects of forest fragmentation on bird communities have been conducted in fragments surrounded by agricultural lands, and principles of island biogeography theory (MacArthur & Wilson, 1967) are usually invoked to explain patterns of species richness (Opdam, 1991). Birds are important model organisms for such studies because their taxonomy and distribution are well known, and because inventory and census methods are well developed (Ralph et al., 1995). However, in other situations, the surrounding habitat is not totally unsuitable for birds, and its characteristic determine how island-like the fragment will be (Hinsley et al., 1995, Stouffer & Bierregaard, 1995). In such cases, habitat fragmentation creates a mosaic of habitat patches of different quality, with forest fragments providing high quality habitat, and the matrix providing lower quality habitat (Wiens, 1994). For example, in North America, forest fragmentation has had an array of effects on neotropical migratory birds through habitat loss, small forest-patch size, reduced proximity of patches, more edge effect, and negative interactions with species surrounding nonforest patches (Faaborg et al., 1995, Freemark et al., 1995, McGarigal & McComb, 1995, Robinson et al., 1995).

The distribution and diversity of bird communities in the tropical forests of Mexico and Central America have certainly been affected by a high degree of deforestation and therefore habitat fragmentation, but little quantitative or comparative data exist (Stiles, 1983, Flores-Villela & Geréz, 1994, Ceballos, 1995, Challenger, 1998). Some studies have identified landscape and habitat structural characteristics associated with the distribution of bird species richness in forest fragments that may be used to predict patterns of species richness in tropical deciduous forest patches (Gillespie & Walter, 2001), because different bird communities occur in response to changes in vegetation structure and species composition following logging (Morrison, 1992, Aleixo & Vielliard, 1995).

The Central Depression of Chiapas, located in southeastern Mexico, is an important area for conservation because highlights key characteristics of Middle American tropical deciduous forests: high level of endemism and the convergence of two biogeographically important migratory routes (the Gulf and the Pacific ones), thus, contains species that have migrated to the dry forest through each of these corridors. Also, there is a high turnover rate (beta diversity) between areas of tropical deciduous forest, which is also important for species conservation (Janzen, 1988, Escalante et al., 1993, Stattersfield et al., 1998). The area has also global importance for avian endemism (Stattersfield et al., 1998), and as a well-defined ecoregion (NT0211; Olson & Dinerstein, 1998, Myers et al., 2000), a Terrestrial Priority Site (Arriaga et al., 2000), an important bird area (IBAS; Arizmendi & Márquez, 2000), and the presence of some Natural Protected Areas including National Parks and Biosphere Reserve (i.e., Sumidero Canyon, El Zapotal; CONANP, 2011).

The understanding of the relationships and factors that influence bird community structure provides valuable information on the impact of habitat disturbance on populations, which is important for the conservation of these species. The goal of this contribution was to investigate differences in the species richness and composition of the bird communities in a mosaic natural and modified habitat and to evaluate how forest habitats perform to preserve species in the Central Depression of Chiapas. The results will be used to inform about appropriate strategies for the conservation of both the remnants of the original forest and the habitats created by humans with the species that inhabit them.

2. Material and methods

2.1 Study area

The study area is located among the Municipalities of San Fernando, Tuxtla Gutiérrez, Chiapa de Corzo, Osumacinta and Chicoasén in the Central Depression region in Chiapas, southern Mexico (Table 1, Fig. 1). The climate is warm sub-humid with rainy summer (June to October), being May the hottest month, to moderate sub-humid in altitudes above the 1000 m (FORTAM, 1984, García, 1996). Mean annual temperature is 18-24 °C and mean annual precipitation varies between 500-2500 mm (FORTAM, 1984, INEGI, 2004, 2006). Annual precipitation shows a marked seasonality. The rainy season begins in mid-May, causing a surge of foliage and regrowth in natural vegetation areas as well as in crops and pasture grasses. This period normally lasts until the end of September. The dry season begins in December, lasting until May. The area includes a complex mixture of tropical habitats that have been classified on the basis of the physiognomic characteristics of the vegetation (Rzedowski, 1988, Reyes-García & Souza, 1997) and on the basis of land management. The natural and semi-natural habitats include tropical deciduous forest, tropical semideciduous forest, tropical oak forest, riparian forest, secondary forest, abandoned tropical forest with distinct successional stages (secondary forest), and agriculture fields, living fences, cattle pasture, shaded coffee plantations, urban and suburban areas (Miranda, 1975, FORTAM, 1984, Reyes-García & Souza, 1997). Common tree species in study area included *Pistacia mexicana*, *Cochlospermum vitifolium*, *Ceiba* sp, *Bursera bippinata, B. simaruba*, *Zuelania guidonia*, *Gyrocarpus* sp, *Acacia cornigera, A. pennatula*, *Haematoxylum* sp, *Lysiloma* sp, *Alvaradoa amorphoides*, *Swietenia humilis*, *Ficus* sp, *Fraxinus purpusii*, *Sideroxylon celastrinum* and *Heliocarpus reticulatus* (Miranda, 1975, Reyes-García & Souza, 1997).

Study sites	Municipality	Geographical coordinates	Elevation (m)	Habitats types
1	Chicoasén	16°57´N, 93°08´W	819	Tdf, Sf, C, Af, Lf
2		16°58´N, 93°10´W	1056	Tdf, Tsf, Sf, Rf, C, Af, Lf
3	Osumacinta	16°56´N, 93°05´W	583	Tdf, Sf, C, Af, Lf
4		16°55´N, 93°04´W	855	Tdf, Sf, C, Af, Lf
5		16°53´N, 93°07´W	630	Tdf, Tsf, Sf, Rf
6	San Fernando	16°54´N, 93°09´W	1068	Tdf, Tsf, Sf, Af
7		16°52´N, 93°11´W	968	Tdf, Sf, C, Af, Lf
8		16°50´N, 93°13´W	1085	Tdf, Sf, C, Af, Lf, Ur
9		16°50´N, 93°12´W	970	Tdf, Sf, C, Af, Lf
10		16°51´N, 93°12´W	862	Tdf, Sf, C, Af, Lf, Ur
11		16°48´N, 93°10´W	835	Tdf, Tsf, Sf, To, Rf, C, Af, Lf
12		16°49´N, 93°11´W	868	Tdf, Sf, To, C, Af, Lf
13		16°49´N, 93°09´W	890	Tdf, Sf, C, Af, Lf
14		16°49´N, 93°12´W	1050	Tdf, Sf, C, Af, Lf
15		16°50´N, 93°11´W	875	C, Af, Lf, Ur
16		16°48´N, 93°11´W	883	Tdf, Sf, C
17		16°47´N, 93°10´W	710	Tdf, Sf, C
18		16°54´N, 93°10´W	995	Tdf, Tsf, Sf, Rf
19	Tuxtla Gutiérrez	16°45´N, 93°06´W	535	Sf, Ur
20		16°45´N, 93°08´W	550	Ur
21		16°45´N, 93°05´W	508	Sf, Ur
22		16°47´N, 93°05´W	845	Tdf, Sf, C, Af, Lf
23	Chiapa de Corzo	16°42´N, 93°01´W	395	Sf, Rf, C, Af, Lf
24		16°41´N, 92°59´W	412	Sf, Rf, C, Af, Lf, Ur

Table 1. Characteristics of study sites in Chiapas Central Depression. Habitat types: Tdf (tropical deciduous forest), C (Cattle pastures), Lf (living fences), Rf (gallery forest), Tsf (Tropical semideciduous forest), Sf (secondary forest), Af (Agricultural fields), To (Tropical oak forest), Ur (Urban and suburban areas).

2.2 Bird data

Base data were collected in the field from February 2003 to November 2004 by sampling by point counts (Hutto et al., 1986, Ralph et al., 1995) that were used to asses species richness and abundance in each habitat. The number of point counts per habitat (4-8 points) was proportional to depended on the extent of different habitat types (between major coverage of the habitat sampled highest number of points). At each count station, the number of individuals of each species detected by sight and sound were recorded during a 5 min count period. Each count lasted for 5 minutes with a 5-minute interval between points. Birds detected at ≥ 100 m were recorded but not used in analyses to reduce the possibility of counting the same individual twice in consecutive points. Birds detected when not conducting counts were also recorded and used to calculate total species richness. No counts were conducted on days when visibility was poor, or under windy or rainy conditions. Counts were conducted between 0700 and 1100 in the morning, and 1600 and 1900 in the afternoon (i.e., during the highest bird activity). No survey was conducted during unfavorable weather conditions (rainy, windy and mist days) because birds were less detectable under those conditions (O'Connor & Hicks, 1980, Robbins, 1981).

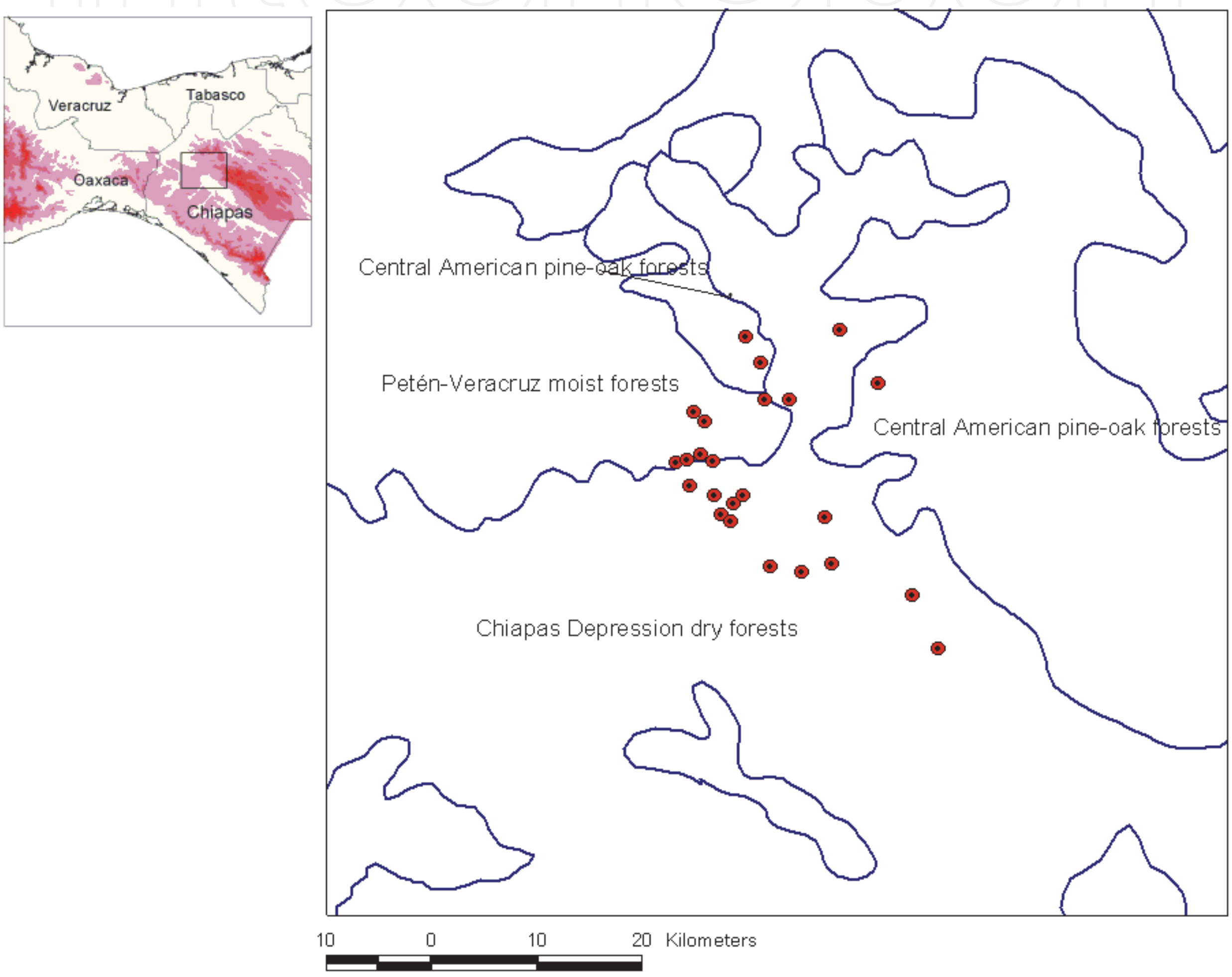

Fig. 1. Map of Tehuantepec Isthmus region in southern Mexico, the quadrangle depicts study region (a). Underlying map is average elevation (http://www.conabio.gob.mx). Study sites (dots) in the Central Depression of Chiapas, Mexico (b). Labels correspond to Ecoregions of World Wildlife Fund (http://www.wwf.org).

Bird species richness was calculated as the total number of species recorded in each habitat. Two estimates of relative abundance (including both visual and aural detections of both sexes) for each species were obtained for each habitat: the average number of individuals per point count, and frequency of occurrence during monthly samples. These two measurements of relative abundance assume that birds are recorded more often in areas where they are more abundant (Renjifo, 2001). The average number of individuals per point count was based on all point counts conducted within a study habitat, and frequency of occurrence was based on presence or absence over all monthly samples. Relative abundances of neotropical or neartic migrants were based upon samples during months when they were present in the study area: January-April and October-January (i.e., winter visitors, summer residents). Each species was classified by a habitat guild (forest interior, generalist, and forest edge). We calculated species richness (We referred to total species richness as the total number of species per habitat) and abundance (bird abundance was obtained as the mean number of individuals detected in the total points counts per habitat) at each study site for forest interior species, generalist species, and forest edge species. Habitat guild classification was based Ehrlich et al. (1988) and also supported by other studies in fragmented forest (Brooks & Croonquist, 1990, Murcia, 1995, McIntyre, 1995, Rodewald & Yahner, 2001). Bird species were categorized into seven broad diet categories (carnivore, insectivore, nectarivore, frugivore, granivore, omnivore and aquatic) based upon primary components of the diet or subdiet obtained directly from field information and with supplemental information from literature (*i.e.*, Ortiz-Pulido et al., 1995, Arizmendi et al., 1990, Ramírez-Albores, 2010).

2.3 Analysis

We used aerial photographs (scale 1:75,000; INEGI, 2001) to map land-use types of study sites and we performed direct surveys throughout the area for confirmation of site suitability. Sampling intensity was stratified among different sites based on the extent and cover proportions of different habitat on the INEGI image. Each sites was surveyed an equal number of times (sites were visited one time each month). At each site, at least 90-100% of the nonforest cover within 1 km of the study site consisted of only one disturbance type (primarily agricultural fields, cattle pastures and urbanization). We determined forest cover from classified thematic mapped imagery using ARC/INFO geographic information system software (ESRI, 1999). We calculated species richness by habitat guild: forest specialist, generalist, and early successional species, at each study site. Species richness was analyzed separately by a multiple regression analysis to assess if there was any differential response to forest disturbance characteristics, based on the species level of dependence on arboreal cover proportion. Stepwise regression analysis was performed on log-transformed total number of species, and on resident and migrant species. Bird abundance data were log (e) x + 1 transformed previous to the analyses to reduce the skewness of the data, resulting in a more interpretable analysis. An *F*-test probability value of 0.05 and 0.001 was used in all cases. Differences in species richness and guild structure of bird communities, represented as the species richness in different foraging guilds, were compared among habitat types using one-way analysis of variance (ANOVA). Tukey´s multiple range test was used for post-hoc comparisons among habitat types (Zar, 1999). The Similarity of species composition between habitats types was measured using Sorenson´s similarity index ($IS=2S/N_1+N_2$, where S is the number of common species, N_1 is the number of species of habitat 1, and N_2 is the number of species of habitat 2; Ravinovich, 1981). To improve the knowledge of the geographic distribution of each individual species we used a set of maps of all species of landbirds of Mexico (Navarro-Sigüenza & Peterson, 2007) constructed by ecological niche modeling (Nix, 1986, Peterson, 2001). Maps depict the potential distributions of the species using the Genetic Algorithm for Rule-set Production (GARP; Stockwell & Noble, 1992), in its PC implementation DesktopGARP (Scachetti-Pereira, 2003), using as primary source the data points contained in the Atlas of the Birds of Mexico data base (Navarro-Sigüenza et al., 2003). For generating the models a set of 19 climatic variables, derived from temperature and precipitation (Hijmans et al., 2005; http://www.worldclim.org), and three topographic (Hydro1k project; http://eros.usgs.gov) was used. Individual summaries of distributions of species were summed to produce species richness maps for total species, summer resident species, winter resident species (Navarro-Sigüenza & Peterson, 2007). From the GARP maps, we derived predicted numbers of resident and migrant species using ArcView (version 3.2; ESRI, 1999). We also compared species richness values for each grid cell (resolution 0.05°) with GIS data layers summarizing Terrestrial Prioritary Regions (Arriaga et al., 2000, CONABIO, 2004) to assess whether areas recognized as priority under diverse criteria coincide with areas of greatest species richness. All statistical analyses were permormed using STATISTICA® 10 and SPSS® 19.5.

3. Results

3.1 Bird species composition

A total of 279 species of 45 families was recorded from the 24 sites (Appendix 1). Of these, 193 were permanent residents and 86 were migrant species (including one occasional, two summer residents, 18 transients and 65 winter visitors). In general, the average bird richness during the study period was of 131 species/month; however, the monthly bird species richness ranged from 100 to 161 (Fig. 2). The fewest species were found in May and the most in March, April, December and January (Fig. 2). The composition of the bird community associated with percentage of disturbance in the study sites, according to habitat preferences, corresponding to 30.2% (N = 84) for forest specialists, 10.4% (N = 29) of early successional species and 39.5% (N= 110) forest generalists (Fig. 3). The distribution of each category in the sites showed greater richness of specialists and forest generalists. Forest specialist species richness ($F_{1,22}$= 5.98, r= 0.46, P= 0.02) and generalist ($F_{1,22}$= 17.53, r= 0.66, P= 0.0003) were negatively associated with percentage of disturbance (Fig. 3). Early succesional species richness ($F_{1,22}$= 4.21, r= 0.40, P= 0.05) was slightly related to disturbance within study sites. Diet or subdiet composition of bird communities in the study sites was: 82 were insectivores, 72 insectivores/frugivores, 39 carnivores, 20 granivores/fruigivores, 14 nectarivores and 13 granivores (Appendix 1).

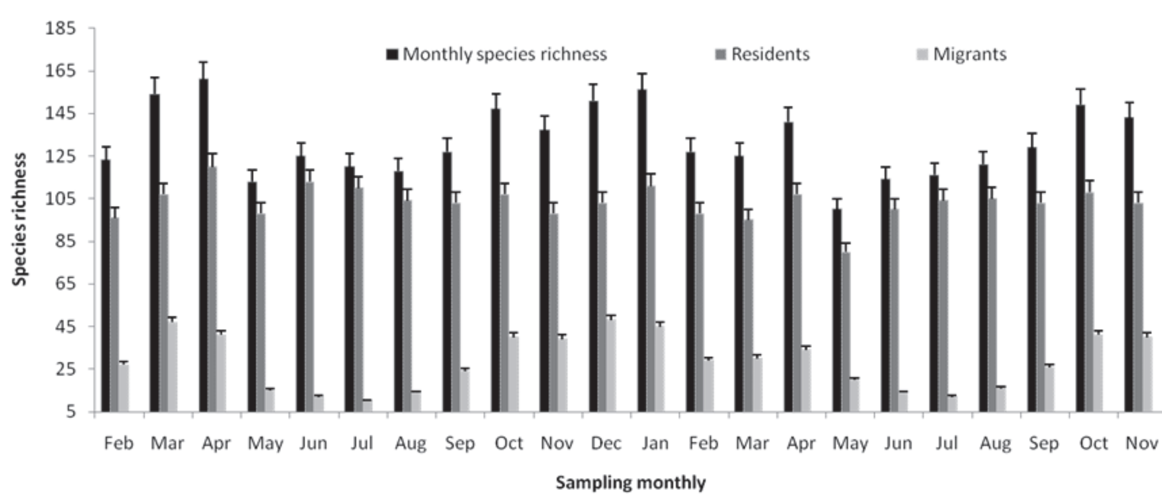

Fig. 2. Monthly species richness during study period. Mean and standard error for data pooled over visit and point count shown (errors bars represent 95% confidence intervals).

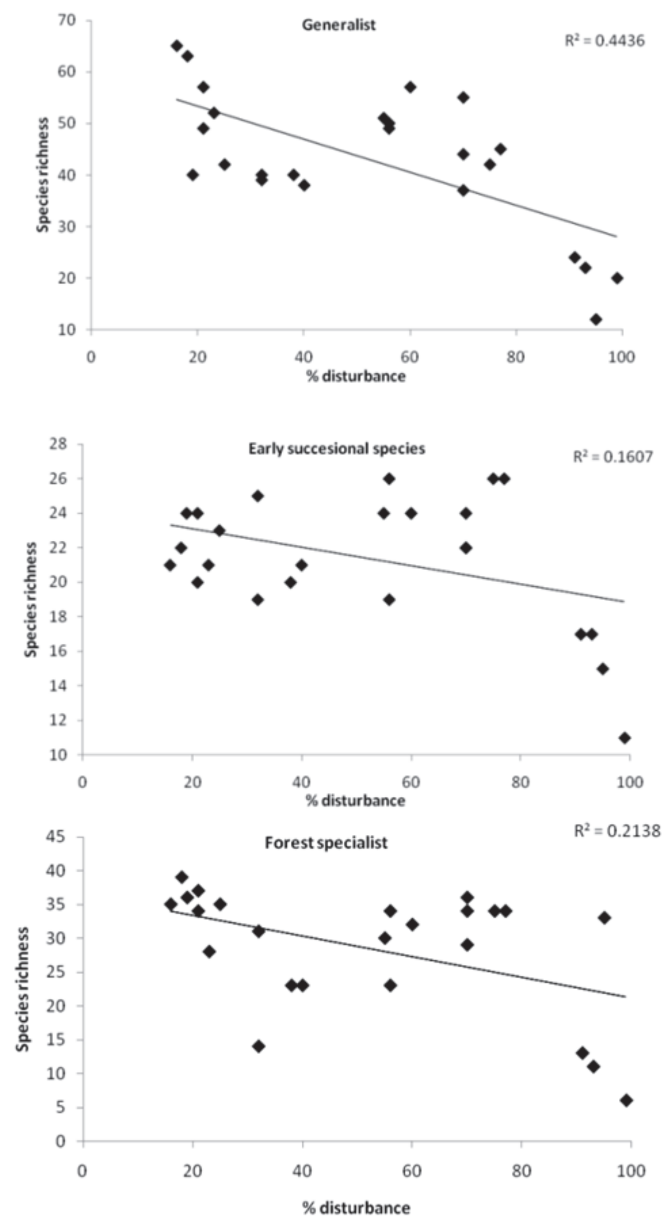

Fig. 3. The relationships between the extent disturbance (%) and bird species richness at the study sites.

3.2 Comparison among habitat types

Tropical deciduous forest (203) had the highest number of species, whereas tropical oak forest (51) and aquatic and semiaquatic habitats (24) had the fewest species (Fig. 4). Of the total bird species recorded (278), 20 were exclusively found in tropical deciduous forest, four of tropical semideciduous forest, two of urban/suburban areas and one of cattle pastures (Appendix 1). To analyzed comparative the habitat types with bird species richness and mean abundance, and we found significant differences ($F_{8,125} = 70.6$, $P < 0.0001$, $F_{8,125} = 106.2$, $P < 0.0001$, respectively). As migration status in the different habitat types, also significant differences between residents species ($F_{8,125} = 79.1$, $P < 0.0001$) and migratory species ($F_{8,125} = 45.3$, $P < 0.0001$).

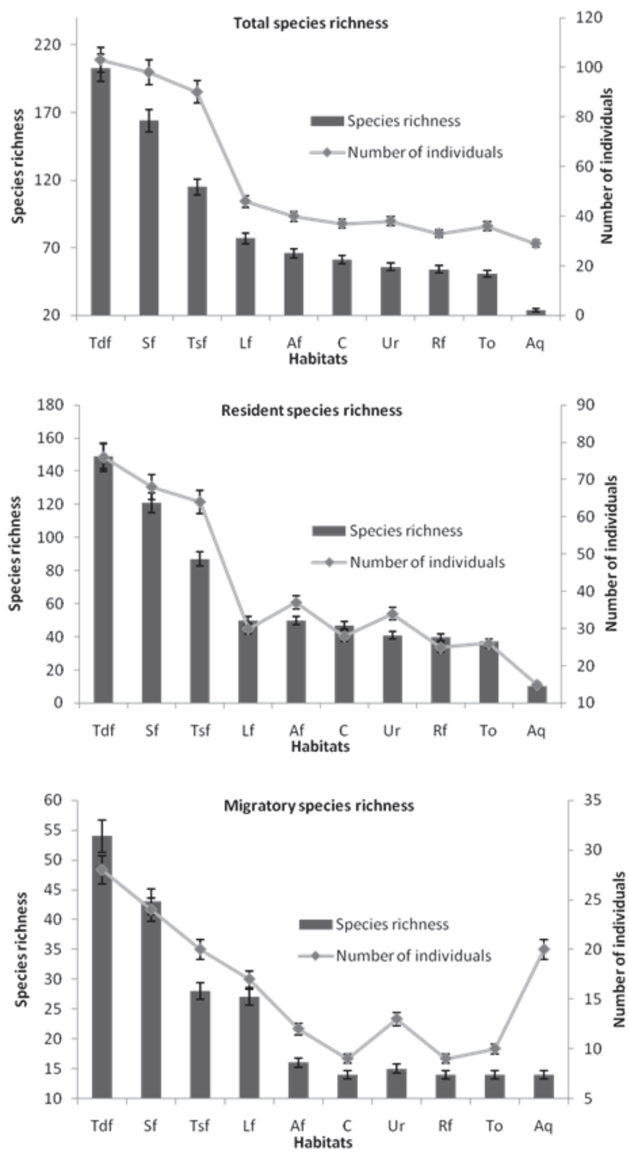

Fig. 4. Species richness of birds in different habitat types at the study sites. Mean and standard error for data pooled over visit and point count shown (errors bars represent 95% confidence intervals). Habitat types: Tdf (tropical deciduous forest), C (cattle pastures), Lf (live fences), Rf (gallery forest), Tsf (tropical semideciduous forest), Sf (secondary forest), Af (agricultural fields), To (tropical oak forest), Ur (urban and suburban areas) and Aq (aquatics and subaquatics).

Carnivores bird species were better represented in the tropical deciduous forest (17), agricultural fields (18) and pastures (17; Fig. 5), while the lowest numbers occurred in the tropical oak forest (5) and urban/suburban zones (4) and there were no species in living fences ($F_{8,125}$ =53.9, P<0.0001). Insectivores-frugivores species were more abundant in the tropical deciduous forest (64) than in agricultural fields (3) and pastures (6; $F_{8,125}$ =35.4, P<0.0001). The lowest number was recorded in living fences and pastures with one species each, presenting significant differences between habitats ($F_{8,125}$ =47.2, P<0.0001). Tropical deciduous forest (70) had a greater number of insectivores species than gallery forest (10; $F_{8,125}$ =80.1, P<0.0001). Tropical deciduous forest had the highest number of nectarivores (14), compared to the tropical oak forest, cattle pastures and agricultural fields where there were no records of these species, the differences between habitats ($F_{8,125}$ =38.0, P<0.0001).

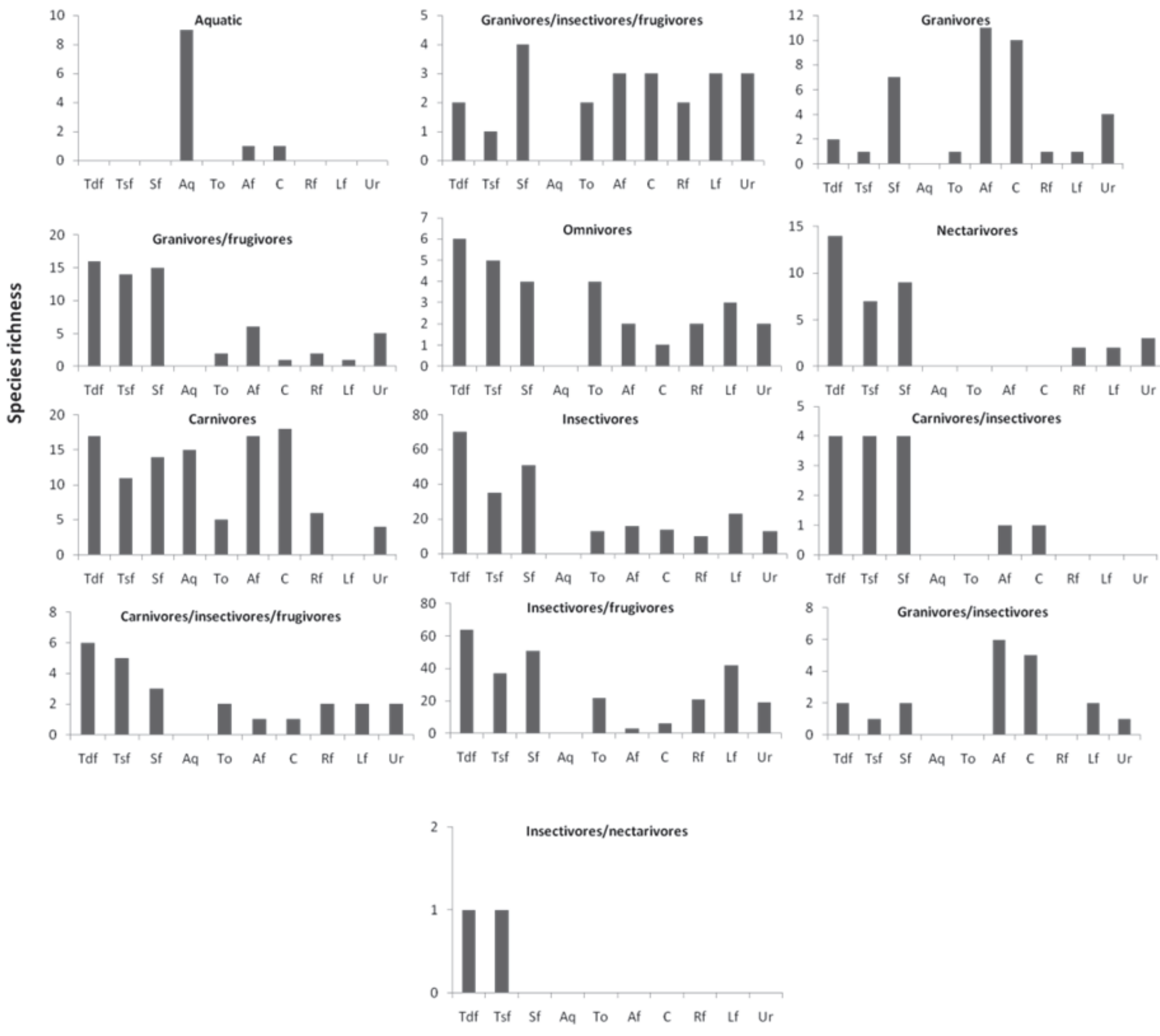

Fig. 5. Diet or subdiet composition of bird communities in different habitat types of study area. Habitat types: tropical deciduous forest), C (cattle pastures), Lf (living fences), Rf (gallery forest), Tsf (tropical semideciduous forest), Sf (secondary forest), Af (agricultural fields), To (tropical oak forest), Ur (urban and suburban areas) and Aq (aquatics and subaquatics). Diet categories: I (insectivore), C (carnivore), O (omnivore), N (nectarivore), A (aquatic), G (granivore), F (frugivore).

Similarity of species composition between habitat types indicates that the highest values were among cattle pastures and agricultural fields (0.81), followed by tropical deciduous forest and secondary forest (0.75) (Table 2). The fewest values were among gallery forest and cattle pastures (0.15), gallery forest and agricultural fields (0.19), and tropical semideciduous forest and cattle pastures (0.19; Table 2).

	Tropical semideciduous forest	Tropical oak forest	Secondary forest	Gallery forest	Cattle pastures	Agricultural fields	Living fences	Urban/suburban areas
Tropical deciduous forest	0.69	0.33	0.75	0.32	0.22	0.23	0.46	0.34
Tropical semideciduous forest		0.44	0.61	0.36	0.19	0.24	0.35	0.39
Tropical oak forest			0.42	0.57	0.34	0.26	0.51	0.46
Secondary forest				0.34	0.31	0.36	0.54	0.40
Gallery forest					0.19	0.15	0.53	0.49
Cattle pastures						0.81	0.24	0.37
Agricultural fields							0.22	0.32
Living fences								0.45

Table 2. Matrix similarity of bird species, based on Sorenson´s Index, among habitat types surveyed in Chiapas Central Depression.

3.3 General patterns of bird diversity

Species per 1 km² cell in the map of the region (Fig. 6) can do a high geographic consistency of the patterns. The richest areas of the study area form a strip that runs in an east-west from the eastern part of the Petén-Veracruz moist forest, following to northern part of the Chiapas Depression dry forest, and continues the Central America pine-oak forest. The richest cells within this region are precisely in the northern part of Chiapas Depression. Two cells differ with high values of richness, which are north of the Central Depression of Chiapas. We can say that there is a continuous strip of high species richness throughout the study area in east-west. In this sense, are evident two regions: the northern part of the Central Depression of Chiapas, and Gulf Coastal Plain. In fact, this latter may represent a decrease in species richness west-east (Fig. 6). The figure 6 helped to identify the species richness of areas of greatest concentration of diversity; the southern region presented the lowest concentration with a maximum of 62 species. The prediction map of migratory species richness shows the greatest number of species concentration mainly in the southern and northeastern. Most species are concentrated in the dry and moist forest, which is apparently a different distribution pattern observed in the Central America pine-oak forest.

4. Discussion

Of a total of 656 bird species occurring in Chiapas according to Álvarez del Toro (1980) and Palomera-García et al. (1994), the species recorded in the study area (Central Depression of Chiapas) corresponds to 42% (279 species; Appendix 1). This high richness is a result of a complex array of habitats, convergence of two important migratory routes (of the Gulf and Pacific), as well as biogeographic (biotic provinces) and physiographic heterogeneity (Arriaga et al., 2000). Bird species richness found in study sites is similar to that in other tropical forest regions in Mexico, such as La Mancha on the coast of Veracruz (250 species; Ortiz-Pulido et al., 1995) and Chamela in Jalisco (270 species; Arizmendi et al., 1990). The study sites showing greater species richness (especially in tropical deciduous forest) are

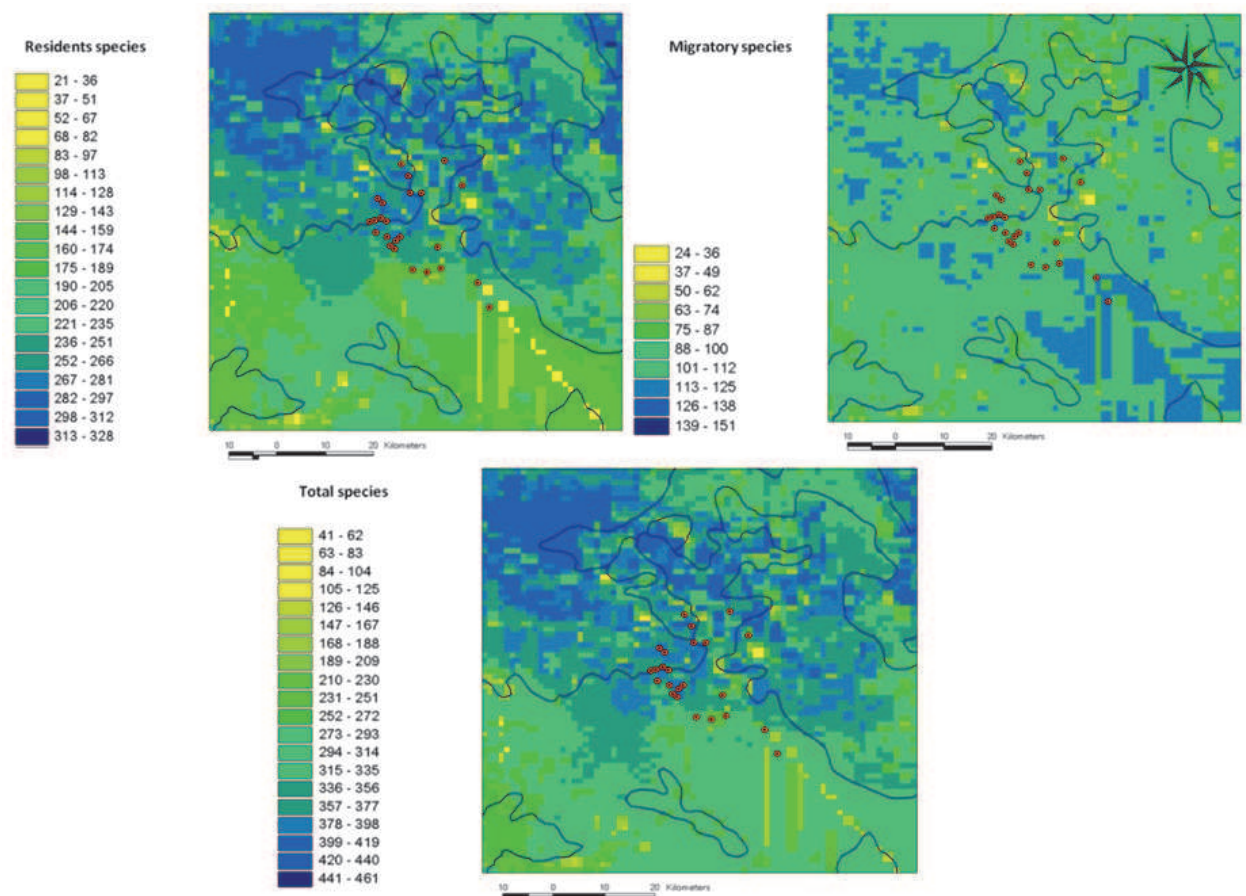

Fig. 6. Maps representing of modeled species richness in the study sites at the Central Depression of Chiapas.

different in forest cover but diverse in habitat types associated with tropical forest are areas that contained continuous secondary forest, the same pattern found in forest fragments in southern Brazil (Anjos, 2001).

The 195 species (70%) were considered residents; as the number of resident species may be higher due to birds with less conspicuous behavior in certain periods of the year and/or difficulty in detecting those (Krügel & Anjos, 2000). Karr et al. (1982) mentioned that in some tropical environments the migratory species are capable of producing changes in the composition of bird communities. In this study migratory species (30%) played a minor role in the observed changes in the bird community. According to Arizmendi et al. (1990) and Moya-Moreno (1990), it is possible that in the study area altitudinal and latitudinal movements are correlated with fluctuations in the abundance of species. For example, some rare species are clearly features temperate environments whose populations are dispersed to other locations during times of scarcity of resources, or are migratory in passing that occur in small amounts within Chiapas. However, these seasonal changes in abundance, possibly also associated with seasonal phenology of the deciduous forest were not assessed, so that needed to be discussed in detail later.

Species richness was greater in April, October, and December, surely due to the presence of migratory species and to the beginning of reproductive activity, which make birds more detectable. On the other hand, a lower richness was found in May and August, a period in which migratory species were absent and birds were quiet, making them difficult to detect.

Seasonal variation of the avifauna in the present study was similar to that found in other tropical forest regions (Chamela region in Jalisco, Mexico and Maringá in Paraná, Brazil; Ornelas et al., 1993, Krügel & Anjos, 2000, respectively) where the species richness was greater from October to November. Our results show that species composition did not differ significantly across the 24 study sites, and similarities of different levels among the sites were common. This could suggest that most tropical forest patches still have suitable habitats that ensure availability of food, nesting sites, and protective cover for the species but are still vulnerable to persistent encroachment evident around them. In the long term this could jeopardize the ability to sustain particular bird species, especially forest-dependent bird, threatened and endemic.

A considerable amount of species associated with secondary forest, open areas, clearings and forest edges remain abundant and are likely to increase in regions with small isolated forest fragments (Bierregaard & Lovejoy, 1989, Thiollay, 1992). Generalist birds, which change their diet from fruit to insects or vice-versa, are also favored in small patches (Willis, 1979). Mota (1990) found increasing, devastation of pristine areas. Although some general tendencies were observed for certain bird groups, the effects of forest fragmentation are certainly different for each species. A study in forest fragments (in Maryland) suggested that the impacts of forest fragmentation on bird communities are complex, species specific and not related only to fragment area or fragment isolation (Lynch & Whigham, 1984). The increase in species richness with fragmentation was primarily due to the addition of several migrants that were associated with edge habitats and secondary forest.

These species showed a lower frequency possibly because they were represented by few individuals, and are more sensitive to forest change and fragmentation than more widespread species, as patterns that has been shown before (Fjeldsa, 1999, Renjifo, 2001). Priority species (i.e., endemic and threatened) are important contributors to biodiversity because their restricted distributions make them globally rare and particularly vulnerable to population declines or extinction (Terborgh & Winter, 1983, Diamond 1986). Species with small ranges are also less abundant at a local scale than large-range species (Brown, 1995). The birds may demonstrate a differential response to forest fragmentation (Hobson & Bayne, 2000, Fahrig, 2003) or that probably bird species richness in the study area can be affected by other factors, such as floristic diversity, and vegetation composition and structure (Gillespie & Walter, 2001). Other effects, such as the extent and nature of the fragments edges, fragment connectivity, or fragment shape (Bierregaard et al., 1992, Laurance & Bierregaard, 1997, Cornelius et al., 2000), might be more important than forest cover in predicting the number of species found in the area (Ramírez-Albores, 2010). As for other studies, it is expected that the effect of forest cover would affect bird species richness (Kattan et al., 1994, Laurance & Bierregaard, 1997).

Diet composition was similar among habitat types, with greatest representation by insectivores and insectivores/frugivores, and decreasing representation by nectarivores and granivores. According to Petit et al. (1999) and Karr (1990), this distribution of foraging guild memberships is typical of that found in tropical forest. Tropical forest fragments resulting from human disturbance of a continuous forest are isolated more rapidly. The remaining areas suffer of progressive degradation due to isolation, which, in the long term, jeopardizes the survival of several species. In tropical environments, modified habitats are very important to a lot of carnivores, granivores and insectivores species as a temporary or permanent supply of these resources depending on their phenology and seasonality (Loiselle & Blake, 1994). On the other hand, the habitats with more complex vegetation structure and formed by several layers of coverage are mainly species of insectivores, frugivores and nectar habits (Rappole et al., 1993). The results in this study are consistent with the above, as modified habitats had a higher proportion of species and individuals of carnivores and granivores habits compared to the original habitats (i.e., tropical deciduous and semideciduous forest).

In general, the variety of habitats present in the study region seems to contribute a high proportion of species, especially considering the number of species occurring in tropical deciduous forest (203). This may be due to the structural complexity that makes an ecosystem with greater species richness in Mexico (Ceballos & García, 1995, Ceballos et al., 2010), and the fact of having a greater horizontal and vertical stratification with respect to others, thus generating increased availability of habitats and ecological niches (Blake & Loiselle, 1991, McIntyre, 1995, Villard et al., 1999), as the plant structure determines the amount and distribution of resources used by birds. The differences in diversity and richness found indicate that the tropical deciduous forest, tropical semideciduous forest, and secondary forest show a greater richness compared to other modified habitats (i.e., agricultural fields, cattle pasture). This coincides with other studies conducted in tropical environments and indicates that the original habitat loss directly affects the presence, abundance and persistence of species (Kattan et al., 1994, Laurance & Bierregaard, 1997). The results of this study suggest that species richness and diversity of habitats ranging from the study. Natural habitats (tropical deciduous forest, tropical semideciduous forest and secondary forest) appear to be attractive to a larger number of bird species, as both the richness and diversity were higher in these, which is consistent with other studies (Estrada et al., 1997, Petit et al., 1999, Blake & Loiselle, 2001, Bojorges & Lopez-Mata, 2005).

Modified habitats (agricultural fields, living fences, cattle pasture) had a significant contribution to the bird species richness in the study area. These habitats provide roosting sites and food resources (Lynch, 1989). This is consistent with that reported by Estrada et al. (1997), which brings a richness of 226 in the region of Los Tuxtlas (Veracruz, Mexico), finding 79% of the species found in forest areas, 80% farmland, 43% in living fences and only 5% in grassland/pasture. In addition, Petit et al. (1999) in the central area of Panama found that species richness in modified habitats (i.e., shade coffee plantations, residential areas, grasslands and pine plantations) is equal or similar to the natural habitat. However, live fences exhibited the highest species richness (77 species) from modified habitats (i.e., agricultural fields, cattle pasture), probably because their plant structure is more complex and diverse. This is consistent with other studies (i.e., Villaseñor, 1993, Villaseñor & Hutto, 1995, Morales, 2002), which state that living fences can be very attractive to a large number of individuals and species of birds, and also can support high densities as they provide food resources, roosting sites and shelter (Villaseñor & Hutto, 1995). For example, in the study area, some birds prefer to use corridors or live fences instead of open or cleared areas (Wegner & Merriam, 1979) and turnover rates are significantly more frequent along corridors connected to original habitats or with other corridors (Hass, 1995, Machtans et al., 1996). In the case where the original habitat remains, the complexity of vegetation provides alternative sites for some species, partially offsetting the fragmentation and allowing the persistence of resident and migratory species (Morales, 2002).

The similarity between the habitats types of study area indicates the existence of a high turnover of species and an apparent high connectivity between them. Suggesting that both the configuration of the environment (i.e., landscape, habitat and microhabitat) and the available amount thereof would not be equally important in the distribution of species (Karr

1990) and could confer changes in the composition of the community birds (Blake & Loiselle, 2001). Although the conservation of bird species depends on a clear understanding of their habitat requirements and the physical and biotic processes that keep (Askins, 2000), has been established that the combination of natural and modified habitats leading to new opportunities differential exploitation of space (Willson, 1974) and diversity of bird species is related to landscape diversity, so that conservation of the latter ensures the preservation of species diversity (Bôhning-Gaese, 1997).

The distribution of birds in different physiographic regions of Chiapas is highly heterogeneous (Rangel-Salazar et al., 2005), and may also occur heterogeneity within each region, or even between adjacent physiographic regions (González-Domínguez, 1998). As the behavior of the birds in the Central Depression of Chiapas can be shared or influenced by other regions such as Montañas del Este, Altiplano Central, and even by the Sierra Madre de Chiapas, giving it the ability to host species of these regions (Altamirano, 2004). Biogeographic research biotic transition zones are an essential part of the study of the processes that govern the distribution and diversity of organisms (Williams et al., 1996). In this regard, species richness captures a fundamental aspect of spatial patterns of biodiversity (Koleff et al., 2003). Studying diversity patterns among the cells used in the present analysis helps to generate hypotheses about the processes that contribute to defining the current distribution patterns in the Isthmus, as the spatial turnover of species may reflect deterministic processes such as adaptation of species to different conditions, speciation, and responses to weather events or other historical effects (Condit et al., 2002).

5. Conclusions

Given the continued fragmentation of natural habitats and according to the results of this study, addition and maintenance of natural and modified habitats are necessary for survival and reproduction of many species of birds in the study area. The study area, like many other regions of the country is being affected by anthropogenic factors, particularly the expansion of the agricultural frontier, forest fires, population growth and livestock, which directly affects wildlife populations wild. Studies of diversity and species richness are approximations that represent the basis to further evaluate information by monitoring the changes associated with environmental factors and especially anthropogenic. And the visualization of the biogeographic patterns over changes in species richness according to changes land permits to locate the sites that have been modified over time. This method facilitates the identification of priority areas for conservation because key to the survival of species groups threatened and endemic. Understanding the patterns of richness is closely linked the establishment of actions at the federal, regional and local levels, as they reflect as conditions of land use change are affecting populations. The need to make a stock assessment and particular requirements of each species; can support the planning, implementation and evaluation. Additional conservation actions can help to assure that these viable long-term populations are sufficient to retain species.

6. Appendix

Bird species record from 24 sites of the Central Depression Chiapas. Taxonomy and order species follow AOU (2010). Migratory status: resident (R), migratory (M; including winter visitor, summer resident and transit). Habitat types: Tdf (tropical deciduous forest), C (cattle pastures), Lf (living fences), Rf (gallery forest), Tsf (tropical semideciduous forest), Sf (secondary forest), Af (agricultural fields), To (tropical oak forest), Ur (urban and suburban areas) and Aq (aquatics and subaquatics). Diet categories: I (insectivore), C (carnivore), O (omnivore), N (nectarivore), A (aquatic), G (granivore), F (frugivore).

Species	**Migratory status**	**Diet or subdiet**	**Habitat types**									
			Tdf	**Tsf**	**Sf**	**To**	**Rf**	**Af**	**C**	**Lf**	**Ur**	**Aq**
Crypturellus soui	R	O	x									
Crypturellus cinnamomeus	R	O	x	x								
Dendrocygna autumnalis	R	A										x
Anas discors	M	A										x
Ortalis vetula	R	GF	x	x	x	x						
Penelope purpurascens	R	GF	x	x								
Colinus virginianus	R	G			x			x	x			
Tachybaptus dominicus	R	A										x
Podilymbus podiceps	M	A										x
Pelecanus occidentalis	M	C										x
Phalacrocorax brasilianus	R	C										x
Anhinga anhinga	R	C										x
Ardea herodias	M	C										x
Ardea alba	M	C										x
Egretta thula	M	C										x
Egretta caerulea	M	C										x
Egretta tricolor	M	C										x
Bubulcus ibis	R	I						x				
Butorides virescens	M	C										x
Nycticorax nycticorax	M	C										x
Nyctinassa violacea	R	C										x
Coragyps atratus	R	C	x	x	x	x	x	x	x		x	
Cathartes aura	R	C	x	x	x	x	x	x	x		x	
Pandion haliaetus	M	C	x	x	x							
Elanus leucurus	R	C						x	x			
Rostrhamus sociabilis	R	C	x		x							
Ictinia mississippiensis	M	C	x	x		x		x	x			
Accipiter striatus	M	C	x	x	x			x	x		x	
Accipiter cooperii	M	C	x	x	x	x		x	x			
Buteogallus anthracinus	R	C	x		x			x	x			
Buteo magnirostris	R	C	x		x	x		x	x			
Buteo nitidus	R	C	x		x			x	x			
Buteo brachyurus	R	C	x		x							
Buteo swainsoni	M	C	x		x				x			
Buteo albicaudatus	R	C	x	x								
Buteo jamaicensis	R	C	x		x			x	x		x	
Caracara cheriway	R	C						x	x			
Herpetotheres cachinnans	R	C						x	x			
Falco sparverius	R	C						x	x			

Species	Migratory status	Diet or subdiet	Habitat types									
			Tdf	Tsf	Sf	To	Rf	Af	C	Lf	Ur	Aq
Falco columbarius	M	C			x			x	x			
Falco femoralis	R	C						x	x			
Falco peregrinus	M	A						x	x			
Charadrius vociferus	M	A										x
Himantopus mexicanus	R	A										x
Jacana spinosa	R	A										x
Actitis macularius	M	A										x
Tringa solitaria	M	A										x
Columba livia	R	G									x	
Patagioenas flavirostris	R	GF	x	x	x							
Patagioenas nigrirostris	R	GF	x	x				x				
Zenaida asiatica	R	GF	x	x	x			x			x	
Zenaida macroura	M	GF	x	x	x			x				
Columbina inca	R	G			x	x		x	x		x	
Columbina passerina	R	G			x			x	x			
Columbina minuta	R	G	x		x		x					
Columbina talpacoti	R	G			x			x	x			
Claravis pretiosa	R	GF	x		x							
Leptotila verreauxi	R	GF	x	x	x		x	x				
Geotrygon montana	R	GF	x		x							
Aratinga holochlora	R	GF	x		x							
Aratinga nana	R	GF	x		x						x	
Aratinga canicularis	R	GF	x	x	x			x			x	
Amazona albifrons	R	GF	x	x								
Amazona autumnalis	R	GF	x	x							x	
Coccyzus minor	R	CI	x	x	x							
Piaya cayana	R	CIF	x	x	x							
Tapera naevia	R	CIF	x					x				
Dromococcyx phasianellus	R	CI	x	x								
Morococcyx erythropygus	R	CI	x	x	x							
Geococcyx velox	R	CI			x			x	x			
Crotophaga sulcirostris	R	GIF			x			x	x	x	x	
Tyto alba	R	C	x					x	x			
Megascops guatemalae	R	C	x	x	x							
Pulsatrix perspicillata	R	C	x	x				x	x			
Glaucidium brasilianum	R	CI	x	x	x							
Ciccaba virgata	R	C	x	x								
Chordeiles acutipennis	R	I	x	x	x						x	
Nyctidromus albicollis	R	I	x	x	x						x	
Caprimulgus ridgwayi	R	I	x	x	x							
Streptoprocne zonaris	R	I	x	x	x	x		x	x			
Chaetura vauxi	R	I	x	x	x	x		x	x		x	
Aeronautes saxatalis	R	I	x	x	x	x		x	x			

Species	Migratory status	Diet or subdiet	Habitat types									
			Tdf	Tsf	Sf	To	Rf	Af	C	Lf	Ur	Aq
Panyptila sanctihieronymi	R	I	x	x	x	x		x	x			
Phaethornis longirostris	R	N	x		x							
Phaethornis striigularis	R	N	x									
Florigusa mellivora	R	N	x	x								
Colibri thalassinus	R	N	x		x						x	
Chlorostilbon canivetii	R	N	x	x	x						x	
Amazilia beryllina	R	N	x	x			x			x		
Amazilia tzacatl	R	N	x		x		x			x	x	
Amazilia yucatanensis	R	N	x		x							
Amazilia viridifrons	R	N	x	x	x							
Eupherusa eximia	R	N	x	x	x							
Lamprolaima rhami	R	N	x	x								
Heliomaster longirostris	R	N	x		x							
Tilmatura dupontii	R	N	x	x	x							
Archilochus colubris	M	N	x									
Trogon melanocephalus	R	IF	x	x								
Trogon violaceus	R	IF	x	x								
Momotus mexicanus	R	CIF	x	x		x	x					
Momotus momota	R	CIF	x	x			x					
Megaceryle torquata	R	C					x					x
Megaceryle alcyon	M	C					x					x
Chloroceryle amazona	R	C					x					x
Chloroceryle americana	R	C					x					x
Aulacorhynchus prasinus	R	GF	x		x							
Pteroglossus torquatus	R	GF	x		x							
Ramphastos sulfuratus	R	GF	x		x							
Melanerpes aurifrons	R	IF	x	x	x	x					x	
Sphyrapicus varius	M	I	x	x	x							
Picoides scalaris	R	I	x		x						x	
Colaptes rubiginosus	R	IF	x	x	x							
Dryocopus lineatus	R	I	x	x	x							
Campephilus guatemalensis	R	I	x	x	x							
Sclerurus guatemalensis	R	I	x									
Synallaxis erythrothorax	R	I	x									
Automolus ochrolaemus	R	I	x		x							
Dendrocincla homochroa	R	I	x									
Dendrocolaptes sancthithomae	R	I	x									
Xiphorhynchus flavigaster	R	I	x	x								
Lepidocolaptes souleyetii	R	I	x	x	x							
Taraba major	R	I	x		x					x		
Thamnophilus doliatus	R	I	x		x			x		x		

Species	Migratory status	Diet or subdiet	Habitat types									
			Tdf	Tsf	Sf	To	Rf	Af	C	Lf	Ur	Aq
Cercomacra tyrannina	R	I	x		x							
Grallaria guatemalensis	R	I	x	x								
Ornithion semiflavum	R	I	x									
Camptostoma imberbe	R	I	x		x					x	x	
Myiopagis viridicata	R	I	x		x							
Elaenia flavogaster	R	IF	x		x							
Leptopogon amaurocephalus	R	I	x		x							
Oncostoma cinereigulare	R	I	x	x	x							
Poecilotriccus sylvia	R	I	x	x								
Rhynchocyclus brevirostris	R	I	x		x					x		
Xenotriccus callizonus	R	I	x		x							
Contopus cooperi	M	I	x		x							
Contopus pertinax	R	I	x		x	x	x		x	x		
Contopus virens	M	I	x		x							
Contopus cinereus	R	I	x		x	x	x		x	x		
Empidonax virescens	M	I	x		x							
Empidonax traillii	M	IF	x	x	x							
Empidonax albigularis	M	IF	x		x	x	x			x		
Empidonax minimus	M	I	x		x							
Sayornis nigricans	R	I	x		x		x					
Pyrocephalus rubinus	R	I							x	x		
Rhytipterna holerythra	R	I	x		x							
Myiarchus tuberculifer	R	IF	x						x	x		
Myiarchus cinerascens	M	IF	x	x	x							
Myiarchus nuttingi	R	IF	x		x	x	x			x		
Myiarchus tyrannulus	R	IF	x	x	x	x	x		x	x	x	
Pitangus sulphuratus	R	CIF	x	x	x	x		x	x	x	x	
Megarhynchus pitangua	R	CIF	x	x	x		x			x	x	
Myiozetetes similis	R	IF	x	x	x	x	x		x	x	x	
Myiodynastes luteiventris	M	IF	x	x	x	x	x		x	x	x	
Legatus leucophaius	M	I	x				x					
Tyrannus melancholicus	R	IF	x		x	x	x		x	x	x	
Tyrannus vociferans	M	IF	x						x	x		
Tyrannus verticalis	M	IF			x				x	x		
Tyrannus tyrannus	M	I			x			x		x		
Tyrannus forficatus	M	IF			x			x		x		
Pachyramphus aglaiae	R	IF	x		x							
Tityra semifasciata	R	IF	x	x	x						x	
Vireo griseus	M	IF	x		x					x		
Vireo bellii	M	I	x							x		
Vireo solitarius	M	IF	x	x	x	x	x			x	x	
Vireo huttoni	R	I	x							x		
Vireo gilvus	M	IF	x	x	x					x		

Species	Migratory status	Diet or subdiet	Habitat types									
			Tdf	Tsf	Sf	To	Rf	Af	C	Lf	Ur	Aq
Vireo leucophrys	R	IF	x									
Vireo philadelphicus	M	I	x	x	x					x	x	
Vireo olivaceus	M	IF	x	x	x		x			x	x	
Vireo flavoviridis	M	IF	x	x								
Hylophilus decurtatus	R	I	x	x	x					x		
Cyclarhis gujanensis	R	IF	x	x	x					x		
Calocitta formosa	R	O	x	x	x	x	x	x		x		
Cyanocorax yncas	R	O	x	x	x	x				x		
Cyanocorax morio	R	O	x	x	x	x						
Progne chalybea	R	I	x	x	x							
Tachycineta albilinea	M	I	x	x	x	x		x	x			
Stelgidopteryx serripennis	R	I	x	x	x	x		x	x		x	
Riparia riparia	M	I	x				x					
Petrochelidon pyrrhonota	M	I						x	x		x	
Petrochelidon fulva	M	I						x	x		x	
Hirundo rustica	M	I						x	x		x	
Catherpes mexicanus	R	I	x	x			x					
Thryothorus maculipectus	R	I	x	x	x	x				x		
Thryothorus pleurostictus	R	I	x	x	x	x	x	x		x		
Thryothorus modestus	R	I	x	x	x			x		x	x	
Troglodytes aedon	R	I	x									
Cistothorus platensis	R	I	x									
Uropsila leucogastra	R	I	x	x								
Henicorchia leucophrys	R	I	x		x							
Microcerculus marginatus	R	I		x								
Ramphocaenus melanurus	R	I	x		x							
Polioptila caerulea	R	I	x		x	x	x			x	x	
Polioptila plumbea	R	I	x	x	x	x	x			x		
Catharus aurantiirostris	R	IF	x									
Catharus minimus	M	IF	x									
Catharus ustulatus	M	IF	x	x								
Hylocichla mustelina	M	IF		x								
Turdus grayi	R	IF	x	x	x	x	x			x	x	
Dumetella carolinensis	M	IF	x		x							
Mimus gilvus	R	IF			x			x		x		
Bombycilla cedrorum	M	IF	x		x	x				x		
Oreothlypis pinus	M	I	x		x							
Oreothlypis celata	M	IF	x									
Oreothlypis ruficapilla	M	IF	x		x	x	x			x	x	
Parula americana	M	I	x							x		
Parula pitiayumi	R	I	x							x		
Dendroica petechia	M	IF	x			x	x			x	x	
Dendroica pensylvanica	M	IF	x									

Species	Migratory status	Diet or subdiet	Habitat types									
			Tdf	Tsf	Sf	To	Rf	Af	C	Lf	Ur	Aq
Dendroica magnolia	M	IF	x	x	x	x	x			x	x	
Dendroica coronata	M	IF		x								
Dendroica virens	M	IF	x	x	x	x	x			x	x	
Dendroica townsendi	M	IF	x							x		
Dendroica occidentalis	M	IF	x	x	x					x		
Dendroica fusca	M	I	x									
Dendroica graciae	R	IF	x	x		x				x		
Mniotilta varia	M	I	x	x	x	x				x	x	
Protonotaria citrea	M	I	x									
Helmitheros vermivorum	M	I		x								
Seiurus aurocapilla	M	I	x	x	x							
Seiurus noveboracensis	M	I	x	x	x							
Oporornis formosus	M	I	x	x								
Oporornis tolmiei	M	I	x									
Geothlypis trichas	M	I						x	x			
Geothlypis poliocephala	R	I						x	x			
Wilsonia citrina	M	I	x		x					x		
Wilsonia pusilla	M	IF	x	x	x	x	x			x	x	
Wilsonia canadensis	M	IF	x		x					x		
Euthlypis lachrymosa	R	I	x	x	x		x					
Basileupterus rufifrons	R	I	x		x					x		
Icteria virens	M	I			x					x		
Eucometis penicillata	R	IF	x		x							
Thraupis episcopus	R	IF			x					x		
Thraupis abbas	R	IF	x	x		x	x			x		
Cyanerpes cyaneus	R	IN	x	x								
Saltator coerulescens	R	IF	x		x					x		
Saltator atriceps	R	IF	x		x					x		
Volatinia jacarina	R	G						x	x			
Sporophila torqueola	R	G						x	x		x	
Oryzoborus funereus	R	G						x	x			
Tiaris olivaceus	R	G			x			x	x	x		
Arremonops rufivirgatus	R	GI	x	x	x			x	x	x	x	
Aimophila botterii	R	G						x	x			
Aimophila rufescens	R	GI						x	x			
Piranga rubra	M	IF	x	x	x							
Piranga ludoviciana	M	IF	x	x	x	x				x		
Habia rubica	R	IF	x	x	x							
Habia fuscicauda	R	IF	x	x	x							
Pheucticus chrysopeplus	R	IF	x	x	x	x	x				x	
Pheucticus ludovicianus	M	IF			x	x						
Granatellus venustus	R	IF	x	x	x							
Granatellus sallaei	R	IF	x	x	x							

Species	Migratory status	Diet or subdiet	Habitat types									
			Tdf	Tsf	Sf	To	Rf	Af	C	Lf	Ur	Aq
Cyanocompsa parellina	R	G	x	x	x			x				
Passerina caerulea	R	GI						x	x	x		
Passerina cyanea	M	GI	x					x	x			
Passerina versicolor	R	GIF	x		x			x	x			
Passerina ciris	M	GI			x			x				
Sturnella magna	R	GI						x	x			
Dives dives	R	GIF	x	x	x	x	x			x	x	
Quiscalus mexicanus	R	O	x	x	x	x	x	x	x	x	x	
Molothrus aeneus	R	GIF			x	x	x	x	x	x	x	
Icterus prosthemelas	R	IF	x		x					x		
Icterus wagleri	R	IF	x		x					x		
Icterus maculialatus	R	IF	x									
Icterus spurius	M	IF			x			x		x		
Icterus mesomelas	R	IF	x		x					x		
Icterus pustulatus	R	IF	x	x	x	x	x			x	x	
Icterus gularis	R	IF	x	x	x		x			x	x	
Icterus galbula	M	IF	x				x			x	x	
Amblycercus holosericeus	R	IF	x	x								
Cacicus melanicterus	M	IF	x									
Psarocolius wagleri	R	GF	x	x								
Psarocolius montezuma	R	GF	x		x							
Euphonia affinis	R	IF	x		x		x			x	x	
Euphonia hirundinacea	R	IF	x	x	x	x	x			x		
Euphonia elegantissima	R	IF	x	x	x	x				x		
Carpodacus mexicanus	R	G						x	x		x	
Spinus psaltria	R	GF			x	x	x	x	x	x	x	
Passer domesticus	R	O									x	

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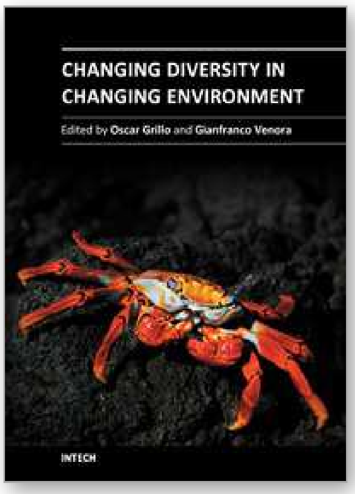

Changing Diversity in Changing Environment

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As everybody knows, the dynamic interactions between biotic and abiotic factors, as well as the anthropic ones, considerably affect global climate changes and consequently biology, ecology and distribution of life forms of our planet. These important natural events affect all ecosystems, causing important changes on biodiversity. Systematic and phylogenetic studies, biogeographic distribution analysis and evaluations of diversity richness are focal topics of this book written by international experts, some even considering economical effects and future perspectives on the managing and conservation plans.

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University Campus STeP Ri
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Phone: +86-21-62489820
Fax: +86-21-62489821