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ORIGINAL PAPER

Diversity of Tabanidae, Asilidae and Syrphidae (Diptera) in natural protected areas of Yucatan, Mexico

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Abstract

Although dipteran communities play a fundamental role in the ecosystem, little is known about their diversity, richness and abundance in different environments. In spite of the importance of Natural Protected Areas (NPAs) as reservoirs of biological diversity, information about community parameters of most insects, including Diptera, are practically unknown in these areas. In this study, we described and compared the composition and structure of Dipteran communities (considering Tabanidae, Asilidae and Syrphidae families) within six (NPAs) of Yucatan, Southeast Mexico, comprising four main vegetation types: seasonally flooded forest, tropical deciduous forest, semi-deciduous tropical forest and coastal dune. We used Malaise-traps to collect samples during a period of two days, twice a month, for one year (2006–2007) within each NPAs. A total of 6 910 specimens belonging to 33 genera and 78 species/morphospecies were recorded. Our results show that the four vegetation types host a vast diversity of dipterans. However, species richness, abundance, diversity and similarity were higher in the communities of tropical deciduous forests compared with those from semi-deciduous forests and coastal dune vegetation, probably as a result of microhabitat differences between sites. We highlight the role of tropical deciduous forests as a refuge for Diptera species and the importance of these forests for conservation of dipteran communities.

Keywords Conservation · Species richness · Brachycera · Community parameters · Morphospecies

Introduction

Diptera (true flies) is one of the megadiverse orders of insects in biotic communities from temperate to tropical areas (Brown 2000; Amorim and Papavero 2008). There are about 153000 described species of dipterans belonging to 180 families worldwide (Hughes et al. 2000; Thompson 2000; Brown et al. 2009; Courtney et al. 2009), with the greatest diversity present in the Neotropics with approximately 31,000 species (Amorim 2009). Mexico hosts around 5000 species of Diptera distributed in 78 families (Morón and Valenzuela 1993; Ibáñez-Bernal et al. 2006; Ibáñez-Bernal and Martín del Campo 2009), from which 41 (including approximately 465 species) have

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been recorded in Yucatan (Manrique-Saide and González-Moreno 2010; León-Cortés et al. 2015), making it an important diversity spot for this group in the region. Interestingly, dipterans are morphologically and ecologically diverse, interacting as predators, pollinators, parasitoids, decomposers of organic matter (plants and animals), and vector of diseases. As such, they play a key ecological role in biotic interactions, in the recycling of elements in biological communities and are of medical-veterinary importance (Gubler 1998; Skevington and Dang 2002; Brown et al. 2009). Hence, studies describing the composition of species in association to the environments in which they grow are very important.

Tabanidae, Asilidae and Syrphidae are conspicuous families of Brachycera flies with a large number of described species that contribute significantly to dipteran biodiversity (Brown et al. 2009). Species from these families play important roles in natural and farm communities. Adult Tabanidae (horse flies and deer flies) include many species with haematophagous females that feed on large mammals and can be important pests of wild and domestic animals. Also, flies of this family can be an important component in the food chain of some bird species (Salgado-Ortiz 2006). In Mexico 207 species are known (Fairchild and Burger 1994), of which 22 species (10%) have been reported in Yucatan (Manrique-Saide et al. 2001, 2010, 2012). Adult Asilidae (robber flies) are predatory dipterans, considered key species maintaining the balance of insect populations (Shurovnekov 1962; Joern and Rudd 1982; Lavigne 2001). Some species are bee predators and have been considered as pests by beekeepers (Rabinovich and Corley 1997; Castelo 2002). In Yucatan 24 genera are known (Ibáñez-Bernal 1998; León-Cortés et al. 2015). Finally, adults of Syrphidae (flower flies or hoverflies) play an important role for flowering plant communities since they are generalist pollinators (Mengual and Thompson 2008). Moreover, given the diversity found in their life histories they have been considered of great ecological importance (Wratten et al. 2003; Fontaine et al. 2006; Hansen and Totland 2006; Pansarin 2008). Their larvae can develop in many types of niches and can belong to different functionally groups (predators, saprophagous, phytophagous, mycophagous, etc.). Also, this group has been used as an environmental indicator (Dziock et al. 2006; Burgio and Sommaggio 2007; Schweiger et al. 2007). In Mexico 221 species of Syrphidae have been recorded, and around 10% (32 species) have been found in Yucatan (Papavero 1966; Papavero and Ibáñez-Bernal 2001, 2003; González-Moreno et al. 2011; León-Cortés et al. 2015). While Tabanidae, Asilidae and Syrphidae contain about 18% of the species of flies reported in Yucatan, only preliminary species lists are available in a few areas (Ibáñez-Bernal 1998; Manrique-Saide et al. 2001; González-Moreno et al. 2011), making it important to develop better and more complete descriptions.

Although Mexico is considered as one of the most megadiverse countries of the world (CONABIO 1998; Mittermeier et al. 1998; Toledo and Ordoñez 1998; Mas et al. 2002), it has lost 35% of its forest cover in the past 20 years (Trejo and Dirzo 2000, 2002). Thus, strategies for the conservation of the biological diversity in the country greatly depend on the existence of Natural Protected Areas (NPAs). NPAs maintain the ecological integrity of ecosystems, providing a wide range of environmental services, means of support and sustenance for local communities (Ervin 2003a; IUCN 2005; Durán-García and Ramos-Pacheco 2010). Unfortunately and paradoxically, in recent years, it has been reported that some NPAs in Mexico could be facing several threats such as deforestation, habitat fragmentation, pollution, encroachment, illegal extraction of native species, invasion of alien species, wild fires, logging and hunting (Ervin 2003b; Carey et al. 2000). In the state of Yucatan around 8 000 species of living organisms have been reported and 12 NPAs covering ca. 20% of the total state territory have been decreed for preserving this biodiversity (Ruíz-Barranco and Arellano-Morín 2010). However, the inventory and knowledge of the biodiversity from NPAs in this region is still incomplete and further studies are needed for future actions, such as monitoring, managing and conservation of diversity. For example, despite the enormous ecological relevance of insects, and particularly dipterans in different communities, studies of this group are rare and community parameters are still scarce in the country, and almost inexistent in NPAs. Here we describe and compare community parameters (species richness, abundance, diversity and similarity) of three families of Diptera in six NPAs of Yucatan, comprising different vegetation types, with the objective of contributing to the knowledge of the diversity of dipterans from southeast Mexico.

Materials and methods

Sampling areas

The Natural Protected Areas (NPA) considered in this study are located in the North and the Center of the Yucatan Peninsula and belong to the biogeographical province of Yucatan (Fig. 1). The NPAs and main vegetation types sampled were: Reserva Estatal Dzilam, (seasonally glooded forest), Parque Nacional Dzibilchaltún (tropical deciduous forest), Parque Estatal Lagunas de Yalahau (tropical deciduous forest), Reserva Estatal Palmar (coastal dune), Parque Estatal Kabah (semi-deciduous tropical forest), and Área Natural Protegida de Valor Escénico, Histórico y Cultural San Juan Bautista Tabi and Anexa Sacnicté (semi-deciduous tropical forest) (Fig. 1; Table 1). These NPAs were selected for their diversity in vegetation types, based on their conservation

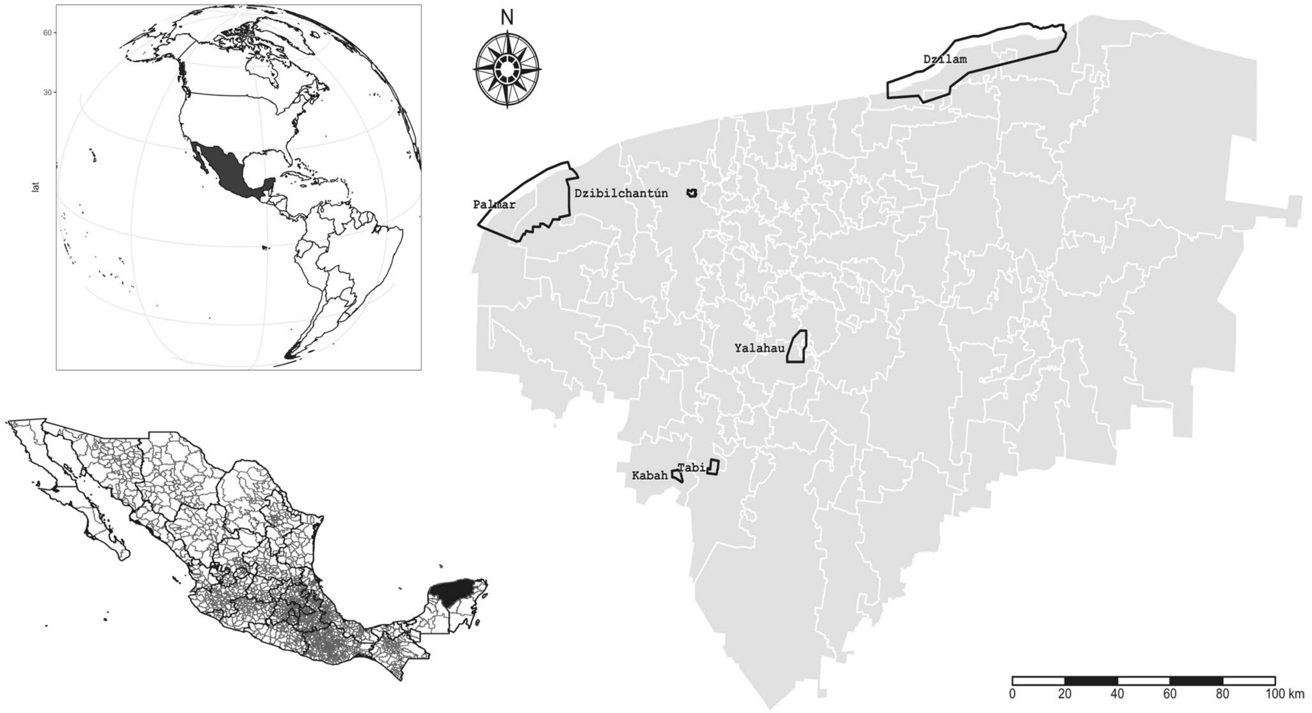

Fig. 1 Location of the NPAs of Yucatan state administration

Table 1 Location of study areas, their main vegetation types, climate, temperature, and precipitation

NPAs	Latitude/Longitude	VT	Climate	MAT (°C)	MAP (mm)
Dzilam	21°26′N–88°47′W	SFF	BS_1	25.5	970
Dzibilchaltún	21°04′N–89°34′W	TDF	AW_0	28	800
Yalahau	20°40′N–89°10′W	TDF	AW_0	26	1200
Palmar	20°55′N–90°00′W	CDV	BS_0	26	600
Kabah	20°14′N–89°39′W	SDTF	AW_0	24.5	986
Tabi	20°14′N–89°30′W	SDTF	AW_0	26	154

NPAs state natural protected areas, *VT* vegetation type, *MAT* = mean annual temperature, *MAP* = mean annual precipitation. Vegetation types according to Flores et al. (1971): *SFF* seasonally flooded forest, *TDF* tropical deciduous forest, *CDV* coastal dune vegetation, *SDTF* semi-deciduous tropical forest. Climatic classification based on Köppen modified by García (1973): AW_0 warm subhumid with lowest humidity percentage; BS_1 Dry with medium humidity percentage, BS_0 dry with lowest humidity percentage

status (Petrosillo et al. 2009), and the minimal knowledge of insect diversity in these areas.

Flies sampling and identification

Twelve Malaise traps were set in paired transect separated every 50 meters within the main vegetation types at each NPA. Between 2006 and 2007, we collected samples in each NPA twice a month, over a two-day period. Identification of genera and species of Tabanidae, Asilidae and Syrphidae was based on Ibáñez-Bernal (1992), Fisher and Hespenheide (1992), and Thompson (1999), respectively. When species identification was not possible due to lack of taxonomic keys (i.e., Asilidae and Syrphidae), we applied the "morphospecies" criterion which is the mostly used term for units sorted by means of morphological differences considering partially taxonomic literature or taxonomic standards. Morphospecies' sorting with minimum or partially involvement of taxonomists has become a widely accepted method in conservation biology and species diversity based ecology (Krell 2004). The criteria of morphospecies have been used as surrogates for taxonomic species as an alternative to overcome the identification issues related in invertebrate inventories, environmental monitoring, conservation studies and biodiversity surveys (Oliver and Beattie 1996a; Derraik et al. 2002, 2010). Different authors have suggested that even non-specialist could classify invertebrates to morphospecies without compromising scientific accuracy (Oliver and

Beattie 1993, 1996a, b; Beattie and Oliver 1994; Pik et al. 1999). The morphospecies can be a useful technique particularly when time and resources are limited (Derraik et al. 2010). In previous papers, accuracy of morphospecies classification has been well supported for Aranea, Coleoptera, Lepidoptera and Hymenoptera (Derraik et al. 2002, 2010; Barratt et al. 2003). Voucher specimens were deposited at Colección Entomológica Regional (CER)—Universidad Autónoma de Yucatán (UADY).

Data analysis

The description of the community structure of the three families (Tabanidae, Asilidae, and Syrphidae) was performed estimating species richness, relative abundance, diversity and similarity, according to criteria established by Moreno (2001).

Species richness

For each family the total number of species in each NPA was considered. The estimate of the total species corresponding to the area was made by species accumulation functions (per family) adjusted to the Clench model: $S(t) = a*t/(1 + b*t)$ where $S(t) =$ number of species, a is the slope at the start of the collection, b is a parameter related to the shape of the accumulation of new species in the collection, t is the sampling effort and a/b indicates the extrapolated species richness. According to the collection methods used for each site, samples were randomized 100 times using the program EstimateS 8 (Colwell 2005). The non-linear regression procedure was applied with the setting option Simplex & Quasi-Newton (Jiménez-Valverde and Hortal 2003) with the program STATISTICA 6.1 (StatSoft Inc. 2003). This model is suggested when the sampling area is large or for census of taxa for which it is common to add new species (up to a maximum) with increasing experience of the observer (Soberón-Mainero and Llorente-Bousquets 1993).

Abundance

Abundance was measured as the number of individuals per sample (NPA). Rank-abundance curves were constructed for each family of Diptera belonging to each NPA. These curves provide a visual representation of species richness and species evenness in each community, taking into account the identity and sequence (Favila and Halffter 1997; Feinsinger 2001). The logarithm of the ratio of each species pi (ni/N) was plotted to obtain rank-abundance curves, ordered from most abundant to least abundant species (Feinsinger 2001). Dominance was determined based on the presence/absence of species/morphospecies in the NPAs, and evenness was determined according to the uniformity in the abundance of species/morphospecies (log abundance) within each community (family).

Diversity

We calculated the Shannon-Wiener diversity index: $H' = -\Sigma\, Ni/N \ \mathrm{In}\ (Ni/N)$ where H’ is the diversity, S is the number of species (species richness), N is the number of individuals in the sample and Ni is the number of individuals of species i in the sample for each community (family) in the NPA. For this index we used the software Species Diversity and Richness ver. 3.0.2 (Henderson and Seaby 2002). The value of this index ranges between zero and log (s). The index tends to zero in low diversity communities and is equal to the logarithm of species richness in communities of high evenness.

Similarity

A classification analysis was performed to determine the similarity between study areas regarding communities of the three dipteran families. The similarity was calculated using the Jaccard index: ($Ij = c/(a + b - c)$, where a is the number of species present at site A, b is the number of species present at site B and c is the number of species present in both sites A and B. The similarity analysis was based on the presence/absence of species given the high species abundances obtained. The index shows the change in species richness between two samples and the interval ranges from 0 when no species are shared between both sites to 1 when the two sites have the same composition of species (Magurran 2004). To facilitate the visualization of this similarity index, dendograms were constructed using the analysis of groupings UPGMA – unweighted pair-group method using arithmetic averages (Sneath and Sokal 1973). The software MVSP 3.01 was used to calculate the similarity (Kovach 2003).

Results

In total we collected 6 910 specimens (See Online Appendix 1–3) belonging to 33 genera and 78 species/morphospecies (38 species, 40 morphospecies). Overall, the greatest species richness was observed at Dzilam (seasonally flooded forest), and the lowest (although with the largest abundance) was observed at Tabi (semi-deciduous tropical forest) (Table 2). Diversity of the three communities measured as H´ was relatively low in the NPAs; particularly because some Tabanidae species were very abundant in all NPAs. The similarity between NPAs is close to 60%.

Table 2 Community parameters of Tabanidae, Asilidae and Syrphidae in each NPA

Family	Parameters	Dzilam	Dzibilchaltún	Yalahau	Palmar	Kabah	Tabi
Tabanidae	SppR	14	6	10	6	5	3
(16)	Ab	1142	300	687	49	1573	2603
	H´	1.16	0.29	1.24	1.34	0.45	1.09
Asilidae	SppR	13	10	15	4	15	10
(26)	Ab	40	42	81	65	71	49
	H´	2.10	1.79	2.17	1.08	2.11	1.72
Syrphidae	SppR	17	11	11	21	7	7
(36)	Ab	51	47	20	66	10	14
	H´	2.24	1.79	2.22	2.33	1.88	1.81

In brackets the total number of species in each family

SppR species richness, *Ab* abundance, *H´* Shannon-Wiener diversity index

Species richness

Tabanidae showed the lowest species richness (16). The highest species richness (14) was observed at Dzilam, and the lowest species richness was observed in Tabi (3) (See Online Appendix 1). According to the Clench model estimations, our collections registered 83% (19 spp.) of tabanids ($R^2 = 0.986$, a = 1.109980, b = 0.057612). For Asilidae 26 morphospecies were found. Kabah and Yalahau communities showed the highest Asilidae species richness (16 and 15 species, respectively), while the lowest richness was found at El Palmar (N = 4). This represents 72% of species richness estimated by the model (35 sp.) ($R^2 = 0.997$, a = 1.120580, b = 0.031448). Finally, Syrphidae communities showed the highest species richness (36 species) of the three families. The community at El Palmar had the highest Syrphidae species richness (21), whereas the lowest species richness was observed at Tabi and Kabah communities (7). The model estimated 43% of species richness (81) ($R^2 = 0.998$, a = 0.831472, b = 0.010149).

Abundance

In general, one or two species in the communities were both dominant and abundant at each area studied, *Tabanuns commixtus* and *Leucotabanus itzarum* (Tabanidae) (Figs. 2, 3); *Leptogaster* sp. 1, and *Atomosia* sp. and *Efferia* sp. 5 (Asilidae) (Fig. 4); and *Pseudodorus clavatus, Copestylum hoya* and *Toxomerus mulio* (Syrphidae) (Fig. 5). The seasonality of dipteran communities showed a similar pattern among NPAs, and the highest abundances were found during the rainy season (July to September) (Fig. 2).

Diversity

Diversity was relatively low in all Diptera communities. Tabanidae from Palmar showed the highest diversity index (H’ = 1.35) whereas the lowest diversity was presented in

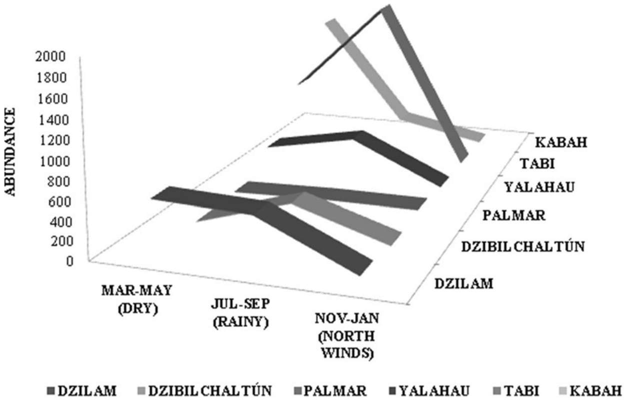

Fig. 2 Seasonality of Tabanidae, Asilidae and Syrphidae communities in the NPAs during a year sampling divided into dry season (March–May), rainy (July–September) and north winds (November-January)

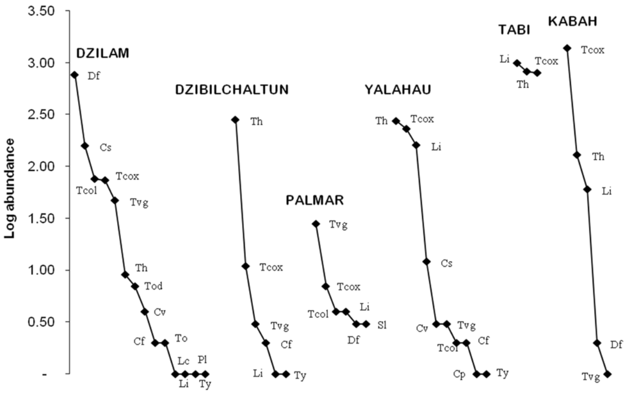

Fig. 3 Rank-abundance curves of Tabanidae communities from each NPAs. *Cf Chrysops flavidus, Cs Chrysops scalaratus, Cp Chrysops pallidefemoratus, Cv Chrysops variegatus, St Stenotabanus littoreus, Df Diachlorus ferrugatus, Li Leucotabanus itzarum, Lc Leucotabanus canithorax, Tcol Tabanus colombensis, Tcox Tabanus commixtus, Th Tabanus haemagogus, Tod Tabanus occidentalis var. dorsovittatus, To Tabanus oculus, Tvg Tabanus vittiger subsp. guatemalanus, Ty Tabanus yucatanus, Pl Phaeotabanus longiappendiculatus*

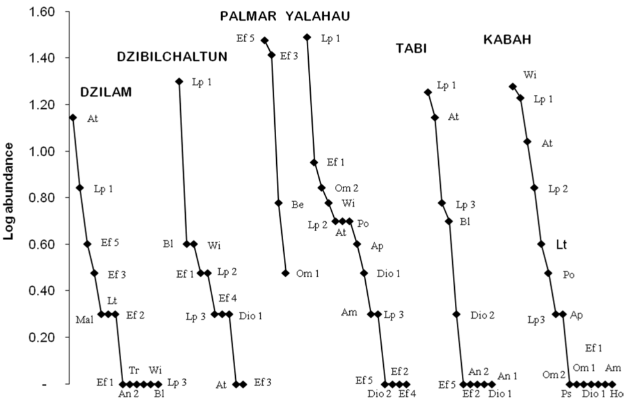

Fig. 4 Rank-abundance curves of Asilidae communities from each NPAs. *An1 Andrenosoma* sp 1, *An2 Andrenosoma* sp 2, *Dio1 Diogmites* sp 1, *Dio2 Diogmites* sp 2, *Bl* Blepharepium, *At Atomosia* sp, *Lp1 Leptogaster* sp 1, *Lp2 Leptogaster* sp 2, *Lp3 Leptogaster* sp 3, *Wi Wilcoxius* sp, *Om1 Ommatius* sp 1, *Om2 Ommatius* sp 2, *Am Amblyonychus* sp, *Mal Mallophora* sp, *Po Polacantha* sp, *Ap Apachekolos* sp, *Lt Leptopteromyia* sp, *Be Beameromyia* sp, *Ps Psilonyx* sp, *Ho Holopogon* sp, *Ef1 Efferia* sp 1, *Ef2 Efferia* sp 2, *Ef3 Efferia* sp 3, *Ef4 Efferia* sp 4, *Ef5 Efferia* sp 5, *Tr Triorla* sp

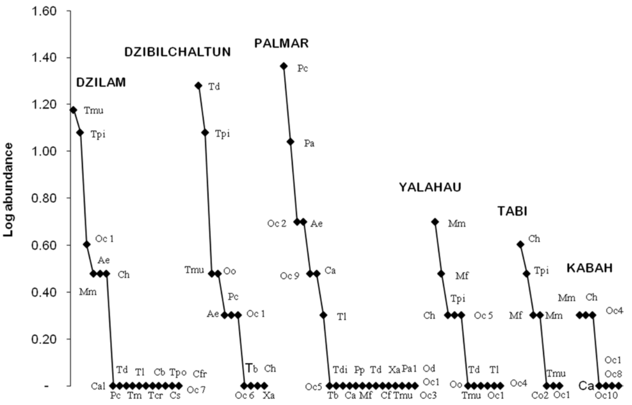

Fig. 5 Rank-abundance curves of Syrphidae communities from each NPAs. *Ae Allograpta exotica, Mf Microdon falcatus, Cal Copestylum alberlena, Ca Copestylum amethystinum, Cb Copestylum bequaerti, Ch Copestylum hoya, Cfr Copestylum fraudulentum, Cs Copestylum sexmaculatum, Co1* Copestylum sp 1, *Co2* Copestylum sp 2, *Oo Ornidia obesa, Tpo Toxomerus politus, Tmu Toxomerus mulio, Tpi Toxomerus pictus, Tb Toxomerus bistriga, Tl Toxomerus lacrymosus, Td Toxomerus difficilis, Tm Toxomerus musicus, Tcr Toxomerus* sp., *Tdi Toxomerus dispar, Xa Xanthandrus* sp, *Pp Palpada pusilla, Pa Palpada albifrons, Pa1 Palpada* sp 1, *Od Ocyptamus dimidiatus, Oc1 Ocyptamus* sp 1, *Oc2 Ocyptamus* sp 2, *Oc3 Ocyptamus* sp 3, *Oc4 Ocyptamus* sp 4, *Oc5 Ocyptamus* sp 5, *Oc6 Ocyptamus* sp 6, *Oc7 Ocyptamus* sp 7, *Oc8 Ocyptamus* sp 8, *Oc9 Ocyptamus* sp 9, *Oc10 Ocyptamus* sp 10, *Mm Mixogaster mexicana, Pc Pseudodorus clavatus*

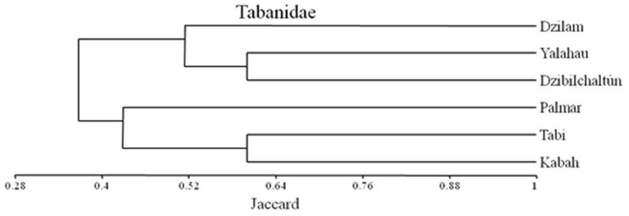

Fig. 6 Similarity between Tabanidae communities from each NPAs in relation to shared species

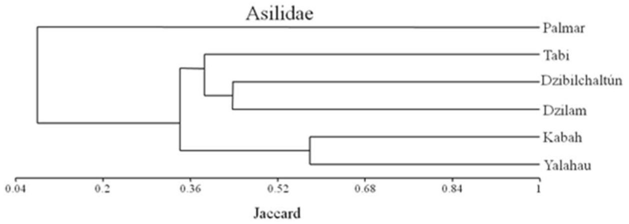

Fig. 7 Similarity between Asilidae communities from each NPAs in relation to shared species

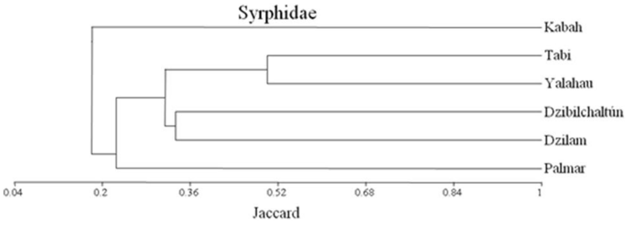

Fig. 8 Similarity between Syrphidae communities from each NPAs in relation to shared species

Dzibilchaltún (Table 2). Asilidae from Yalahau showed the highest diversity (H' = 2.17), with similar diversity at Kabah and Dzilam (Table 2). Syrphidae of El Palmar showed the highest diversity (H' = 2.3), followed by the Dzilam community, and the lowest diversity was observed at Kabah (Table 2).

Similarity

The set of communities is represented in the form of a UPGMA dendogram (Figs. 6, 7, 8). The similarity was approximately 60% at each collection point. The coastal dune vegetation of El Palmar showed the lowest similarity in comparison with those from the tropical forest vegetation. For Tabanidae, the primary division is found in two clades: the first corresponds to the tropical deciduous forest (Yalahau and Dzibilchaltún) and the second, to the semi-deciduous tropical forest (Tabi and Kabah), both with a similarity close to 60%. Asilidae and Syrphidae were composed in two main clades, the first one is an association between tropical deciduous forest (Dzibilchaltún and Dzilam in both cases) with about 45 and 50% of similarity, respectively. The second showed an association between semi-deciduous tropical forest and tropical deciduous forest (Kabah and Yalahau in

Asilidae, Tabi and Yalahau in Syrphidae, respectively) with ca. 55 and 35%, respectively. These results show the importance of the spatial and vegetation type component in the forecast of the community structure.

Discussion

A total of 6 910 individuals of Tabanidae, Asilidae and Syrphidae were collected during the entire sampling period. Generally, all parameters analyzed (species richness, abundance, diversity and similarity) were higher in the communities from tropical deciduous forests compared with those from semi-deciduous forests and coastal dune vegetation.

We registered 78 species/morphospecies in the Tabanidae, Asilidae and Syrphidae families (Table 2). From these, 38 were identified at the species level and 40 as morphospecies, representing 16.28% of the species reported in Mexico. This number of species/morphospecies is similar (84 species) compared with estimates recorded previously for these groups in Yucatan (Ibáñez-Bernal 1998; Manrique-Saide et al. 2001, 2010, 2012; León-Cortés et al. 2015). Tabanidae species richness recorded in this study (16 species) represented 6.96% of the species reported in Mexico (201 species, Fairchild and Burger 1994; Ibáñez-Bernal and Coscarón 2000; BDWD 2008). For Asilidae, 17 genera of Asilidae were recorded in the six NPAs studied, which corresponds to 58% of total genera reported in Mexico (29) (Ibañez-Bernal and Martín del Campo 2009). Finally, from the 221 species of Syrphidae that have been recorded in Mexico, in this study 36 species/morphospecies were recorded representing 16% of the total species for Mexico (Papavero 1966; Papavero and Ibáñez-Bernal 2001, 2003; León-Cortés et al. 2015). The Clench model had a good adjustment (even if none of the species accumulation curves reached an asymptote) to the curves, with percentages of reasonable variance ranging between 97 and 98%. This result indicates that the model provides a reliable estimation with minimum effort required to obtain an efficient inventory of species (Soberón-Mainero and Llorente-Bousquets 1993). Furthermore, this model showed that the number of expected species is equivalent to the actual number of species in Tabanidae and Asilidae (León-Cortés et al. 2015). Communities of Tabanidae and Asilidae showed a high percentage of recorded species (84 and 74%, respectively). In the case of Syrphidae communities, the model only recorded 36% of species richness; which would probably be explained by the effect of the sampling method (Malaise trap), time of exposition and the behavior of rare species.

Tabanidae species richness in Dzilam and Yalahau (flooded areas) could be explained by the biology and behavior of larvae, which usually occupy aquatic and semiaquatic habitats (*v.g. Tabanus*), while the pupae of some species (*Chrysops*) are found more often on beaches with abundant organic matter (Salom and Vega 1990). McElligott and Galloway (1991) suggested that in temperate regions, peatland is essential for tabanid breeding, as eggs are laid near water. Species richness within this family in NPAs analyzed in this study could be explained by the variation of the conditions necessary for the development of these insects, thus generating microhabitats in the tropical deciduous forest and seasonally flooded forest (SECOL 2004b, 2006). Additionally, it is likely that richness is determined by temporal phenology of each species and its association with the vegetation type (Barros and Foil 1999; Foil 1999; Ibáñez-Bernal 1998; Barros 2001; Koller et al. 2002). The abundance of many Tabanidae species seems to be determined by the temporal phenology. *Tabanus haemagogus* and *Leucotabanus itzarum*, for example, emerged and were more abundant during the rainy season (July), and although *T. commixtus* was present all year long, it had a higher abundance at the beginning of the rainy season (May). In general, heterogeneity and abundance of all Tabanidae species recorded in this study were higher during the rains, while their populations reduced during north winds (December–January) and dry (March–April) seasons. These results can be explained by the development of immature stages during the first months of the rainy season, followed by the emergence of adults. Similarly, some authors found an increase in horseflies' abundance in the Pantanal region of Brazil (Barros and Foil 1999; Barros 2001; Koller et al. 2002) during the early part of the rainy season. This evidence remarks the importance of sampling during different seasons for studies of biodiversity. The dominance in abundance of Tabanidae (adult females) could be explained by the phenology of the species, which is strongly associated to temporary bodies of water that form during the rainy season. Also, the high number of individuals found in our study could be related to livestock activity, and this variable should be considered in future studies of diversity in this region, since livestock activity occurs inside and surrounding most of the NPAs in Yucatán (e.g., Dzilam) (SECOL 2006; Ortiz et al. 2016).

In the UPGMA analysis, Tabanidae communities are defined in two groups, the first being Dzilam, Yalahau, Dzibilchaltún and Palmar, Tabi, Kabah. In the first group the similarity follows a pattern according to the type of dominant vegetation (seasonally flooded and deciduous tropical forest), indicating that the presence of a permanent body of water is important for the development of this group (SECOL 1993, 2007b; SECOL and UADY 2004a). The second group showed the same pattern related with the vegetation type (semi-deciduous tropical forest). These results also indicate that specialists and generalist species are sensitive to vegetation types and geographic regions, as suggested in another studies (Ibáñez-Bernal 1998; Hughes et al. 2000).

The species richness found in Asilidae could be explained partially because of the variety of habitats in which they live. This is especially true for areas with undisturbed forests, with primary or late secondary growth. The Asilidae richness also depends on the variety and availability of roosting sites, types and sizes of prey, temporal phenology of each species and others aspects of the microhabitat (Fisher and Hespenheide 1982; Shelly 1985). In this regard, McCravy and Baxa (2011) demonstrated that richness in a recently burned prairie was lower than expected compared with forest habitats. Also, Kartawich (2009) corroborated that richness is greater in unmanaged temperate forests. Moreover, modern agricultural practices have been related to the decrease and disappearance of robber fly populations in certain industrialized countries (Larsen and Meier 2004). In addition, some authors have discussed that high species richness in Asilidae communities from tropical and temperate areas is related to the conservation status of vegetation and microhabitat (Fisher and Hespenheide 1982; Shelly 1985; Larsen and Meier 2004; Kartawich 2009; McCravy and Baxa 2011). Therefore, the presence of vegetation patches without management of NPAs Dzilam, Dzibilchaltún and Yalahau (SECOL and UADY 2004b; SECOL 1993, 2006) can be another factor that favors the maintenance of Asilidae communities. The abundance of Asilidae communities seems to be affected mainly by perturbations (fire, anthropocentric activities, etc.), showing significant variation in robber fly communities that occur over relatively small geographic areas, which may affect its abundance and diversity (Larsen and Meier 2004; McCravy and Baxa 2011). Most of the NPAs have different degrees of perturbation due to livestock, agriculture, pollution, etc. (SECOL 1993; SECOL and UADY 2004a, 2004b; SECOL 2006, 2007a, b). Robber fly abundance also depends on the availability of prey at different distances above the ground level (vertical abundance), which may determine their abundance/activity (Kartawich 2009). Robber fly species composition showed an association with both NPAs deciduous forests (Yalahau) and semi-deciduous forests (Kabah). This association may be due to the biology of the species selecting microhabitats (fallen logs, hunting and perch sites) and the degree of conservation. The forests at this site seem to have some availability of sites and resources (*v.g.* preys) (Morgan et al. 1985; Cannings 1997, 1998).

Syrphidae community richness could be related to the diversity and availability of floral resources in plant communities, since some species of hoverflies forage for nectar and/or pollen and have proven to be good pollinators (Fontaine et al. 2006; Sarmiento-Cordero et al. 2010). The high richness of hoverfly species in the Palmar compared to the other sites could result from two factors, (i) low richness of wild bees (Reyes-Novelo 2009), as some studies have suggested that hoverflies occupy niches that wild bees do not occupy (Zamora-Carrillo et al. 2011), and (ii) the hostile conditions of coastal dune vegetation for some flying insects (e.g. bees), such as the constant strong winds that could favor pollination by anemophily and small insects (SECOL 2007a). Evidence indicates that species richness of hoverflies within communities can vary temporally, thus requiring multi-year studies and a combination of sampling methods for more accurate estimations (Namaghi and Husseini 2009). According to Humphrey et al. (1998) the diversity of Syrphidae communities could be correlated with a high diversity of habitat and microhabitats for larvae, thus supporting their function as good environmental indicators. Seasonality in the abundance of Syrphidae seems to be related to the availability of resources (Sarmiento-Cordero et al. 2010). Rains are crucial for phenological responses of tropical deciduous forest, which have two flowering peaks: the beginning of July and October (Bullock and Solis-Magallanes 1990). Given the interaction between flowering plants and hoverflies, many pollen feeders and meliphagus can possibly be synchronized with the phenology of these flies and some plants (Janzen and Schoener 1968). It is well known when the heterogeneity of the land cover type increase, this have a positive effect on Syrphidae biodiversity. This dependence is related with the flowers resources. The homogeneity of the vegetation and limited flowers resources in the NPAs of Yucatan may explain the low diversity of the hoverflies (SECOL 1993, 2004a, b, 2006, 2007a, b).

Hoverfly similarity was confirmed by the groups Tabi-Yalahau and Dzibilchaltún-Dzilam. These species compositions were associated with different vegetation types. Naderloo and Pashaei (2014) found that the similarity of species composition may be related to a wide range of habitats, water bodies and plant richness with floral resources, which can support representative species of these vegetation types in the NPAs (Sarmiento-Cordero et al. 2010; SECOL and UADY 2004a, b; SECOL 1993, 2006).

Currently there is not a globally accepted protocol for collecting forest insects (Fast 2003). Generally it is accepted that Malaise traps can commonly be combined with other traps, such as pans for insect biodiversity surveys. Brown (2005) mentioned that the Malaise trap is one of the most popular collecting methods to gather insects, primarily flies, in tropical biodiversity surveys. Marshall et al. (1994) suggested that in all habitats there should be at least one Malaise and one pan trap. Kartawich (2009) and McCravy and Baxa (2011) also mentioned that Malaise traps are very useful in forest habitats for dipterous species. The Malaise trap has been proven to be the best method for collecting Tabanidae in Yucatan, where the tabanids are one of the well-known groups (Fairchild and Burger 1994; Manrique-Saide et al. 2001, 2010, 2012). However, for the other groups there is not a consensus about which collecting method is the best. Cannings (1997, 1998) and Finn (2003) mentioned that Malaise traps tends to be very effective for Asilidae, especially when standing next to fallen logs and even above them. Forest edges also are good places to place these traps in temperate areas. Robber flies behavioral particularities may increase or decrease the relative likelihood of capture in Malaise traps. Such biases have been shown for epigeal spiders in pitfall trap collections (Topping 1993) and for bees with a variety of trap types, including Malaise traps (Geroff et al. 2014). Therefore it is probably that some Asilidae species present at the study sites are relatively unlikely to be collected by Malaise traps. In further studies, combining Malaise traps with another collection method, such as active aerial netting, would likely provide a better robber fly species inventory (McCravy and Baxa 2011). It is known that the best way to get a representative sample of hoverflies is the sweep net (Pérez-Bañón 2000; Sánchez and Amat-García 2005; Ricarte and Marcos-García 2008; Naderloo and Pashaei 2014). In contrast, the use of Malaise traps in temperate zones (Ouin et al. 2006; Burgio and Sommaggio 2002) and in the Neotropics (Gutiérrez et al. 2005) has proven to be a very efficient catching method. There are also studies comparing the effectiveness of Malaise traps and sweep nets to yellow plates in temperate zones, the previous two being more efficient than Malaise traps (Burgio and Sommaggio 2002, 2007). On the contrary, Namaghi and Husseini (2009) demonstrated that Malaise traps are more effective than sweep net and yellow plates. Other studies have used entomological nets and Malaise traps (Sarmiento-Cordero et al. 2010; Arcaya et al. 2013). Therefore, Malaise traps are a useful method to supplement intended sampling of hoverflies (Pineda and Marcos-García 2008; Ricarte and Marcos-García 2008). Hence, in order to draw a complete species list of an area, a combination of both collecting methods should be implemented (Petanidou et al. 2011). Many studies have focused on comparing the effectiveness of different trapping methods in insect biodiversity surveys, frequently lacking conclusive results (Fast 2003). In a Neotropical insect survey using Malaise traps, Brown (2005) found that flies constituted 64 to 84% of the samples. Even if there is not a consensus on which method would be best to characterize different families of Diptera, we believe that the extensive sampling we have performed with Malaise traps should contain a large portion of the dipteran diversity of these NPAs and give some insights of the dynamics of these communities.

Conclusions

This study constitutes an initial attempt to set an insect diversity survey, focusing on Diptera communities (Tabanidae, Asilidae and Syrphidae) in Natural Protected Areas of Yucatan, Mexico. In the state NPAs of Yucatan is known that shelter over 200 species of Diptera (Ibañez-Bernal 1998). Tropical deciduous forests showed the highest values of diversity, richness, and abundance of the studied groups. Paradoxically, tropical deciduous forests are among the vegetation types that suffer the greatest losses and fragmentation due to anthropocentric activity (Trejo and Dirzo 2000, 2002). Measurement of species diversity has become a vital aspect in understanding tropical communities and their conservation (DeVries et al. 1997). In this study, the species richness was similar compared with the species recorded in Yucatan for Tabanidae, Asilidae and Syrphidae which could indicate that, even using other sampling methods, the species composition could be similar across the Peninsula of Yucatan (geographic homogeneity). We suggest that further studies should be done combining different sampling methods (sweep net, McPhail) and for a longer period of time. Taxonomy provides an organizational framework to recognize, interpret and value the diversity, and is therefore the cornerstone of conservation (Bisby et al. 1995). However, taxonomic and logistic constraints frequently encountered during conventional taxonomic treatment have greatly restricted its use. In order to overcome the issues related with species identification, we suggest that non-specialists or taxonomist (specialist in different groups of arthropods/insects) may classify invertebrates/insects to morphospecies without compromising scientific accuracy (Oliver and Beattie 1996a, b). It should be a priority to increase the environmental monitoring, biodiversity and conservation surveys/evaluations in terrestrial habitats, as well as increase the invertebrate inventories in the NPAs of Yucatan. This information will be valuable for conservation purposes taking into account that some of these areas are in risk, due to illegal human settlements, land use changes, illegal logging, illegal hunting of wildlife, final disposal of chemicals and wastes close to water bodies, ecotourism, etc (Ruíz-Barranco and Arellano-Morín 2010).

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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