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ODONATA DIVERSITY IN A TROPICAL DRY FOREST OF MEXICO, 1. SIERRA DE HUAUTLA, MORELOS

E. GONZÁLEZ-SORIANO[1], F.A. NOGUERA[2], S. ZARAGOZA-CABALLERO[1], M.Á. MORALES-BARRERA[1], R. AYALA-BARAJAS[2], A. RODRÍGUEZ-PALAFOX[2]† and E. RAMÍREZ-GARCÍA[2]

[1] Departamento de Zoología, Instituto de Biología, Universidad Nacional Autónoma de México, Avenida Universidad 3000, MX-04510 Ciudad Universitaria, D.F., Mexico

[2] Estación de Biología Chamela, Instituto de Biología, Universidad Nacional Autónoma de México, Km. 59 Carretera Barra de Navidad-Puerto Vallarta, MX-48980 San Patricio, Jalisco México

† deceased

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A study of the fauna of Odonata of a tropical deciduous forest is presented. Collections were made monthly during a 1-yr period (Nov. 1995-Oct. 1996) during 5 days each month. A total of 2595 adult specimens were collected, belonging to 57 species, 33 genera and 8 families. Estimated richness value using the non-parametric estimator ICE was 76.28.

INTRODUCTION

This paper is part of a long-term project to study the diversity and patterns of distribution of the fauna of insects associated with the tropical dry forest (TDF) in México (NOGUERA et al., 2002; ZARAGOZA et al., 2003).

The TDF is one of the most diverse ecosystems in America and also one of the most endangered (JANZEN, 1988). In México it covers almost 8% of the country's surface and harbors a large number of endemic species (TOLEDO & ORDOÑEZ, 1993; FLORES & GEREZ, 1994; CEBALLOS & GARCÍA, 1995). This plant community extends in a more or less continuous fashion from Sonora to Chiapas states with other intrusions in the Yucatan Peninsula and in some areas of the Gulf of Mexico (PENNINGTON & SARUKHÁN, 2005). Since 1990 only 27% of its surface has remained intact (TREJO & DIRZO, 2000).

Odonata are predacious insects which do not depend directly upon plants, at least in the trophic level, as most of the other insects do. However, they use vegetation in several other ways: e. g. as breeding sites for larvae (e. g. phytotelmata

and ground litter) (PAULSON, 2006) or for shelter, oviposition, roosting sites or habitat selection for adults (BUCHWALD, 1992; CORBET, 1999; PAULSON, 2006). Vegetation is also used for concealing adults from predators and as mating areas and feeding perches (BUCHWALD, 1992). The study of the diversity and distribution of Odonata associated to the TDF is almost non-existent and only a few published works deal with this topic for Mexico (DUNKLE, 1976; GONZÁLEZ-SORIANO et al., 2004).

MATERIAL AND METHODS

STUDY AREA – The study area is located in a portion of the Sierra of Huautla Biosphere Reserve (SHBR), located in south central Morelos State, México (18°20´10" to 18°34´20"N and 98°51´20" to 99°08´15"W) (DORADO, 1997). The climate is warm subhumid, type *Awo"(w) (i') g* according the Köeppen classification modified by GARCIA (1981). Average annual precipitation for the period 1981-1997 was 824 mm, with 80% of the rain falling from June to September. Mean temperature for the same period was 24.7°C, with an average maximum temperature of 34.3°C and an average minimum temperature of 15.0°C (CNA, 2000). The site is included within the Atoyac and the Amacuzac river basins. The area is covered mostly by TDF although other plant associations are also found here (e.g. gallery forest, secondary vegetation and agriculture lands).

Odonate collections were made at three sites. The first of these is located along the Quilamula river (18°27'671"N, 99°02'475"W) near the facilities of the Center of Environmental Education and Research Sierra de Huautla (CEAMISH), the second along a canyon made by the Ajuchitlán river (18°27'065"N, 98°59'546"W) near the town of Ajuchitlán and the last one (Arroyo Los Idolos) at a secondary stream confluent with the Ajuchitlán river near the entrance of the town. The first site (Quilamula river) has water throughout the year specially down river due to the presence of the Lorenzo Vázquez dam. The last two streams lack water during the dry season. Collections were made during five days of every month (between November 1995 and October 1996) and they were carried out by two persons; the senior author and one student (Ma. de los Angeles Morales), except in September when collections were made only by the student.

ANALYTICAL METHODS – The values of richness and abundance correspond to the number of species and individuals recorded. Diversity and evenness were analyzed with Shannon Index, using the natural logarithm, and values were obtained with the program BioDiversity Pro (McALEECE et al., 1999).

Considering that the observed number of any sample of individuals from a species rich community underestimates the true number of species present, a non-parametric estimator of species richness was performed using data obtained during the year of the study to determine how close the richness value recorded was representative of the true local richness. The estimator used was ICE, an incidence-based estimator, because it best satisfied the requirements for an ideal species-richness estimator (CHAZDON et al., 1998). ICE estimator is based on species found in ≤ 10 sampling units and its formula is (COLWELL, 2006):

$$S_{ice} = S_{freq} + \frac{S_{infr}}{C_{ice}} + \frac{Q_1}{C_{ice}} \gamma^2_{Ice}$$

where S_{freq} is the number of species found in > 10 samples, S_{infr} is the number of species found in 10 or fewer samples; C_{ice} is the sample incidence coverage estimator. Q_1 is the number of species that occur in only one sample and γ^2ice is the estimated coefficient of variation of the Q_1's for infrequent species.

The estimates were calculated using Estimate S 6.0b1 (COLWELL, 2006). The species collected within each day were considered one sample unit (53 in total).

For phenology analysis of the data, we considered the rainy season to last from May to November and the dry season to last from December to April. This was based on the occurrence of individual storm events totaling greater then 15 mm, because the canopy intercepts smaller amounts almost completely (CERVANTES, 1988).

RESULTS

RICHNESS

A total of 2595 adult specimens were collected, belonging to 57 species, 33 genera and eight families. These values represent 61% of the species, 82% of the genera and 89% of the families previously reported for the state of Morelos, México (GARCÍA, 1987; GONZÁLEZ-SORIANO& NOVELO-GUTIERREZ, 1996, 2007; NOVELO, 1997).

The family with the greatest number of species was Libellulidae with 27 species (47% of the total), followed by Coenagrionidae with 16 (28%), Aeshnidae with 7 (12%), Gomphidae with 3 (5%) and Calopterygidae, Lestidae, Platystictidae and Protoneuridae with one each (2% each).

Libellulidae was also the family with the greatest number of genera with 16 (48%) followed by Coenagrionidae and Aeshnidae with 5 each (15% each), Gomphidae with 3 (9%); Calopterygidae, Lestidae, Platystictidae and Protoneuridae with one each (the remaining 13%).

Argia was the most diverse genus with 9 species (15.8%) followed by *Enallagma*, *Erythrodiplax*, *Dythemis* and *Micrathyria* with three species each (21%), *Ischnura*, *Rhionaeschna*, *Gynacantha*, *Libellula*, *Macrothemis*, *Orthemis*, *Perithemis* and *Tramea* with two species each (28.1%). The rest (21) of the genera consisted of one species each (37%). Thus, 65% of the genera recorded were represented by two or fewer species.

ESTIMATED RICHNESS. – The richness estimated was larger than the richness observed: 76.28 (SD ± 0.02) against 57 species. This may mean that we only recorded 75% of the true local richness. On the other hand, the species accumulation curve computed had began to reach the asymptote (Fig.1), which probably indicates that the estimated value could be a true reflection of

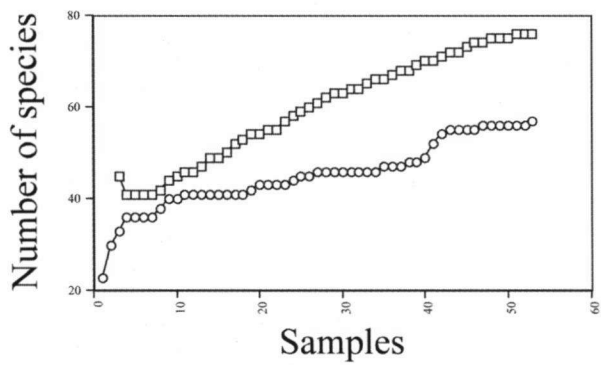

Fig. 1. Observed (circle) and estimated (square) species accumulation curves of Odonata fauna of Huautla, Morelos.

the estimated richness for this locality.

ABUNDANCE

The distribution per species of 2595 adult specimens was heterogeneous; a few species were very abundant but most others were represented by one or a few individuals (Fig. 2). The most abundant species was *Argia tezpi* with 443 individuals, followed by *A. pulla* with 362, *A. oenea* with 194, *Hetaerina americana* with 190, *Telebasis salva* with 151, *Dythemis nigrescens* with 119 and *Protoneura cara* with 109. All abundant species (excepting the libellulid *D. nigrescens*) are zygopterans. In contrast, 11 species were represented by one individual and 17 by less than 10 individuals.

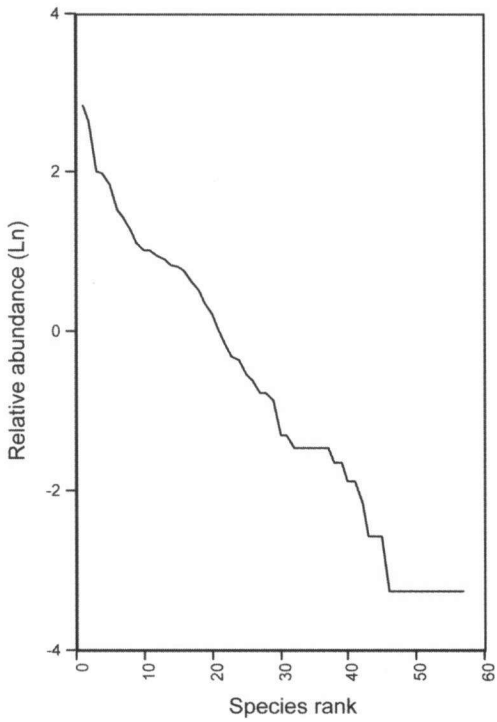

Fig. 2. Rank-abundance pattern of the Odonata of Sierra de Huautla.

DIVERSITY

The diversity value calculated with the Shannon Index over the entire year was 3.04 and the evenness index was 0.75. The diversity values by month varied, with the lowest value recorded in May (2.2) and the highest recorded in July (3.1). The lowest and highest values of the evenness index were recorded in April (0.755) and July (0.91) respectively (See Table 1)

Table I
Diversity and evenness indexes obtained monthly of the Odonata fauna from Huautla, Morelos

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Diversity	2.99	2.8	2.6	2.8	2.4	2.4	2.2	2.3	3.1	2.3	3.01	2.8
Evenness	0.84	0.85	0.82	0.87	0.79	0.75	0.78	0.76	0.91	0.88	0.85	0.89

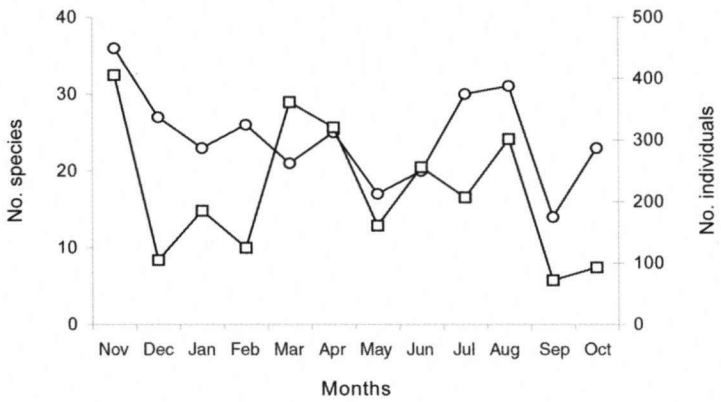

Fig. 3. Pattern of species richness (circles) and abundance (squares) of Odonata of Sierra de Huautla per month.

PHENOLOGY

The annual activity pattern showed that the richness reached the highest value in November (36), at the end of the rainy season and the lowest in May (17), at the end of the dry season, with a gradual and nonconstant decrement between the highest and lowest value (Fig. 3).

The abundance showed a greater variation than the richness, recording the highest values in November, March and August and the lowest in December and October (Fig. 3).

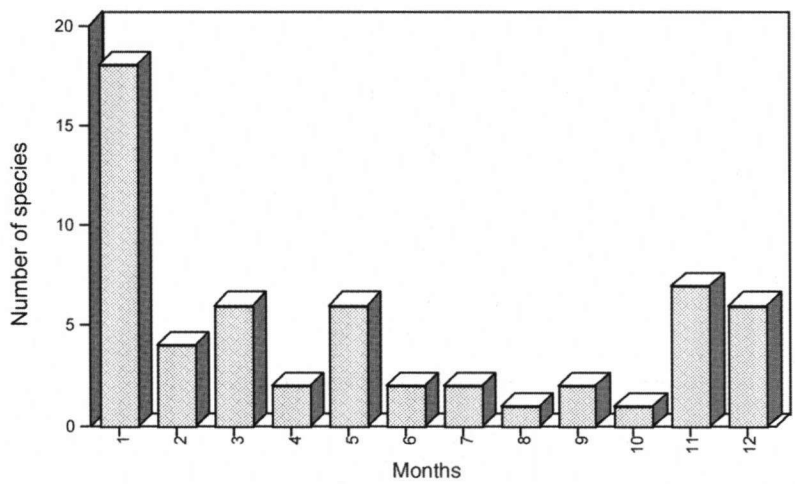

Fig. 4. Number of active species per month of Odonata of Huautla.

Despite the temporal variation recorded in richness and abundance, there was not significant differences of these variables between the rainy and the dry season (Mann-Whitney U, p = 0.6 and p = 0-5 respectively).

On the other hand, sixteen (28%) species were recorded only in the rainy season, seven (12%) during the dry season, and 34 (60%) within both periods.

The number of months adults were on the wing was variable. Eighteen species (31.6%) were active during only one month and 28 (49%) were active during three months or less. Contrastingly, 13 (22.7%) species were active at least during 11 months (Fig.4).

LIST OF ODONATE SPECIES RECORDED IN THE SIERRA DE HUAUTLA, MÉXICO

The list includes numbers of individuals collected (in bold), information when the adults were collected and in some cases information about natural history.

ABBREVIATIONS USED: **YR** = species that fly throughout the year; – **AYR** = species which apparently fly throughout the year.

Zygoptera

CALOPTERYGIDAE

Hetaerina americana (Fabricius, 1798). **190**. November to October. **YR**. Lotic.

LESTIDAE

Archilestes grandis (Rambur, 1842). **64.** November to February and April to October.

PLATYSTICTIDAE

Palaemnema domina Calvert, 1903. **3**. July. Collected at the sunset, one pair in tandem.

PROTONEURIDAE

Protoneura cara Calvert, 1903. **109**. November to August, October. **AYR**.

COENAGRIONIDAE

Apanisagrion lais (Brauer in Selys, 1876). **1**. February.

Argia anceps Garrison, 1996. **44**. November, January to April, June to September.

Argia carlcooki Daigle, 1995. **18**. November, February-March.

Argia extranea (Hagen, 1861). **73**. November to April, June to August.

Argia harknessi Calvert, 1899. **59**. April to August.

Argia oculata Hagen *in* Selys, 1865. **7.** November to February, July.

Argia oenea Hagen *in* Selys, 1865. **194**. November to October. **YR**.

Argia pallens Calvert, 1902. **73**. May to August, October.

Argia pulla Hagen *in* Selys, 1865. **362.** November to October. **YR**.

Argia tezpi Calvert, 1902. **443**. November to October. **YR**.

Enallagma civile (Hagen, 1861). **1.** March.

Enallagma novaehispaniae Calvert, 1907. **68**. November, January to October. **AYR**.

Enallagma semicirculare Selys, 1876. **60**. November, January to May, July-August, October.

Ischnura hastata (Say, 1839). **6**. December, February-March.

Ischnura ramburi (Selys, 1850). **1**. August.

Telebasis salva (Hagen, 1861). **151**. November to June, August to October. **AYR**.

AESHNIDAE

Anax walsinghami MacLachlan, 1883. **1**. July.

Coryphaeschna adnexa (Hagen, 1861). **1**. November.

Gynacantha helenga Williamson & Williamson, 1930. **1**. September.

Gynacantha nervosa Rambur, 1842. **1**. January.
Remartinia luteipennis florida (Hagen, 1861). **1**. November.
Rhionaeschna multicolor (Hagen, 1861). **1**. August.
Rhionaeschna psilus (Calvert, 1947). **6**. November to January, October.
GOMPHIDAE
Aphylla protracta (Hagen *in* Selys, 1859). **14**. July-August.
Phyllogomphoides pacificus (Selys, 1873). **79**. November, June to August.
Progomphus clendoni Calvert, 1905. **4**. July.
LIBELLULIDAE
Brachymesia furcata (Gundlach, 1889). **4**. April.
Brechmorhoga praecox postlobata Calvert, 1898. **56**. December, May to August.
Dythemis maya Calvert, 1906. **27**. November-December, February, July –August.
Dythemis nigrescens Calvert, 1899. **119**. November to October, **YR**.
Dythemis sterilis Hagen. **6**. November.
Erythemis plebeja (Burmeister, 1839). **11**. November-December, February-March.
Erythrodiplax basifusca (Calvert, 1895). **19**. November-December, February, April, October.
Erythrodiplax funerea Hagen. **2**. April.
Erythrodiplax fusca Rambur. **5**. November, January, April.
Libellula croceipenis Selys, 1868. **22**. November-December, April, June to August, October.
Libellula saturata Uhler, 1857. **1**. October.
Macrothemis inacuta Calvert, 1898. **6**. November-December, April, June to August, October.
Macrothemis pseudimitans Calvert, 1898. **37**. November-December, February to August, October.
Miathyria marcella (Selys *in* Sagra, 1857). **32**. November to August, October. **AYR**.
Micrathyria aequalis (Hagen, 1861). **6**. November, April.
Micrathyria didyma (Selys *in* Sagra, 1857). **7**. November.
Micrathyria sp. nov. **1**. July.
Orthemis discolor (Burmeister, 1839). **12**. November to February, August.
Orthemis ferruginea (Fabricius, 1775). **12**. November-December, April, July to October.
Paltothemis lineatipes Karsch, 1890. **15**. June to August.
Pantala flavescens (Fabricius, 1798). **5**. December-January, August.
Perithemis domitia (Drury, 1773). **2**. August, October.
Perithemis intensa Kirby, 1889. **94**. November to October. **YR**.
Pseudoleon superbus (Hagen, 1861). **49**. November to August, October. **AYR**.
Sympetrum illotum (Hagen, 1861). **1**. November.
Tramea abdominalis (Rambur, 1842). **1**. December.
Tramea onusta Hagen, 1861. **6**. November, January, August.

DISCUSSION

The number of species recorded in Huautla is lower than that recorded in the region of Chamela, Jalisco state (57 vs 78 spp respectively) (GONZÁLEZ-SORIANO et al., 2004). Chamela is situated at higher latitude than Huautla (19°30' vs 18°20' respectively) but at a lower altitude (<150 vs 900-940 m respectively) (BULLOCK, 1988) and is also covered by TDF. The differences in richness between Huautla and Chamela apparently are determined by the sampling of a greater diversity of habitats in Chamela than in Huautla. In Huautla most of the sampled habitats were lotic whereas in Chamela both lotic and lentic habitats were sampled.

GONZÁLEZ-SORIANO et al. (2004) commented that the species richness of Chamela is magnified by the presence of species belonging to Libellulidae and some Coenagrionidae both inhabitants of standing waters. Species found in such habitats are usually not found flying over small streams or in small openings in primary forest. LOUTON et al. (1996) considered Libellulidae, Coenagrionidae (minus *Argia*) and also Aeshnidae as "weed" species by their wide distribution and great capacity to colonize new sites for their development. On the contrary, species not included in those groups likely have narrow distributions and they characterize better the fauna of one region. If we eliminated the weed species in our comparison, the resulting number of species between both regions is almost identical: 17 spp. in Chamela vs 16 spp in Huautla. On the other hand, a comparison between Libellulidae and Coenagrionidae in both areas show that there were 42 spp. of Libellulidae and 14 of Coenagrionidae in Chamela versus 27 and 16, respectively for Huautla. In this way, the bigger difference was observed in Libellulidae and this family is responsible for 71% of the richness differences recorded between both regions (see Fig 5). Species collected in Huautla which have not been collected in Chamela are: *Palaemnema domina*, *Argia carlcooki*, *A. extranea*, *A. harknessi*, *A. pallens*, *Aphylla protracta* and *Phyllogomphoides pacificus*.

The absence of a seasonal pattern in both richness and abundance contrasts with the strongly seasonal nature of the area and with those observed for other groups

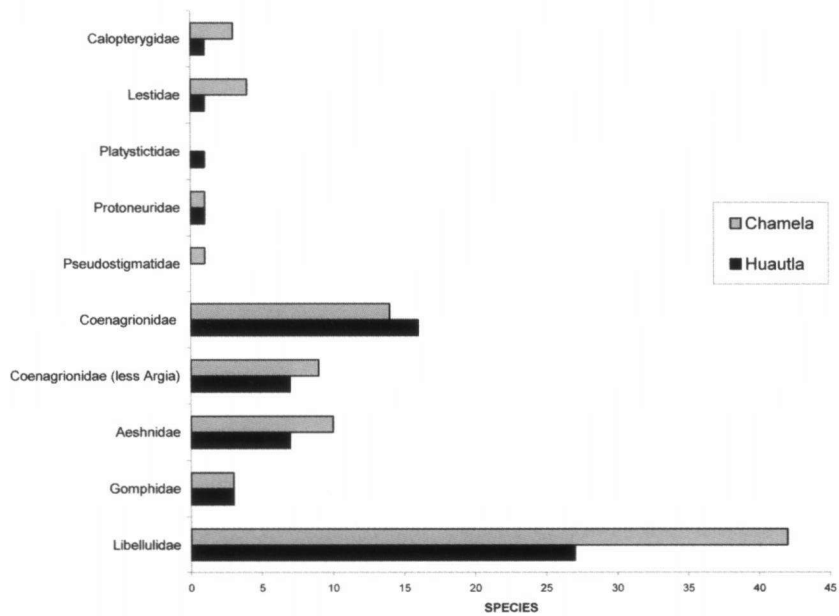

Fig. 5. Species and families of Odonata at Chamela (grey bars) and Huautla (solid bars).

of insects within the same study area (NOGUERA et al., 2002; ZARAGOZA et al., 2003). Although this pattern has been reported in other groups of insects (LEVINGS & WINDSOR, 1985; PESCADOR et al., 2002), the absence of a seasonal pattern in both variables could have been influenced in one of the collecting sites by the Lorenzo Vázquez dam located in the Quilamula river. During the dry season the odonates were collected after the damming of the reservoir, where the water supplement was constant all year long, thus creating continuous conditions for many species along the entire year. This effect was also observed in two species of Lampyridae, that during the dry season were collected only after the damming of the reservoir but not up-stream (ZARAGOZA et al., 2003) a fact that seems to support our previous statement. Additionally, in Chamela (an area with temporal water bodies) the proportion of species recorded between seasons is inverse, with 65% of the species recorded only in the rainy season (versus 28% in Huautla) and 32% recorded in both seasons (versus 60% in Huautla).

CONCLUSIONS

The species richness of Odonata of the Sierra de Huautla Biosphere Reserve (SHBR) is outstanding. The SHBR with an extension of 59 031 hectares constitutes almost 12% of the Morelos state surface. In this small area it is represented almost the 56% of the total Morelos odonate diversity (GONZÁLEZ-SORIANO & NOVELO-GUTIERREZ, 1996, 2007). Although other sites with tropical dry forest in Mexico have a higher species richness than the SHBR, (for example Chamela region), a close analysis showed that the increased richness of the last site is due to the higher number of species belonging to groups with wide distribution as Libellulidae, Aeshnidae and some Coenagrionidae.

Finally, the following 7 species are recorded for the first time in the state of Morelos: *Argia anceps*, *A. carlcooki*, *Anax walsinghami*, *Gynacantha nervosa*, *Dythemis sterilis*, *Macrothemis pseudimitans* and *Tramea abdominalis*. *Argia anceps* was formerly recorded as *A. fissa* (GARRISON, 1996; GONZÁLEZ-SORIANO & NOVELO-GUTIÉRREZ, 1996).

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