12-2023

Can the Vegetation Structure and Composition in Urban Green Spaces Determine Diversity of Green Lacewings (Neuroptera: Chrysopidae)?

Jose I. Martinez
University of Florida, joemartinez@ufl.edu

Raiza J. Castillo
University of Florida, raizajcastilloar@ufl.edu

Adrián Ardila-Camacho
Universidad Nacional Autónoma de México, aardilac88@gmail.com

Charles V. Covell
University of Florida, ccovell@flmnh.ufl.edu

José Isabel López-Arroyo
Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, lopez.jose@inifap.gob.mx

See next page for additional authors

Authors
Jose I. Martinez, Raiza J. Castillo, Adrián Ardila-Camacho, Charles V. Covell, José Isabel López-Arroyo, and Francisco Javier Nava-Guízar

A journal of world insect systematics
INSECTA MUNDI

1023

Can the vegetation structure and composition in urban green spaces determine diversity of green lacewings (Neuroptera: Chrysopidae)?

Jose I. Martinez
McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, Gainesville, FL, USA

Raiza J. Castillo
Agronomy Department, University of Florida, Homestead, FL, USA

Adrian Ardila-Camacho
Posgrado en Ciencias Biológicas, Instituto de Biología, Universidad Nacional Autónoma de México, Coyoacán, CDMX, Mexico

Charles V. Covell
McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, Gainesville, FL, USA

Jose Isabel López-Arroyo
Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental General Teran, NL, Mexico

Francisco Javier Nava-Guízar
Tecnológico Nacional de México Campus Conkal, YUC, Mexico

Date of issue: December 29, 2023

Center for Systematic Entomology, Inc., Gainesville, FL

Martinez JI, Castillo EJ, Ardila-Camacho A, Covell CV, López-Arroyo JI, Nava-Guízar FJ. 2023. Can the vegetation structure and composition in urban green spaces determine diversity of green lacewings (Neuroptera: Chrysopidae)? Insecta Mundi 1023: 1–22.

Published on December 29, 2023 by
Center for Systematic Entomology, Inc.
P.O. Box 141874
Gainesville, FL 32614-1874 USA
http://centerforsystematicentomology.org/

Insecta Mundi is a journal primarily devoted to insect systematics, but articles can be published on any non-marine arthropod. Topics considered for publication include systematics, taxonomy, nomenclature, checklists, faunal works, and natural history. Insecta Mundi will not consider works in the applied sciences (i.e. medical entomology, pest control research, etc.), and no longer publishes book reviews or editorials. Insecta Mundi publishes original research or discoveries in an inexpensive and timely manner, distributing them free via open access on the internet on the date of publication.

Insecta Mundi is referenced or abstracted by several sources, including the Zoological Record and CAB Abstracts. Insecta Mundi is published irregularly throughout the year, with completed manuscripts assigned an individual number. Manuscripts must be peer reviewed prior to submission, after which they are reviewed by the editorial board to ensure quality. One author of each submitted manuscript must be a current member of the Center for Systematic Entomology.

Guidelines and requirements for the preparation of manuscripts are available on the Insecta Mundi website at http://centerforsystematicentomology.org/insectamundi/

Printed copies (ISSN 0749-6737) annually deposited in libraries

Florida Department of Agriculture and Consumer Services, Gainesville, FL, USA
The Natural History Museum, London, UK
National Museum of Natural History, Smithsonian Institution, Washington, DC, USA
Zoological Institute of Russian Academy of Sciences, Saint-Petersburg, Russia

Electronic copies (online ISSN 1942-1354) in PDF format

Archived digitally by Portico.
Florida Virtual Campus: http://purl.fcla.edu/fcla/insectamundi
University of Nebraska-Lincoln, Digital Commons: http://digitalcommons.unl.edu/insectamundi/
Goethe-Universität, Frankfurt am Main: http://nbn-resolving.de/urn/resolver.pl?urn:nbn:de:hebis:30:3-135240

Can the vegetation structure and composition in urban green spaces determine diversity of green lacewings (Neuroptera: Chrysopidae)?

Jose I. Martinez
McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, Gainesville, FL, USA
joemartinez@ufl.edu

Raiza J. Castillo
Agronomy Department, University of Florida, Homestead, FL, USA

Adrian Ardila-Camacho
Posgrado en Ciencias Biológicas, Instituto de Biología, Universidad Nacional Autónoma de México, Coyoacán, CDMX, Mexico

Charles V. Covell
McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, Gainesville, FL, USA

Jose Isabel López-Arroyo
Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental General Teran, NL, Mexico

Francisco Javier Nava-Guízar
Tecnológico Nacional de México Campus Conkal, YUC, Mexico

Abstract. Green spaces represent the only natural areas in several cities around the world, providing good shelters for the local fauna. Based on this premise, many ecological studies have been conducted focused on these areas. Most of these works are about insects, particularly butterflies and beetles. Our study is centered on a different group: green lacewings (Neuroptera: Chrysopidae). These insects exhibit a similar feeding behavior to some other groups, such as beetles. We estimated diversity, richness, distribution, abundance and similarity employing two methods: sweep netting and suction trapping. Also, oviposition hosts were identified in 20 different green spaces. Approximately 740 specimens were collected representing 15 species in five genera. Seven species are **new state records** for Yucatán, Mexico. We identified about 300 species of plants, if which 75 are considered ovipositional associated hosts. Our work is the first of its kind, employing green lacewings in an urban ecological model and additionally providing new information about chrysopids in South Mexico. We encourage the conduct of similar studies not only in Mexico but also in other Central and South American countries.

Key words. Urban ecology, ovipositional associated hosts, richness, chrysopids, distribution.

ZooBank registration. urn:lsid:zoobank.org:pub:2EDE9BDC-ECDD-4613-82A0-36C6877DD6A7

Introduction

A worldwide problem in urbanized areas is the reduction of natural green spaces. This in turn decreases and alters the biodiversity associated with these areas (Blair 2001; Brown and Freitas 2002; Aronson et al. 2014). Mexico is no exception to this rule. Over one half of its territory has undergone some kind of land use change, which in turn has drastically altered natural ecosystems (Soto-Pinto 2008; Chavez-Zichinelli et al. 2010). Despite remarkable changes in the landscape some small natural areas called "green spaces" remain that provide recreational opportunities for humans as well as refuges for local flora and fauna (Niemelä 2014; Banaszak-Cibicka et al. 2016). A common misconception is the assumption that rural areas in Mexico contain higher biodiversity than urban areas, but a high percentage of rural areas in this country are used for agricultural activities. Agricultural practices, especially high-density farming, can severely alter or destroy entire ecosystems (Ramirez-Restrepo and Halffter 2013; Ramirez-Restrepo and MacGregor-Fors 2017). While many ecologists are dedicated to the study and preservation of natural areas, few have studied the flora and fauna of urban green spaces. These spaces sometimes present higher biodiversity than do agroecosystems (McKinney 2002; Koh and Sodhi 2004). Because green spaces can include both native and exotic and ornamental vegetation the mixture can accordingly influence the insect diversity (Uno et al. 2010). One of the groups showing affinity for urban green spaces are insects (Raupp et al. 2010; van Heezik et al. 2016). Of these the butterflies (Lepidoptera) represent the most successful model for adaptability in urban ecology (Oliveira et al. 2018; Aguillera et al. 2019; Sing et al. 2019). However, this preference does not apply to all members of the class Insecta, making it necessary to continue studying these kinds of habitats.

The green lacewings (Order Neuroptera; family Chrysopidae) have a worldwide distribution, and they are well represented in Mexico (Fig. 1). Because both larval and adult green lacewings are predatory, they have been widely used as biocontrol agents, including urban areas (Nair et al. 2020). They are ecologically reminiscent of butterflies in that there is a shift food preference from larval to adult forms. Chrysopid larvae are exclusively predacious on small invertebrates while adults feed on other insects, pollen, nectar, and insect honeydew (Devatak and Klokocovnik 2016; Ye et al. 2017; Koczor et al. 2019). Female lacewings also are very selective as to their choices of oviposition sites on plants (Clark and Messina 1998). In addition to their previously noted behaviors, it has been observed that a high diversity of chrysopids can be an indicator of good environmental health in many terrestrial ecosystems (Thierry and Canard 2007; Deloya and Ordoñez-Resendiz 2008).

The family Chrysopidae currently includes about 1,400 species and subspecies, divided into three subfamilies and 82 genera (Garzón-Orduña et al. 2019; Oswald 2023). So far, 100 species in 17 genera have been recorded in Mexico (Tauber and De León 2001; Contreras-Ramos and Rosas 2014; Cancino-López and Contreras-Ramos 2019; Oswald 2023). Many of these have not been found in other countries, and yet this family is less well known

Figure 1. *Ceraeochrysa claveri* Navás. the most abundant species in the green places in Mérida.

in Mexico than some other insect groups (Valencia-Luna et al. 2006). In the case of the Yucatán state of Mexico, there have been few studies on the Neuroptera, including the green lacewings.

The present study was undertaken to increase the knowledge of the ecology of chrysopids in urban ecosystems in Mexico, and further raise awareness on their importance in those places with respect to the overall faunal diversity. This work is the first study of urban ecology using chrysopids as a model. We also present the first checklist of ovipositional associated hosts for green lacewings anywhere.

Materials and Methods

Study area. The study area was located in Mérida, the capital city of Yucatán state, Mexico (20°06′06″N, 89°02′39″W; Fig. 2). Mérida has 541 green spaces, including urban parks, gardens and sport centers. These vary considerably in structure and plant composition (Ayuntamiento de Mérida 2018). Within this area, we collected green lacewings from 20 green spaces (Table 1). The climate in this zone is tropical subhumid with a summer rainy period and a long winter dry season. The total annual precipitation is about 1024.1 mm, and maximum rainfall typically occurs from June to September. The annual average temperature is 26.5°C; the warmest month is May, while the coolest month is December (14.8°C; CONAGUA 2015).

The plant species most common in the green spaces are *Sabal yapa* Wright ex Beccari, *Rhrinax parviflora* Swartz, *Yucca elephantipes* var. *ghiesbreghtii* Molon, *Delonix regia* (Bojer ex Hooker) Rafinesque, *Enterolobium cyclocarpum* (Jacquin) Griesbach, *Guazuma ulmifolia* Lamarck, *Brosimum alicastrum* Swartz, *Ficus benjamina* Linnaeus, *Ficus elastica* Roxburgh, *Leucaena leucocephala* (Lamarck) de Wit, *Lysoloma latisiliquum* (Linnaeus)

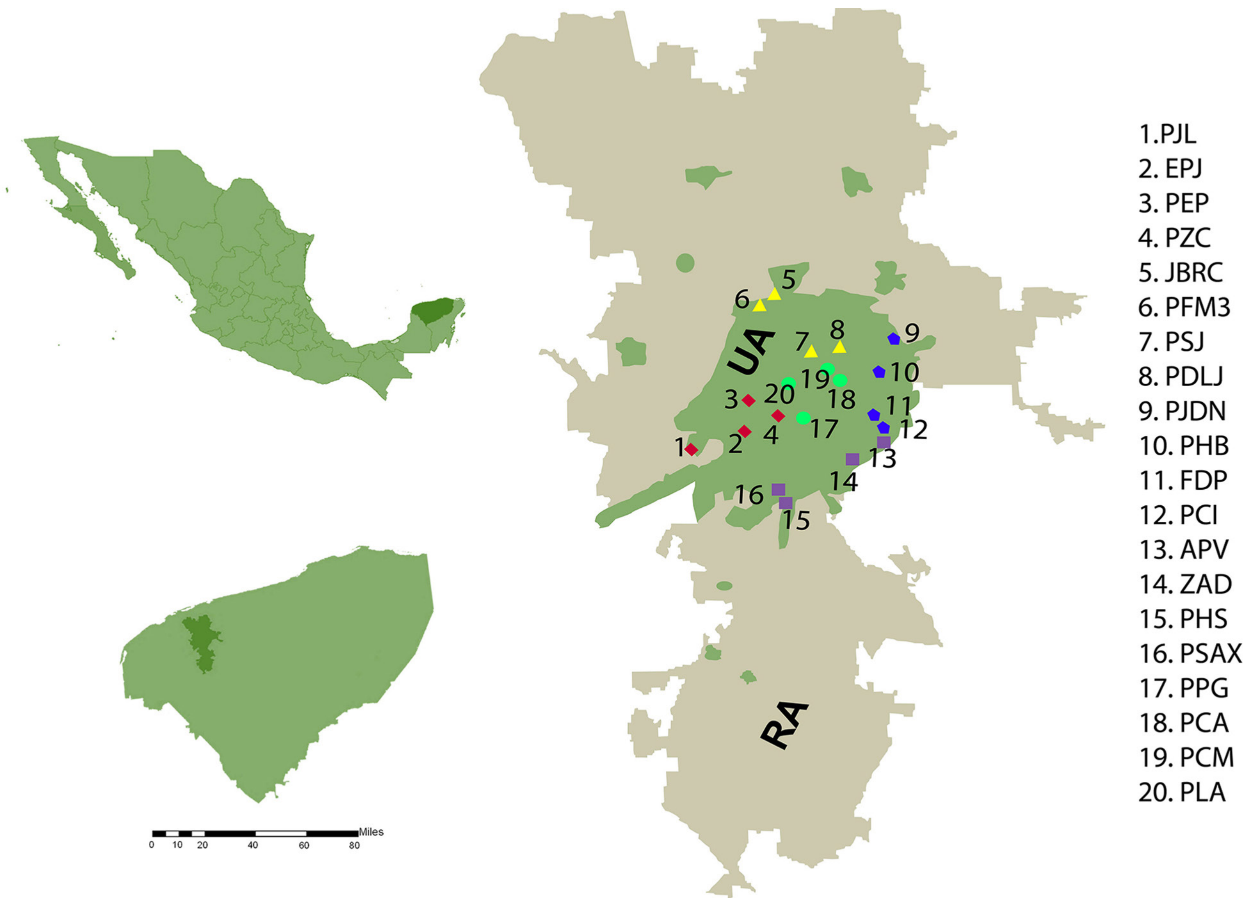

Figure 2. Locality of study area and sampling sites in Mérida Municipality, Yucatán, Mexico. UA=Urban area, RA= Rural area. Western sites=Red, Northern sites=Yellow, Eastern sites=Blue, Southern sites=Purple, Central sites=Green.

Table 1. Green lacewing sampling sites in Mérida, Yucatán, Mexico.

Site		Sampling site characteristics	Acres	Plant species	Coordinates
JBRC	Jardín Botánico Regional del CICY	Conserved zone of tropical dry deciduous forest with artificial aquifer	6.2	322	21°02′38″N, 89°38′22″W
PZC	Parque Zoológico Del Centenario	Wooded areas with recreational areas and fountains	22.2	203	20°58′7.19″N, 89°38′25.72″W
ZAD	Zona Arqueológica Dzoyilá	Archaeological area with shrubbery	19.8	194	20°56′17.77″N, 89°35′41.36″W
PEP	Parque Ecológico del Poniente	Wooded areas with recreational areas and artificial ponds	12.4	142	20°58′34.15″N, 89°39′26.44″W
APV	Acuaparque de Vergel	Wooded areas, with aquatic and flood vegetation, artificial lagoon and public pools	24.7	101	20°56′50.10″N, 89°34′40.34″W
FDP	Fraccionamiento del Parque	Wooded areas with recreational areas and archaeological area	24.2	98	20°58′7.53″N, 89°35′8.68″W
PHS	Parque Hundido del Sur	Wooded areas with recreational areas	3.5	93	20°54′41.34″N, 89°38′4.80″W
EPJ	Parque Japonés	Shrubbery with recreational areas and artificial pond	6.2	87	20°57′24.65″N, 89°39′39.35″W
PCI	Parque Chichen Itza	Wooded areas with recreational areas	2.5	83	20°57′50.20″N, 89°34′50.09″W
PJDN	Parque Jardines del Norte	Wooded areas with recreational areas	2.5	77	21°0′51.07″N, 89°34′7.90″W
PHB	Parque Hundido de Brisas	Wooded areas with recreational areas and artificial pond	2.5	74	20°59′31.09″N, 89°35′0.17″W
PCM	Parque de la Colonia México	Wooded areas with recreational areas and fountains	2.5	72	20°59′53.33″N, 89°36′35.83″W
PLA	Parque de Las Américas	Wooded areas with concrete corridors, artificial aquifer and fountains	9.9	69	20°59′14.59″N, 89°37′56.26″W
PDLJ	Parque de La Juventud	Wooded areas with recreational areas	3.5	67	21°0′34.40″N, 89°35′59.61″W
PSAX	Parque San Arturo Xluch	Wooded areas with recreational areas	2.5	66	20°55′10.63″N, 89°38′21.76″W
PLJ	Parque La Joya	Wooded areas with recreational areas	2.5	55	20°56′40.53″N, 89°41′29.76″W
PFM3	Parque de Francisco de Montejo III	Wooded areas with recreational areas	3.2	32	21°2′14.23″N, 89°38′43.41″W
PCA	Parque de la Colonia Alemán	Wooded areas with recreational areas and fountains	6.7	22	20°59′28.66″N, 89°36′5.61″W
PSJ	Parque San Juanistas	Wooded areas with recreational areas	2.5	21	21°0′34.13″N, 89°37′3.48″W
PPG	Parque de la Plaza Grande	Wooded areas with recreational areas	2.5	9	20°58′1.38″N, 89°37′25.47″W

Bentham, *Citrus aurantifolia* Swingle, *Citrus aurantium* Linnaeus, *Murraya paniculata* (Linnaeus) Jack, *Manilkara zapota* (Linnaeus) van Royen, and *Cedrela odorata* Linnaeus (Orellana et al. 2007).

Sampling sites and site characterization. We selected 20 different green spaces with relatively high abundance and diversity of vegetation, but also with varied composition. The sites were chosen taking into account the three vegetational strata (trees including palms, shrubs, and herbaceous plants). Sites were also chosen in five areas of the city: northern, southern, eastern, western and central. The sites also had to cover an area at least 100 × 100 m (Table 1). We identified only species of deciduous trees, shrubs, and palms since the green lacewings were most common on these. The ovipositional plants were identified with field guides such as Carnevali et al. (2010). Specimens that could not be identified in the field were collected, pressed, and dried for identification. We made those determinations using the websites of the Missouri Botanical Garden (2022) and the Centro de Investigacion Cientifica de Yucatán A. C. (Herbario-CICY, 2010). Tentative identifications were then confirmed using the U Najil Tikin Xiw herbarium in that institution.

Green lacewings. We sampled the 20 sites for an entire year from March 2010 to February 2011 in order to maximize information related to total diversity, distribution and abundance of the chrysopid faunas. Since the parks varied in size, we made a quadrant of 100 × 100 m. We sampled for five days in each month. We split the days into two working periods, two sites in the mornings (8:00–11:00) and two in the afternoon (15:00–18:00) with an hour to move from one site to another. We used two collecting methods to capture lacewings: sweep netting and suction trapping. These are considered to be the best methods for collecting lacewings (Ábrahám et al. 2003).

We employed a portable vacuum as a suction trap (Dirt Devil AccuCharge Hand Vac®) to avoid damaging the lacewings, which were immediately after sampling. Plants chosen randomly were sampled for 10 minutes each for the whole study (120 plants per month). Adult specimens were killed using Ethyl acetate and placed in glassine envelopes, and larvae were put in vials containing 95% ethanol (Agnew 1983). Larvae and adults were identified available literature addressing green lacewing (Banks 1945, 1948; Brooks and Barnard 1990; Penny et al. 2000; Stange 2000; De Freitas and Penny 2001; López-Arroyo 2007; Tauber et al. 2000, 2001; Tauber 2003, 2004; De Freitas et al. 2009; Silva et al. 2013). Larvae that were difficult to identify to species were kept alive and reared to adults using brown citrus aphids (*Toxoptera citricida* Kirkaldy) as food. Identifications were confirmed by personnel at the Biological Control Research Laboratory of the Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (INIFAP), General Teran Experimental Field Station. All specimens were deposited in the entomological collection at the Instituto Tecnologico de Conkal (ITC).

Statistical analyses. Species richness was determined by counting the number of species per site, while the abundance was determined by considering the number of individuals of each species for each species. Abundance estimates were transformed using Log-10 to estimate rank abundance curves (Whittaker 1965; Barrientos et al. 2016). The diversity from each site was rarefied and extrapolated applying the Hill numbers (q0 = Richness, q1 = Shannon diversity, q2 = Simpson diversity) with 1000 Bootstrap runs, and standardized by means of a sample coverage in the R package iNEXT (Chao and Jost 2012; Chao et al. 2014; Barrientos et al. 2016; Hsieh et al. 2016).

To determine the similarity pattern among collecting sites through abundances, we performed an unweighted pair group method with arithmetic mean (UPGMA) using as distance the Bray-Curtis Index to decrease double zero effect as mentioned by Zuur et al. (2007). f or this we used PAST 4.03 (Hammer et al. 2001).

An ombrometric diagram was created to visualize any correlation between the climatic variables (total monthly rainfall, average monthly temperature, and average extreme maximum and minimum temperature) and ecological variables (richness and abundance). We test all the variables using the Pearson correlation coefficient and to assess the correlation between the environmental and ecological variables, we conducted a Canonical Correspondence Analysis (CCA) using PAST 4.03 (Hammer et al. 2001) and running 1000 permutations to determine the significance of the model.

Results

Diversity, distribution, and abundances. We collected 738 specimens that represented 15 species in five genera. Seven of the species were not previously recorded from the Yucatán (Table 2). The genus *Ceraeochrysa* Adams

Table 2. Species of Chrysopidae observed during the 2010–2011 sampling period in Mérida, Yucatán. *=new state record.

ID #	Species abbr.	Species
1	Ce. ci	*Ceraeochrysa cincta* (Schneider)
2	*Ce. cl*	*Ceraeochrysa claveri* (Navás)
3	*Ce. co*	*Ceraeochrysa cornuta* (Navás)
4	*Ce. cu*	*Ceraeochrysa cubana* (Hagen)
5	*Ce. sa*	*Ceraeochrysa sanchezi* (Navás)*
6	*Ce. sm*	*Ceraeochrysa smithi* (Navás)*
7	*Ce. sp*	*Ceraeochrysa* sp. nr. *cincta* (Mexico) (Schneider)
8	*Ce. va*	*Ceraeochrysa valida* (Banks)
9	*Ch. eo*	*Chrysoperla exotera* (Navás)*
10	*Ch. et*	*Chrysoperla externa* (Hagen)*
11	*Ch. ru*	*Chrysoperla rufilabris* (Burmeister)
12	*Ch. sp.*	*Chrysopodes* sp.*
13	*Le. fl*	*Leucochrysa floridana* Banks*
14	*Le. sp.*	*Leucohrysa* sp. *
15	*Pl. br*	*Plesiochrysa brasiliensis* (Banks)

Table 3. Abundance and richness of green lacewing species at Mérida sampling sites.

Species	PEP	EPJ	PLJ	PZC	APV	PHS	PSAX	ZAD	FDP	PCI	**PHB**	**PJDN**	**PCA**	**PCM**	**PLA**	**PPG**	**JBRC**	**PFM3**	**PDLJ**	**PSJ**	**Total**
Ce. ci	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	5
Ce. cl	6	7	10	25	19	13	24	9	10	19	9	19	3	7	10	11	32	11	10	6	**260**
Ce. co	5	8	5	15	5	6	26	5	8	9	8	7	1	13	11	2	36	7	5	4	**186**
Ce. cu	0	0	0	1	2	1	0	0	2	2	0	1	4	0	0	0	1	0	0	0	**14**
Ce. sa	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	**4**
Ce. sm	0	0	1	1	0	1	1	1	0	1	1	2	0	0	3	0	3	0	1	0	**16**
Ce. sp	10	3	0	23	6	5	17	6	10	4	4	7	8	1	9	4	28	2	0	6	**153**
Ce. va	3	0	2	1	0	2	1	0	0	1	1	0	0	1	1	0	2	0	2	0	**17**
Ch. eo	0	1	1	2	1	1	0	2	1	0	0	1	1	1	1	0	1	0	1	0	**15**
Ch. et	0	0	1	1	0	1	2	0	2	3	0	1	0	0	0	0	1	0	1	0	**13**
Ch. ru	0	0	1	4	1	2	1	0	0	2	0	0	0	0	1	0	4	0	1	0	17
Ch. sp.	0	2	0	1	0	1	2	0	0	1	0	0	0	0	0	0	2	0	0	2	**11**
Le. fl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Le. sp.	2	0	2	2	0	0	0	0	1	0	1	1	0	1	0	0	3	0	2	0	**15**
Pl. br	0	0	0	1	0	2	1	1	3	1	0	1	0	0	0	0	1	0	0	0	**11**
Abundance	27	21	23	77	34	36	76	24	38	43	24	40	17	24	36	18	118	21	23	18	**738**
Richness	6	5	8	12	6	12	10	6	9	10	6	9	5	6	7	4	15	4	8	4	**15**

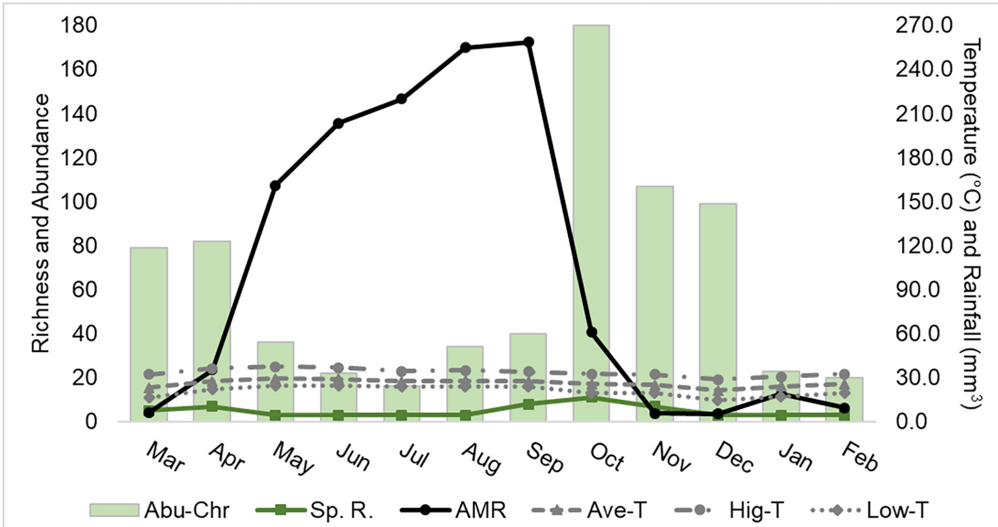

Figure 3. Relationship among climatic variables, abundances and richness of green lacewings of Mérida City, through the sampling months. Abu-Chr = Abundance of Chrysopidae, Sp. R. = Species richness, AMR = Total monthly rainfall, Ave-T = Monthly average temperatures, Hig-T = Monthly average high temperatures, Low-T = Monthly average low temperatures.

was represented by eight species, followed by *Chrysoperla* Steinmann (three species) and *Leucochrysa* Banks (two species). The three most abundant species in our samples were *Ceraeochrysa claveri* Navas (260 specimens), *Ceraeochrysa cornuta* Navas (186 specimens), and *Ceraeochrysa* sp. nr. *cincta* (Schneider) (153 specimens). The three species least represented were *Ceraeochrysa cincta* (Schneider) (Five specimens), *Ceraeochrysa sanchezi* (Navas) (Four specimens), and *Leucochrysa floridana* Banks (One specimen) (Table 3).

Throughout the collecting process we found three green lacewing species that appeared every month of the year: *Ceraeochrysa claveri*, *Ceraeochrysa cornuta*, and *Ceraeochrysa* sp. nr. *cincta*, while *Ceraeochrysa sanchezi*, *Chrysoperla exotera* Navas, *Leucochrysa floridana* and *Plesiochrysa brasiliensis* (Schneider) were each found in only one month. There were two periods of time during which abundance increased considerably, and which also showed the greatest richness. The first period was from March (Five species, 79 specimens) to April (Seven species, 82 specimens). The second period lasted three months: September (Eight species, 107 specimens), October (Eleven species, 180 specimens) and November (Seven species, 99 specimens). The remaining months yielded only three species with low abundance: < 40 specimens (Fig. 3).

The collecting sites that showed the highest abundance and richness were the Jardin Botanico Regional del CICY (JBRC) (Fifteen species, 118 specimens), the Parque Zoologico del Centenario (PZC) (Twelve species, 77 specimens), and the Parque San Arturo Xluch (PSAX) (Twelve species, 76 specimens) (Table 3). These were followed by the Parque Hundido del Sur (PHS), Parque Chichen Itza (PCI) and the Parque Jardines del Norte (PJDN), all of which had high diversity but low abundance. Lowest richness and abundance were recorded in the Parque de Francisco de Montejo III (PMF3), the Parque de la Plaza Grande (PPG), and the Parque San Juanistas (PSJ) with four species and from 18 to 21 specimens each (Table 3).

Correlation between climatic and ecological variables. We determined that during the coldest and hottest months the richness and abundance decrease considerably. Likewise, this occurred during the rainy season. The highest temperature was recorded in May (37.6°C) while lowest temperature occurred in December (14.8°C). Rainfall was greatest between May and September. There were two periods when the abundance and richness increased considerably: March to April and September to November (Fig. 3). The Pearson correlation coefficient showed a negative correlation between environmental variables and species abundance (Fig. 4). This negative correlation between these two variables was corroborated by the CCA as well (Fig. 5). Also, the axis 1 showed to be the most explanatory (eigenvalue = 0.060671, % = 99.93), while the axis 2 is very low (eigenvalue = 4.0682E-05, % = 0.06701). Similarly, the axis 1 was not significant (P = 0.766) as a result of no correlation between the two datasets.

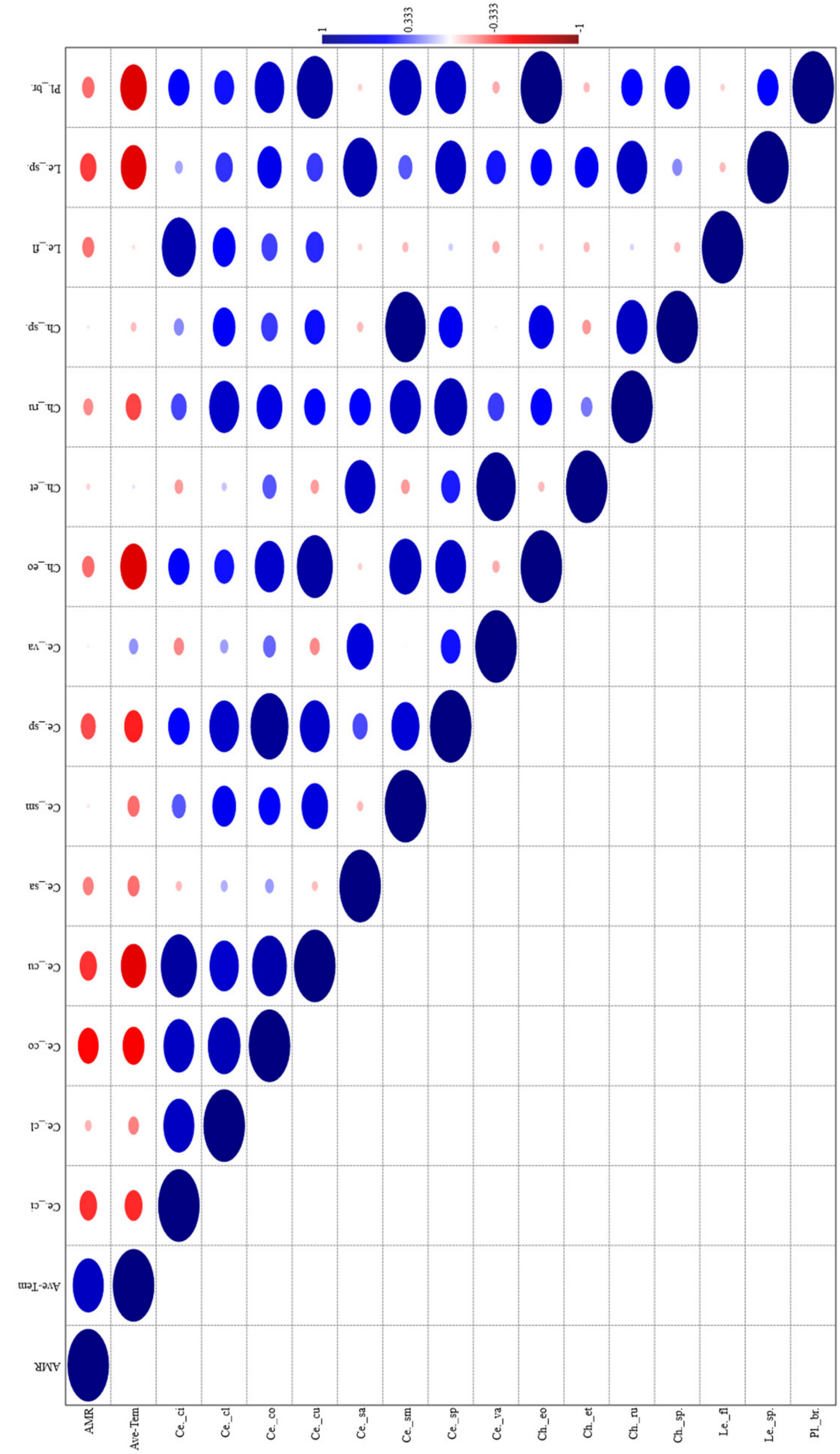

Figure 4. Correlation between the ecological and environmental variables using the Pearson correlation coefficient (r).

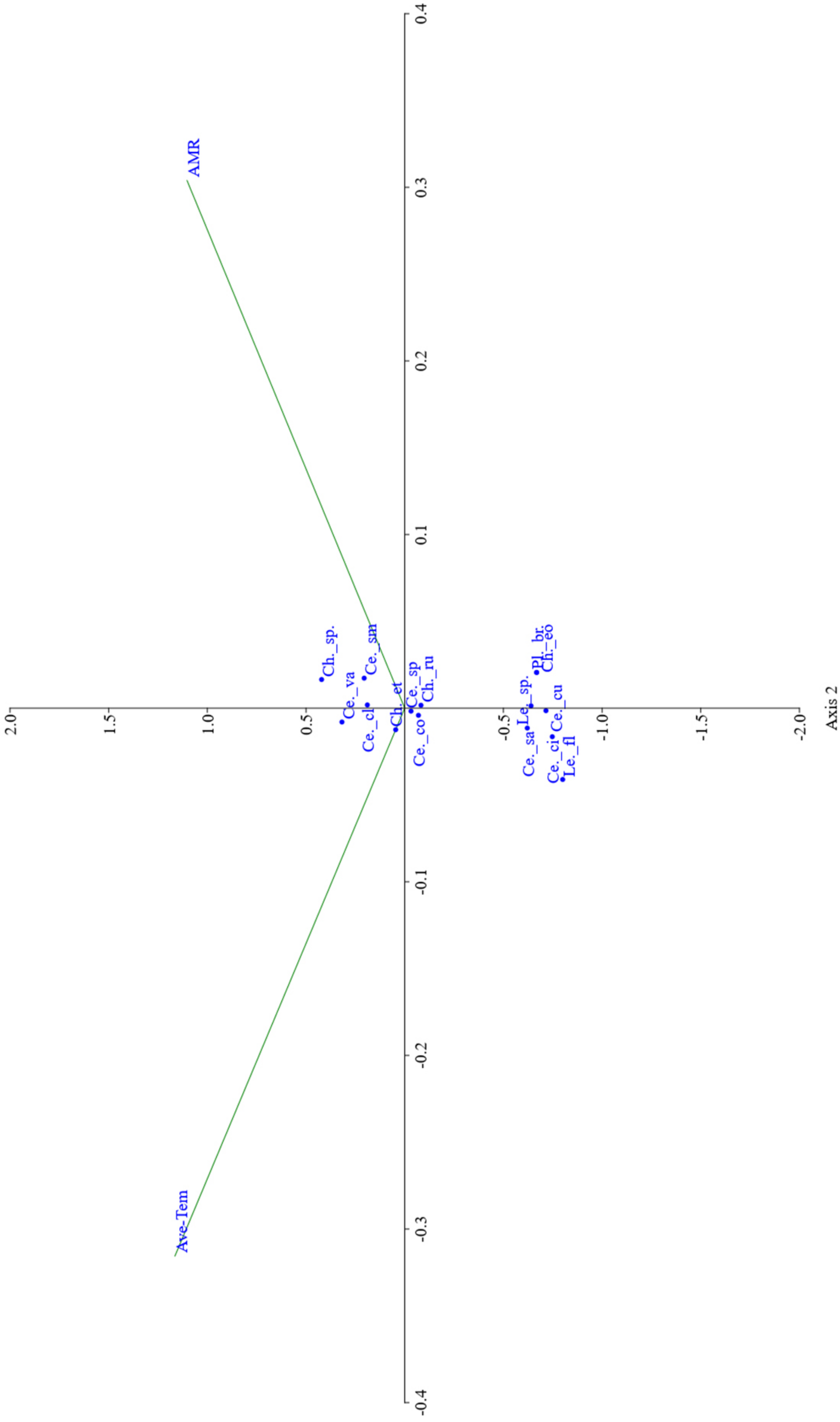

Figure 5. Canonical Correspondence Analysis triplot of the distribution of chrysopids species in relation to the total monthly rainfall (AMR) and monthly average temperatures (Ave-T).

Table 4. Ecological measurements of green lacewings for each sampling site in Mérida.

Sampling sites	Samples	Richness	Abundance	Sample coverage	Diversity		
					q = 0	q = 1	q = 2
PEP	12	6	27	0.97	6	4.8	4.2
EPJ	12	5	21	0.96	5	4	3.5
PLJ	12	12	23	0.83	8	5.3	3.9
PZC	12	8	77	0.92	12	5.6	4.2
APV	12	6	34	0.94	6	3.6	2.7
PHS	12	12	36	0.84	12	7.5	5.2
PSAX	12	10	76	0.93	10	4.7	3.7
ZAD	12	6	24	0.92	6	4.5	3.9
FDP	12	9	38	0.92	9	6.2	5.1
PCI	12	10	43	0.91	10	5.6	3.9
PHB	12	6	24	0.88	6	4.2	3.5
PJDN	12	9	40	0.88	9	4.8	3.4
PCA	12	5	17	0.88	5	3.8	3.2
PCM	12	6	24	0.83	6	3.4	2.6
PLA	12	7	36	0.92	7	4.8	4.1
PPG	12	4	18	0.95	4	2.8	2.3
JBRC	12	15	118	0.95	15	6.1	4.4
PFM3	12	4	21	0.96	4	2.9	2.5
PDLJ	12	8	23	0.83	8	5.3	3.9
PSJ	12	4	18	1.00	4	3.7	3.5
Estimates	**240**	**15**	**738**	**0.91**			

Our rarefaction/extrapolation analysis resulted in a general sampling representability and coverage of 91% from the total of observed species in every site (Table 4). The results by zones were slightly different: eastern sites (92%), western sites (90%), central sites (90%), northern sites (93%), and southern sites (91%) (Fig. 6–10, Table 4). On the other hand, the diversity profiles showed that highest diversity is presented by FDP and PCI in the eastern sites (Fig. 6, Table 4), PZC for the western sites (Fig. 7, Table 4), JBRC in the northern sites (Fig. 8, Table 4), and PHS in the southern sites (Fig. 9, Table 4). All of the central sites presented a low diversity profile with PLA being slightly higher than the other sites (Fig. 10, Table 4).

In the assemblage of green lacewings, we found six different groups of sites. The most distant (<40%) is the Parque de la Colonia Aleman (PCA), which is represented by the lowest diversity of plants and number of individual plants. The second group is formed by APV, PJDN, PCI, PHS, FDP, and PLA, which present a low diversity of plants (~70%). The third group consist of ZAD, PSJ, and PEP showing a remarkable vegetation diversity, but trees and shrubs are notably distant one to each other (~67.5%). It is worth mentioning that these green spaces are rarely receive lawn care. On the other hand, the fourth group that contains PPG, PFM3, EPJ, PHB, and PCM have similar vegetation that those in the third group, but they receive lawn care weekly (~67.5%). PLJ and PDLJ form the fifth group with low plant diversity (~60%). Finally, the last group is comprised of JBRC, PZC, and PSAX represented by the largest diversity of plants with daily lawn care (~50%) (Fig. 11).

Vegetation composition. During this study we identified 322 species of plants (trees, shrubs, and palms), of which 75 species of ovipositional associated hosts distributed among native, ornamental and fruit trees representing 30 families and 65 genera. Despite we proposed three vegetational strata, we could not find chrysopids

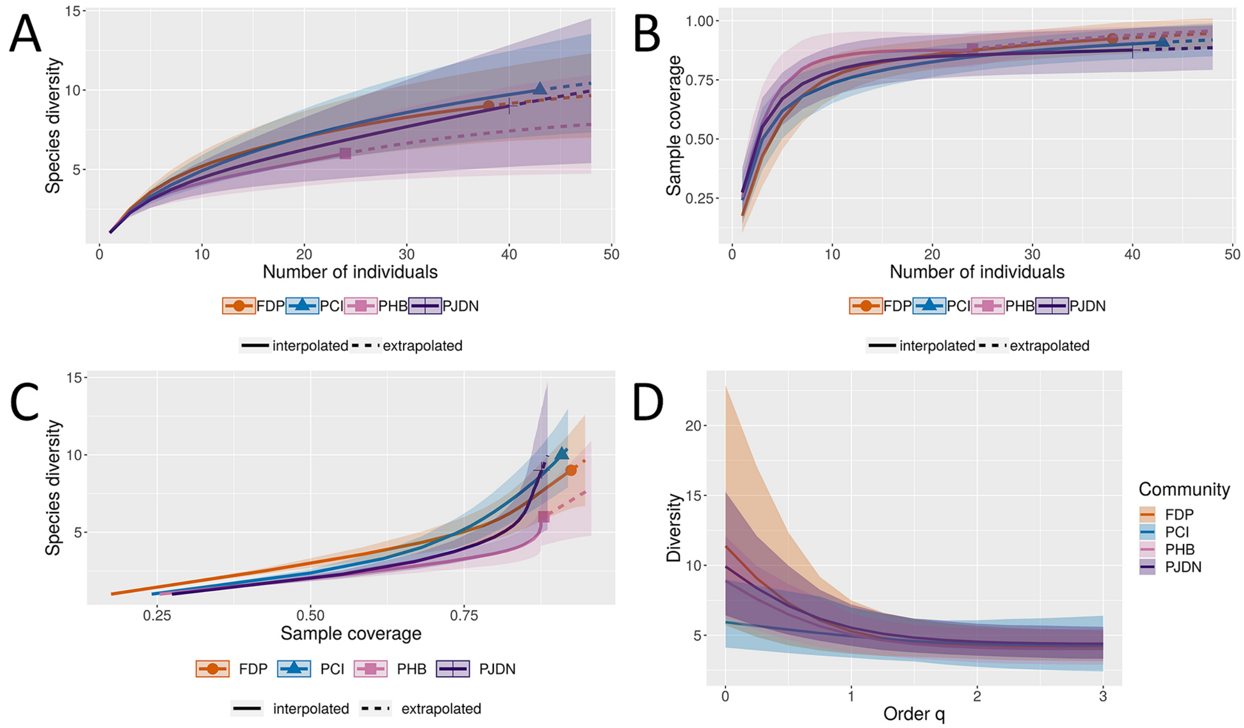

Figure 6. Rarefaction/extrapolation. **A)** Sample-size-based rarefaction and extrapolation sampling curve. **B)** Sample completeness curve. **C)** Coverage-based rarefaction and extrapolation sampling curve. **D)** Estimated diversity profiles for each sampled eastern site in Mérida.

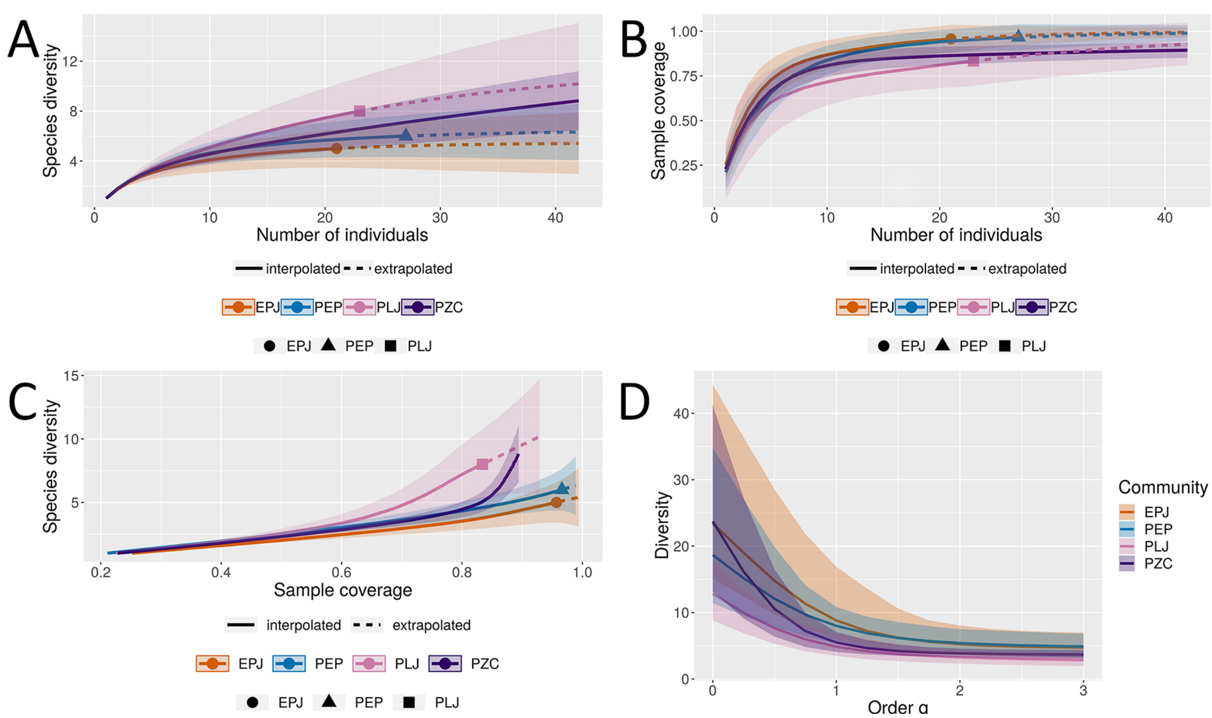

Figure 7. Rarefaction/extrapolation. **A)** Sample-size-based rarefaction and extrapolation sampling curve. **B)** Sample completeness curve. **C)** Coverage-based rarefaction and extrapolation sampling curve. **D)** Estimated diversity profiles for each sampled western site in Mérida.

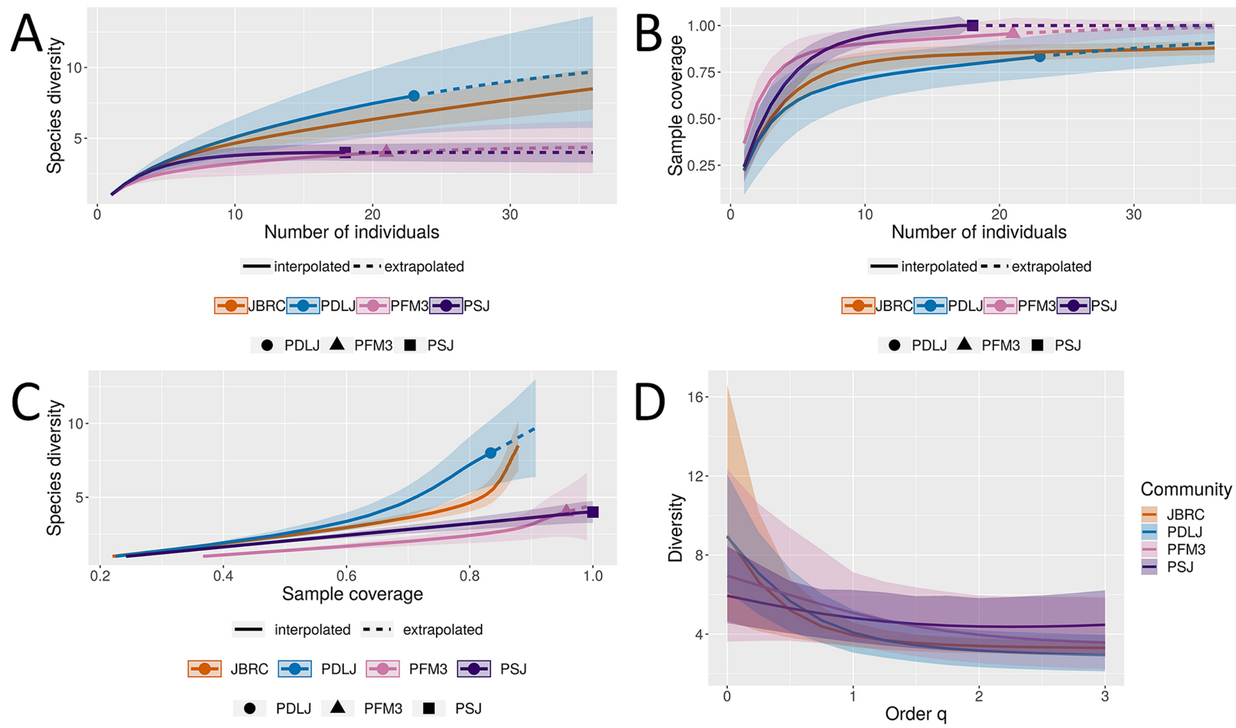

Figure 8. Rarefaction/extrapolation. **A)** Sample-size-based rarefaction and extrapolation sampling curve. **B)** Sample completeness curve. **C)** Coverage-based rarefaction and extrapolation sampling curve. **D)** Estimated diversity profiles for each sampled northern site in Mérida.

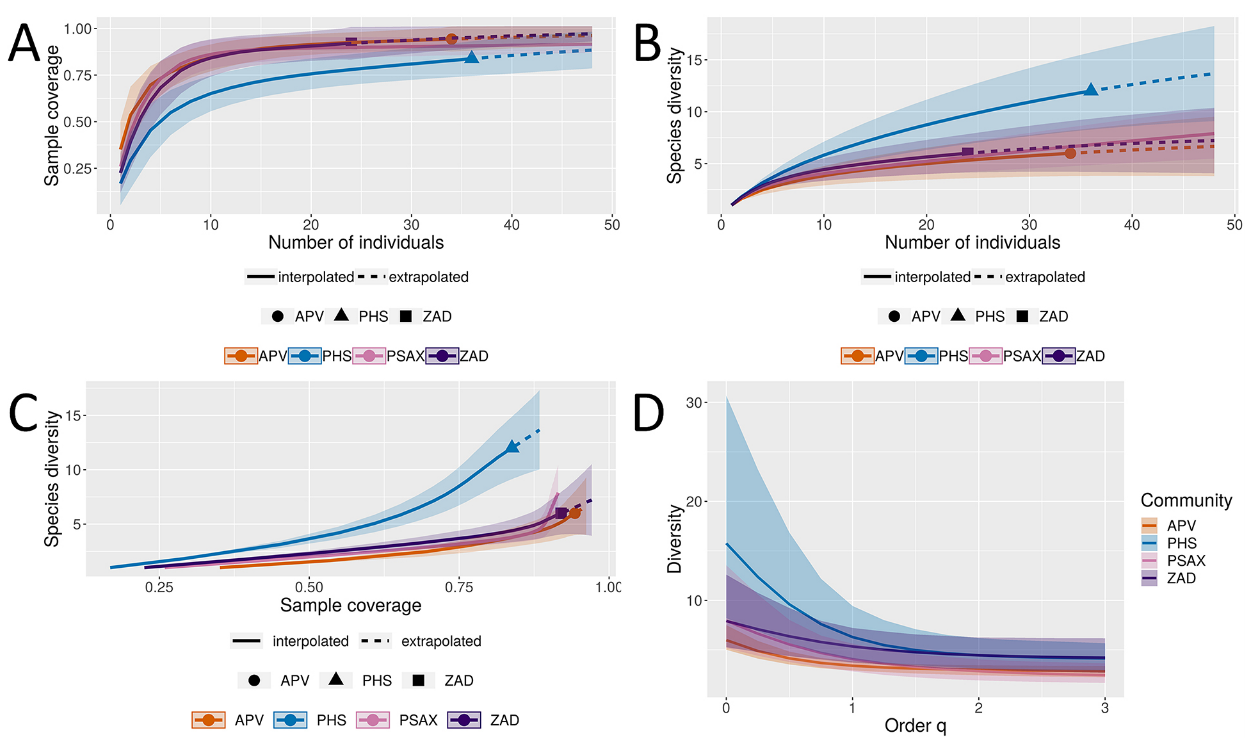

Figure 9. Rarefaction/Extrapolation. **A)** Sample-size-based rarefaction and extrapolation sampling curve. **B)** Sample completeness curve. **C)** Coverage-based rarefaction and extrapolation sampling curve. **D)** Estimated diversity profiles for each sampled southern site in Mérida.

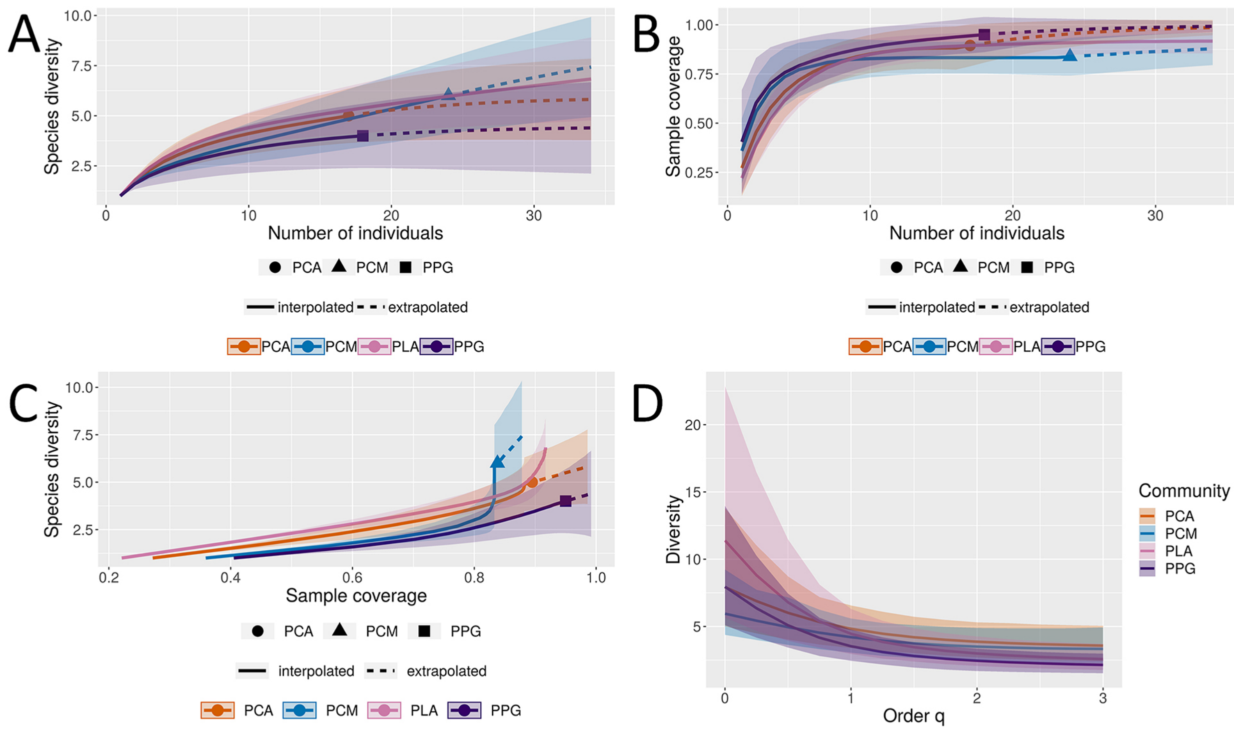

Figure 10. Rarefaction/Extrapolation. **A)** Sample-size-based rarefaction and extrapolation sampling curve. **B)** Sample completeness curve. **C)** Coverage-based rarefaction and extrapolation sampling curve. **D)** Estimated diversity profiles for each sampled central site in Mérida City.

Table 5. Checklist of ovipositional associated hosts for green lacewing species listed in Table 2. F= Fruit tree, N= Native, O= Ornamental plant.

Host plant	**Plant type**	***Ce. ci***	***Ce. cl***	***Ce. co***	***Ce. cu***	***Ce. sa***	***Ce. sm***	***Ce. sp***	***Ce. va***	***Ch. eo***	***Ch. et***	***Ch. ru***	***Ch. sp.***	***Le. fl***	***Le. sp.***	***Pl. br***	**Total**
AGAVACEAE																	
Agave sisalana (Perrine)	**O**			1													**1**
Beaucarnea pliabilis (Baker)	O		7														**7**
Tradescantia pallida (Rose) (D.R.Hunt)	**O**			3													**3**
Yucca elephantipes (Baker)	**O**		1	5													6
ANACARDIACEAE																	
Mangifera indica (Linnaeus)	**F**		1														**1**
Metopium Brownei (Jacq.)	**N**		6					3									**9**
Spondias mombin (Linnaeus)	**N**			6													6
ANNONACEAE																	
Annona cherimola (Mill.)	**F**		3														**3**
Annona muricata (Linnaeus)	**F**		1														**1**
Annona squamosa (Linnaeus)	**F**		2	7													9
APOCYNACEAE																	
Plumeria obtusa (Linneaus)	**O**							5									**5**

Host plant	**Plant type**	***Ce. ci***	***Ce. cl***	***Ce. co***	***Ce. cu***	***Ce. sa***	***Ce. sm***	***Ce. sp***	***Ce. va***	***Ch. eo***	***Ch. et***	***Ch. ru***	***Ch. sp.***	***Le. fl***	***Le. sp.***	***Pl. br***	**Total**
Plumeria rubra (Linneaus)	**N**		1	2			3	7	1	6			1				**21**
Cascabela gaumeri (Hemsl.) Lippold.	**N**	1						4				1	2				8
ARACEAE																	
Monstera deliciosa (Liebm.)	**O**		1		1												2
ARECACEAE																	
Chamaedorea seifrizii (Burret)	**O**		1														**1**
Sabal yapa (Wright ex Becc.)	**O**		14	18	1		7	15	2								**57**
Thrinax parviflora (Sw)	**O**						3	4	1			3	1		15		27
BIXACEAE																	
Bixa orellana (Linnaeus)	**N**			1													1
BORAGINACEAE																	
Bourreria pulchra (Millsp)	**N**	1		1													2
Cordia dodecandra (A. DC)	**N**		1	1													**2**
Ehretia tinifolia (A. DC.)	**N**			2													2
BURSERACEAE																	
Bursera simaruba (Linnaeus)	**N**		2														2
CARICACEAE																	
Carica papaya (Linnaeus)	**F**	1															1
CELASTRACEAE																	
Hippocratea volubilis (Linnaeus)	**O**			1													1
COMBRETACEAE																	
Terminalia catappa (Linnaeus)	**O**			1				1									**2**
Terminalia oblonga (Ruiz & Pav.)	**O**			2													2
CONVOLVULACEAE																	
Ipomoea heterodoxa (Standl. & Steyerm.)	**N**		1					2									3
EBENACEAE																	
Diospyros digyna Jacq	**N**		1														1
EUPHORBIACEAE																	
Acalypha gaumeri (Pax & Hoffmann)	**N**											3					**3**
Cnidoscolus aconitifolius (Mill.) I.M. Johnst.	**N**				1												**1**
Croton arboreus (Millsp.)	**N**			5													**5**
Jatropha curcas (Linnaeus)	**N**		1														1
FABACEAE																	
Acacia collinsii (Safford)	**N**		1														**1**
Acacia gaumeri (Blake)	**N**		1														**1**
Acacia pennatula (Schlecht. & Cham.) (Benth.)	**N**		3														**3**

Host plant	**Plant type**	***Ce. ci***	***Ce. cl***	***Ce. co***	***Ce. cu***	***Ce. sa***	***Ce. sm***	***Ce. sp***	***Ce. va***	***Ch. eo***	***Ch. et***	***Ch. ru***	***Ch. sp.***	***Le. fl***	***Le. sp.***	***Pl. br***	**Total**
Acaciella angustissima (Mill.) Britton & Rose	**N**		1														**1**
Apoplanesia paniculata (Presl.)	**N**							2	1								**3**
Bauhinia divaricata (Linnaeus)	**N**		3														**3**
Caesalpinia pulcherrima (Linnaeus) (Swartz)	**O**							5									**5**
Caesalpinia mollis (Kunth) Spreng.	**N**		1					4									**5**
Delonix regia (Bojer ex Hook.) (Raf.)	**O**		1														**1**
Desmanthus virgatus (Linnaeus)	**N**							4				1					**5**
Enterolobium cyclocarpum (Jacq.) (Griseb.)	**N**			1													**1**
Leucana leucocephala (Lam.) (De Witt)	**N**			1				6									**7**
Lysiloma latisiliquum (Linnaeus) (Benth.)	**N**		5	1													**6**
Piscidia piscipula (Linnaeus)	**N**			1													**1**
Pithecellobium dulce (Roxb.) Benth	**N**							6									6
HERNANDIACEAE																	
Gyrocarpus jatrophifolius Domin	**N**		1														1
MALPIGHIACEAE				1													**1**
Byrsonima crassifolia (Linnaeus) (HBK)	**N**																
MALVACEAE				1													**1**
Ceiba pentandra (Linnaeus) (Gaertn)	**N**																
Guazuma ulmifolia (Lam.)	**N**	1	47	19	1			17	1	9	3	4	2	1			**105**
Hibiscus rosa sinensis (Linnaeus)	**O**		1					6									**7**
Thespesia populnea (Linnaeus)	**O**		1														1
MELIACEAE			1		1												**2**
Cedrela odorata (M. Roemer)	**O**																
MORACEAE			1	1	1		3		1				1				**8**
Brosimum alicastrum (Swartz)	**O**																
Cecropia obtusifolia (Bertol)	**N**		1	1													**2**
Ficus benjamina (Linnaeus)	**O**		4			1											**5**
Ficus elastica (Roxb)	**O**		6	3				9	1								**19**
Ficus benjamina 'Variegata' (Linnaeus)	**O**		2	3													5

Host plant	**Plant type**	***Ce. ci***	***Ce. cl***	***Ce. co***	***Ce. cu***	***Ce. sa***	***Ce. sm***	***Ce. sp***	***Ce. va***	***Ch. eo***	***Ch. et***	***Ch. ru***	***Ch. sp.***	***Le. fl***	***Le. sp.***	***Pl. br***	**Total**
MUSACEAE																	
Musa X paradisiaca (Linnaeus)	**F**		3	1													4
PASSIFLORACEAE																	
Passiflora foetida L.	**N**			1													1
POLYGONACEAE																	
Coccoloba uvifera (Linnaeus)	**N**		1	1	1			15									18
RUBIACEAE																	
Alseis yucatanensis (Standley)	**N**		1														**1**
Hamelia patens (Jacq.)	**N**		2														**2**
Morinda citrifolia (Linnaeus)	**O**		1														1
RUTACEAE																	
Citrus aurantifolium (Linnaeus)	**F**		53	36	4	3		6	4		6	2	3			11	**128**
Citrus aurantium (Linnaeus)	**F**		67	29	2			20	5		4	3	1				**131**
Citrus maxima (Linnaeus)	**F**		1	9				2									**12**
Citrus nobilis (Linnaeus)	**F**		1	17				3									**21**
Muralla paniculata (Linnaeus)	**O**	1	1														2
SAPINDACEAE																	
Cardiospermum corindum (Linnaeus)	**N**		1	1	1												3
SAPOTACEAE																	
Manilkara zapota (Linnaeus) (P. Royen)	**F**		1														**1**
Pouteria zapota (Jacq.)	**F**		1					7									8
SOLANACEAE																	
Solanum erianthum (D. Don)	**N**			1													1
ULMACEAE																	
Trema micrantha (Linnaeus) (Blume)	**N**		1	1													**2**
Grand total		5	260	186	14	4	16	153	17	15	13	17	11	1	15	11	**738**

on herbaceous plants with the only exception of *Musa × paradisiaca* (Linnaeus). The greatest number of species were native (40 species), next the ornamentals (23 species), while the fewest species were fruit trees (12 species). The most abundant plant species were *Citrus aurantifolia* Swingle, *Citrus aurantium* Linnaeus, *Ficus benjamina* Linnaeus, *Ficus elastica* Roxburgh, *Guazuma ulmifolia* Lamarck, *Gymnopodium floribundum* Rolfe, *Leucaena leucocephala* (Lamarck) de Wit, *Lysiloma latisiliquum* (Linnaeus) Bentham, *Murraya paniculata* (Linnaeus) Jack, and *Piscidia piscipula* (Linnaeus) Sargent. Those species were found at all sites. The plants used by the most chrysopid species were *G. ulmifolia* (12 species), *C. aurantifolia* (10 species), and *C. aurantium* (eight species). There were 39 plant species on which only one green lacewing was recorded (Table 5).

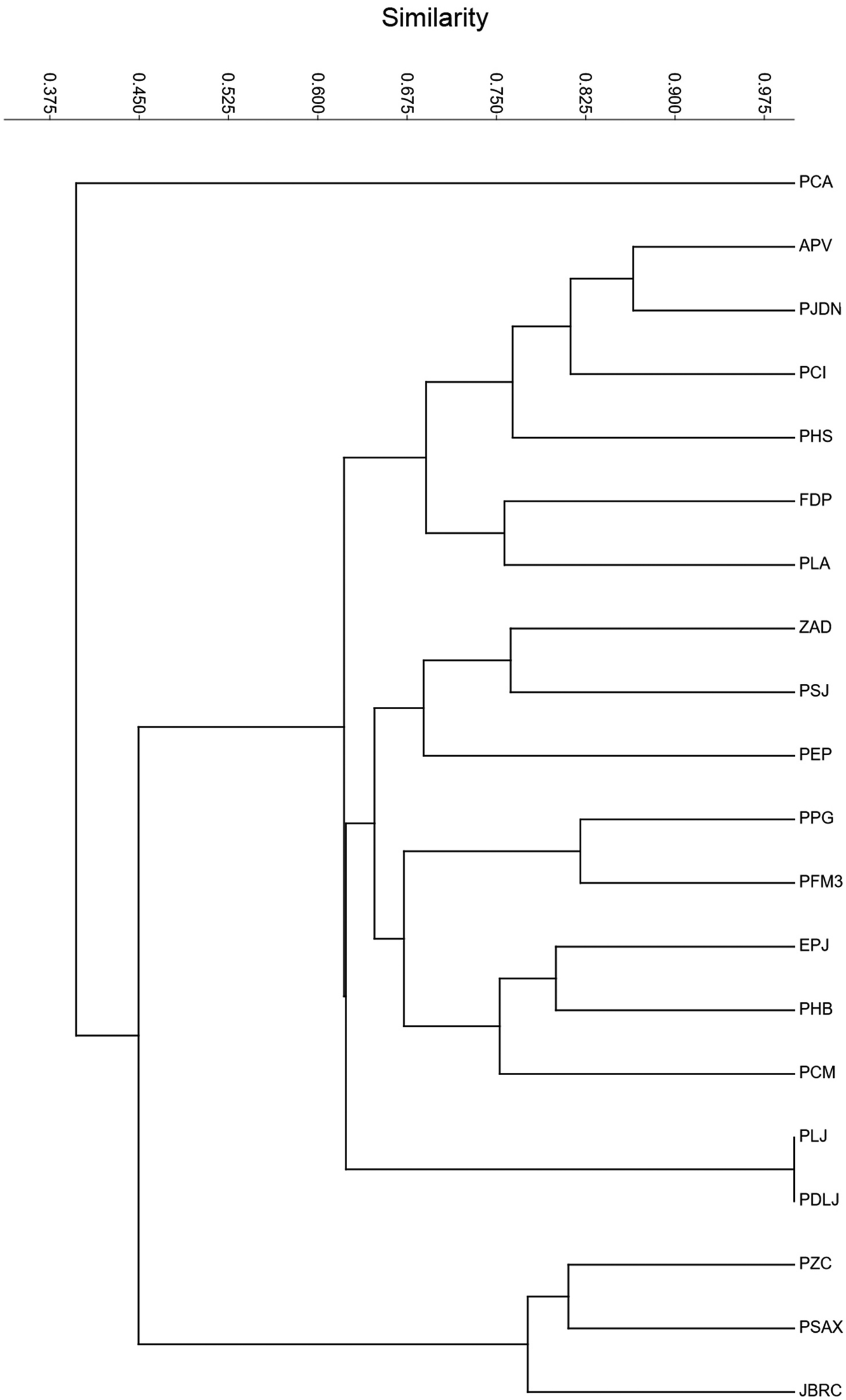

Figure 11. Cluster analysis (Bray-Curtis index), showing similarities in the assemblage of green lacewings from the sampling sites of Mérida.

Discussion

The chrysopid species recorded in Mérida City represent 15% of all green lacewings known from Mexico (Valencia-Luna et al. 2006; Contreras-Ramos and Rosas 2013). We feel that the sampling effort was sufficient to demonstrate the representative species richness in the City. The species accumulation curve showed that the sampling effort was sufficient with 91% of observed species in general. About half of the chrysopids documented in this study are new state records, which is a marked advancement on the diversity of this group in the Yucatán peninsula. However, most of these new records are not a surprise due they have been reported in many places from Mexico, Caribbean Basin, Central, and South America, but never reported to Yucatán (Tauber and De León 2001). Some examples of *Chrysopodes* sp. and *Leucohrysa* sp. could not be identified to species with certainty, and they may represent previously undescribed species (JI Martinez, unpublished data).

A confounding issue with this study is that many agricultural and horticultural studies intentionally introduced non-native species of chrysopids for pest control purposes. Thus, it is difficult to separate the native species from those that are non-native, and determine the potential impacts the non-native species may have had on the natives (López-Arroyo and De León 2002). For example, a serious consequence of those introductions is competition between the native and non-native species, which can produce displacement of the native species (Mochizuki et al. 2006).

The site JBRC has the highest diversity of green lacewings perhaps because it contains the largest number of different plant species in vivo in the Yucatán, resulting in high floral heterogeneity. In contrast, sites PFM3, PPG, and PSJ had the least abundance and richness of green lacewings, probably because those places had low heterogeneity in vegetation, with little or no understory. In addition, two of the southern sampling sites (PHS and PSAX) had high diversity of green lacewings despite having a low diversity of plants in the assessed sites. These sites, however, were close to rural areas, surrounded by patches of tropical dry deciduous forest, thereby increasing the diversity of green lacewings. We observed three other sites with high diversity of plants but low diversity of green lacewings: APV, PEP, and ZAD. The first two of sites include bodies of water and are treated with insecticides monthly every year during the rainy season mainly for control of mosquitoes and other pests. Some of the insecticides used for this purpose (i.e, bifenthrin and deltamethrin) also kill beneficial insects, among them green lacewings, thus reducing their diversity in these sites (Garzon et al. 2015; Ullah et al. 2017; Sandoval et al. 2018). In the case of ZAD, there are frequent fires started by people for various purposes, thus altering the structure and composition of the vegetation as well as decreasing the richness and abundance of chrysopids.

Ceraeochrysa was the most diverse genus in this survey with eight species collected, a result similar to that in the state of Morelos (Valencia-Luna et al. 2006; Fig. 1). Other studies that were focused on fruit tree crops in north and central Mexico produced similar patterns to those which we obtained (López-Arroyo et al. 2007). On the other hand, studies that were focused on biological control differed from our study, finding that *Chrysoperla* was the most diverse genus (Cortez-Mondaca et al. 2001; Tarango-Rivero et al. 2013). However, our work can be considered the first of its kind since both biotic and abiotic features were taken into account to understand the biology and ecology of Chrysopidae in urban areas.

Temporally the greatest number of chrysopid species and their abundance occurred in March, April, September, October and November and gradually declined in the remaining months. This could be because leafing out of some ovipositional associated hosts occurs during those months (Patiño-Arellano 2012). Large numbers of small pests congregate when leaves are freshly emerged, providing increased sources of prey for chrysopids (Jasso-Argumedo 2012; Lozano-Contreras 2013). Also, other environmental characteristics such as temperature and humidity may play important roles for each region, resulting in phenological variations in different green lacewing communities (Trouvé et al. 2002). Additionally, although all larvae are predators of other soft-bodied insects, most adults feed on pollen, nectar and honeydew, and accordingly they are attracted to patches of flowering plants (Villenave et al. 2006). Flowering of the plant species we recorded coincides with the months when richness and abundance of the green lacewings increases and match the two flowering seasons in the study area (Ayala-Arcipreste 2001).

The urban parks and gardens of Mérida contain both native and introduced plants. In addition, patches of conserved and successional tropical dry deciduous forest still exist. There are also orchards and Mayan home gardens (Orellana et al. 2007) containing *G. ulmifolia*, *C. aurantifolia*, *C. aurantium*, *S. yapa* and *T. parviflora* as fundamental components. These are used for multiple purposes such as construction, medicine, fodder and food (Salazar 1991; Jiménez-Osornio 1999). Thus, their importance to chrysopid biology is substantial given their use as ovipositional sites. These patches of urban vegetation provide shelter and food for a broad variety of organisms, among them Chrysopidae. However, despite the importance of the urban plants, green lacewing diversity does not appear to depend on the dimension of the park or garden, but rather on the nearby vegetation of tropical deciduous forest (Brown and Hutchings 1997; Ramirez-Restrepo et al. 2007). Furthermore, chrysopid diversity is linked to the amount and constitution of microhabitats that provide ovipositional associated hosts for larvae and food sources for adults. It is important to mention here that since our study most of the citrus in parks and gardens have been eliminated in the campaign to eradicate the bacterium *Candidatus liberibacter*, which causes "HLB" or "citrus greening disease." A follow-up survey would be valuable in assessing the effect of the absence of these hosts on the diversity of Chrysopidae in Mérida. It is possible that the removal of these citrus trees may result in a comparable loss of chrysopid diversity.

Currently there are few works concerning ovipositional hosts of Chrysopidae in Mexico and most deal exclusively with crop plants (López-Arroyo et al. 2007). The current work is the first of its kind in Mexico. The 75 host species list and makeup of host plant groups (native, ornamental and fruit) comprise useful information. We should emphasize that more studies are needed of the neuropterofauna for all of Mexico in order to know more about their biology, diversity and distributions. We hope that the results presented here will stimulate further survey work on green lacewings in other parts of Mexico.

Conclusions

We were able to identify 15 species of green lacewings, seven species of which are new records for the state of Yucatán. This demonstrates the general lack of information about the order Neuroptera in Yucatán. It also shows the importance of green spaces as shelters for insect diversity.

The vegetational structure and composition of the green spaces we studied play an important role in maintaining the diversity of green lacewings thus changes in any of them may increase or decrease that diversity. We also observed that weather influences the richness and abundance of green lacewings, which decreases during the rainy season and winter. However, it is necessary to conduct more studies of this kind not only to corroborate these results, but to know the effect of the removal of citrus plants in the green areas on green lacewing diversity.

Acknowledgments

We want to thank the ITC for providing the facilities to identify the species mentioned in this study. Many thanks to Ruben Arana-Gamboa for his help with statistical analysis. Thanks are due to Jacqueline Y. Miller for help and personal support. We thank the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), General Terán experimental field extension and the Centro de Investigaciones Científicas de Yucatán (CICY) for allowing us to work in their facilities. Finally, we are indebted to Yesenia Marquez López and Rodolfo Cancino López for their helpful comments.

Literature Cited

Ábrahám L, Markó V, Vas J. 2003. Investigations on a neuropteroid community by using different methods. Acta Phytopathologica et Entomologica Hungarica 38: 199–207.

Agnew CW. 1983. Mounting and preserving Neuroptera for scientific study. Entomological News 94: 205–212.

Aguilera G, Ekroos J, Persson AS, Pettersson LB, Öckinger E. 2019. Intensive management reduces butterfly diversity over time in urban green spaces. Urban Ecosystems 22: 335– 344.

Aronson MF, La Sorte FA, Nilon CH, Katti M, Goddard MA, Lepczyk CA, Warren P, Williams N, Cilliers S, Clarkson B, Dobbs C, Dolan R, Hedblom M, Klotz S, Kooijmans JL, Kühn I, MacGregor-Fors I, McDonnell M, Mörtberg U, Pyšek P, Siebert S, Sushinsky J, Werner P, Winter M. 2014. A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. Proceedings of the Royal Society B: Biological Sciences 281: 1–8.

Ayala-Arcipreste ME. 2001. La apicultura de la Península de Yucatán un acercamiento desde la ecología humana. M.Sc. Thesis, Instituto Politécnico Nacional, Centro de Investigación y estudios avanzados Press. Available at http://bibliotecasibe.ecosur.mx/sibe/book/000028703 (Last accessed March 20, 2019.)

Ayuntamiento de Mérida. 2018. Sistema de gestión de espacios públicos. Available at http://isla.Mérida.gob.mx/servicios internet/ordenamientoterritorial/docs/SistemaGestion.pdf. (Last accessed November 19, 2023.)

Banaszak-Cibicka W, Ratyńska H, Dylewski L. 2016. Features of urban green space favourable for large and diverse bee populations (Hymenoptera: Apoidea: Apiformes). Urban Forestry and Urban Greening 20: 448–452.

Banks N. 1945. A review of the Chrysopidae (Nothochrysinae) of Central America. Psyche 52: 139–174.

Banks N. 1948. Chrysopidae (Nothochrysidae) collected in México by Dr. A. Dampf (Neuroptera). Psyche 55: 151–177.

Barrientos R, Leirana J, Navarro J. 2016. Métodos gráficos para la exploración de patrones de diversidad en Ecología. Bioagrociencias 9: 11–18.

Blair RB. 2001. Birds and butterflies along urban gradients in two ecoregions of the United States: Is urbanization creating a homogeneous fauna? p. 33–56. In: Lockwood JL, McKinney ML (eds.). Biotic homogenization. Springer; NY. 299 p.

Brooks SJ, Barnard PC. 1990. The green lacewings of the world: a generic review (Neuroptera: Chrysopidae). Bulletin of the British Museum (Natural History) Entomology 59: 117–286.

Brown KS, Freitas AVL. 2002. Butterfly communities of urban forest fragments in Campinas, São Paulo, Brazil: structure, instability, environmental correlates, and conservation. Journal of Insect Conservation 6: 217–231.

Brown KS, Hutchings RW. 1997. Disturbance, fragmentation, and the dynamics of diversity in Amazonian forest butterflies. p. 91–110. In: Laurance WF, Bierregaard RO Jr. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. University of Chicago Press; Chicago, IL. 616 p.

Cancino-López RJ, Contreras-Ramos A. 2019. A new species of *Ceraeochrysa* Adams (Neuroptera, Chrysopidae), with a key to the species from Mexico. ZooKeys 888: 95–104.

Carnevali G, Tapia-Muñoz JL, de Stefano RD, Morillo IR. 2010. Flora ilustrada de la península de Yucatán: listado florístico. Centro de Investigación Científica de Yucatán; Mérida, Mexico. 326 p.

Chávez-Zichinelli CA, MacGregor-Fors I, Rohana PT, Valdéz R, Romano MC, Schondube JE. 2010. Stress responses of the house sparrow (*Passer domesticus*) to different urban land uses. Landscape and Urban Planning 98: 183–189.

Chao A, Gotelli NJ, Hsieh TC, Sander EL, Ma KH, Colwell RK, Ellison A.M. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs 84: 45–67.

Chao A, Jost L. 2012. Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. Ecology 93: 2533–2547.

Clark TL, Messina FJ. 1998. Foraging behavior of lacewing larvae (Neuroptera: Chrysopidae) on plants with divergent architectures. Journal of Insect Behavior 11: 303–317.

CONAGUA (Comisión Nacional del Agua). 2015. Datos meteorológicos del Organismo de Cuenca: península de Yucatán. Mérida: Dirección técnica jefatura de proyecto de aguas superficiales y meteorología. Available at https://smn.conagua.gob.mx/es/climatologia/temperaturas-y-lluvias/resumenes-mensuales-de-temperaturas-y-lluvias (Last accessed March 10, 2019.)

Contreras MGL, Argumedo JJ. 2012. Identificación de enemigos naturales de *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) en el estado de Yucatán, México. Fitosanidad 16(1): 5–11.

Contreras-Ramos A, Rosas MV. 2014. Biodiversidad de Neuroptera en México. Revista Mexicana de Biodiversidad 85: S264–S270.

Cortez-Mondaca E, Lugo-Angulo NE, Pérez-Márquez J, Apodaca-Sánchez MA. 2001. Primer reporte de enemigos naturales y parasitismo sobre *Diaphorina citri* Kuwayama en Sinaloa, México. Revista Científica UDO Agrícola, 11: 97–103.

De Freitas S, Penny ND. 2001. The green lacewings (Neuroptera: Chrysopidae) of Brazilian agro-ecosystems. Proceedings of the California Academy of Sciences 52: 245–395.

De Freitas S, Penny ND, Adams PA. 2009. A revision of the New World genus *Ceraeochrysa* (Neuroptera: Chrysopidae). Proceedings of the California Academy of Sciences 60: 503– 610.

Deloya C, Ordoñez-Resendiz MM. 2008. Escarabajos (Insecta: Coleoptera). p. 123–134. In: Manson RH, Hernández-Ortiz V, Gallina S, Mehltreter K (eds.). Agroecosistemas cafeteros de Veracruz: Biodiversidad, manejo y conservación. Instituto de Ecología A.C. (INECOL); Veracruz, Mexico. 330 p.

Devetak D, Klokočovnik V. 2016. The feeding biology of adult lacewings (Neuroptera): a review. Trends in Entomology 12: 29–42.

Garzón A, Medina P, Amor F, Viñuela E, Budia F. 2015. Toxicity and sublethal effects of six insecticides to last instar larvae and adults of the biocontrol agents *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) and *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae). Chemosphere 132: 87–93.

Garzón-Orduña IJ, Winterton SL, Jiang Y, Breitkreuz LC, Duelli P, Engel MS, Liu X. 2019. Evolution of green lacewings (Neuroptera: Chrysopidae): a molecular supermatrix approach. Systematic Entomology 44: 499–513.

Hammer O, Harper DA, Ryan PD. 2001. Palaeontological statistics software package for education and data analysis. Palaeontologia Electronica. 4: 1–9.

Herbario-CICY. 2010. Flora de la Península de Yucatán. Available at http://www.cicy.mx/sitios/flora%20digital/ (Last accessed March 20, 2019.)

Hsieh TC, Ma KH, Chao A. 2016. iNEXT: an R package for rarefaction and extrapolation of species diversity (H ill numbers). Methods in Ecology and Evolution 7: 1451–1456.

Jiménez-Osornio JJ, Ruenes-Morales MR, Montañez-Escalante P. 1999. Agrodiversidad de los solares de la Península de Yucatán. Red, Gestión de Recursos Naturales 14: 30–40.

Koh LP, Sodhi NS. 2004. Importance of reserves, fragments, and parks for butterfly conservation in a tropical urban landscape. Ecological Applications 14: 1695–1708.

Koczor S, Szentkirályi F, Tóth M. 2019. New perspectives for simultaneous attraction of *Chrysoperla* and *Chrysopa* lacewing species for enhanced biological control (Neuroptera: Chrysopidae). Scientific reports. 9: 1–6.

Lassau SA, Hochuli DF. 2004. Effects of habitat complexity on ant assemblages. Ecography 27: 157–164.

López-Arroyo JI. 2001. Depredadores de áfidos asociados a los cítricos en Nuevo León, México. Abstrac E-153. In: Sociedad Mexicana de Entomología. Memorias XXXVI Congreso Nacional de Entomología y XXVIII Congreso Nacional de Fitopatología; Querétaro, México.

López-Arroyo JI, Cortez-Mondaca E, Arredondo-Bernal HC, Ramírez-Delgado M, Loera-Gallardo J, Mellín-Rosas MA. 2007. Uso de artrópodos depredadores para el control biológico de plagas en México. p. 90–105. In: Rodríguez-Del Bosque LA, Arredondo-Bernal HC. (eds.). Teoría y aplicación del control biológico. Sociedad Mexicana de Control Biológico; Mexico City, Mexico 303 p.

López-Arroyo JI, De León T. 2002. Producción de *Ceraeochrysa* (Neuroptera: Chrysopidae) In: Arredondo-Bernal HC, Pérez-Serrato P, Mellín-Rosas MA (eds.). Control biológico del pulgón café de los cítricos, *Toxoptera citricida*, vector del virus de la tristeza de los cítricos. 3ra. ed. SAGARPA. Comisión Nacional de Sanidad Agropecuaria; Mérida, Mexico. 149 p.

Lozano-Contreras MG, Jasso-Argumedo J. 2013. Identificación de enemigos naturales de *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) en el estado de Yucatán, México. Fitosanidad. 16: 5–11.

Mata L, Threlfall CG, Williams NS, Hahs AK, Malipatil M, Stork NE, Livesley SJ. 2017. Conserving herbivorous and predatory insects in urban green spaces. Scientific Reports 7: 1–12.

McKinney ML. 2002. Urbanization, biodiversity, and conservation: The impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. BioScience 52: 883–890.

Missouri Botanical Garden. 2022. Tropicos. Available at http://legacy.tropicos.org/Home.aspx (Last accessed February 16, 2022.)

Mochizuki A, Naka H, Hamasaki K, Mitsunaga T. 2006. Larval cannibalism and intraguild predation between the introduced green lacewing, *Chrysoperla carnea*, and the indigenous trash-carrying green lacewing, *Mallada desjardinsi* (Neuroptera: Chrysopidae), as a case study of potential nontarget effect assessment. Environmental Entomology, 35: 1298–1303.

Nair IJ, Sharma S, Kaur R. 2020. Efficacy of the green lace wing, *Chrysoperla zastrowi sillemi* (Esben-Peterson)(Neuroptera: Chrysopidae), against sucking pests of tomato: an appraisal under protected conditions. Egyptian Journal of Biological Pest Control 30: 1–6.

Niemelä J. 2014. Ecology of urban green spaces: The way forward in answering major research questions. Landscape and Urban Planning 125: 298–303.

Oliveira IF, Lion MB, Cardoso MZ. 2018. A plaza too far: High contrast in butterfly biodiversity patterns between plazas and an urban reserve in Brazil. Landscape and Urban Planning 180: 207–216.

Orellana R, Carrillo L, Franco V. 2007. Árboles recomendables para las ciudades de la Península de Yucatán. Unidad de Recursos Naturales, Centro de Investigación Científica de Yucatán, AC; Mérida, Mexico. 78 p.

Oswald JD. 2023. Neuropterida Species of the World. Available at https://lacewing.tamu.edu/SpeciesCatalog/Main (Last accessed November 3, 2023.)

Patiño-Arellano SA. 2012. Complejo de áfidos y riesgo de dispersión del virus de la tristeza de los cítricos en la península de Yucatán. M.Sc. Thesis Colegio de Posgraduados Press. https://doi.org/10.13140/rg.2.1.1671.8969

Penny ND, Tauber CA, De León T. 2000. A new species of *Chrysopa* from western North America with a key to North American species (Neuroptera: Chrysopidae). Annals of the Entomological Society of America 93: 776–784.

Ramirez-Restrepo LR, Chacon De Ulloa P, Constantino LM. 2007. Diversity of diurnal butterflies (Lepidoptera: Papilionoidea and Hesperioidea) in Santiago de Cali, Valle del Cauca, Colombia. Revista Colombiana de Entomología 33: 54–63.

Ramirez-Restrepo LR, Halffter G. 2013. Butterfly diversity in a regional urbanization mosaic in two Mexican cities. Landscape and Urban Planning 115: 39–48.

Ramírez-Restrepo LR, MacGregor-Fors I. 2017. Butterflies in the city: a review of urban diurnal Lepidoptera. Urban Ecosystems 20: 171–182.

Raupp MJ, Shrewsbury PM, Herms DA. 2010. Ecology of herbivorous arthropods in urban landscapes. Annual Review of Entomology 55: 19–38.

Salazar R. 1991. Guácimo *Guzuma ulmifolia* Lam., Especie de Árbol de Uso Múltiple en América Central. Centro Agronómico Tropical de Investigación y Enseñanza. CATIE. Serie Técnica. Informe Técnico 165: 1–69.

Sandoval-Gío JJ, Sánchez-Castillo LE, Zarza-Meza EA, Hernández-Jiménez JM, Fernández-Serrano JH, Pineda-Doporto A. 2018. Toxicidad aguda diferencial de TALSTAR® (bifentrina) y BIOTHRINE® (deltametrina) en la tilapia nilótica *Oreochromis niloticus*. Revista Internacional de Contaminación Ambiental 34: 45–55.

Sing KW, Luo J, Wang W, Jaturas N, Soga M, Yang X, Dong H, Wilson JJ. 2019. Ring roads and urban biodiversity: distribution of butterflies in urban parks in Beijing city and correlations with other indicator species. Scientific Reports 9: 7653.

Soto-Pinto L, Schroth G, Laderach P, Dempewolf J. 2010. Adaptación al cambio climático y sistemas productivos. p.193–199. In: Fletes OHB (ed.). Pequeños productores y vulnerabilidad global agroalimentaria. Universidad Autónoma de Chiapas Red de Investigación Socioeconómica en Hortalizas, Frutas y Flores (RISHORT); Tuxtla Gutiérrez, Mexico. 385 p.

Stange LA. 2000. The green lacewings of Florida: (Neuroptera: Chrysopidae). 1. Genera. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Entomology Circular 400: 1–4.

Tarango-Rivero SH, García-Nevárez G, Burrola-Morales JR. 2013. Manejo de áfidos del nogal pecanero. INIFAP Folleto Técnico 33: 1–42.

Tauber CA. 2003. Generic characteristics of *Chrysopodes* (Neuroptera: Chrysopidae), with new larval descriptions and a review of species from the United States and Canada. Annals of the Entomological Society of America 96: 472–490.

Tauber CA. 2004. A systematic review of the genus *Leucochrysa* (Neuroptera: Chrysopidae) in the United States. Annals of the Entomological Society of America 97: 1129–1158.

Tauber CA, De León T. 2001. Systematics of green lacewings (Neuroptera: Chrysopidae): larvae of *Ceraeochrysa* from México. Annals of the Entomological Society of America 94: 197–209.

Tauber CA, De León T, Penny ND, Tauber MJ. 2000. The genus *Ceraeochrysa* (Neuroptera: Chrysopidae) of America north of México: larvae, adults, and comparative biology. Annals of the Entomological Society of America 93: 1195–1221.

Tauber CA, Tauber MJ, Albuquerque GS. 2001. *Plesiochrysa brasiliensis* (Neuroptera: Chrysopidae): larval stages, biology, and taxonomic relationships. Annals of the Entomological Society of America 94: 858–865.

Thierry D, Canard M. 2007. The biodiversity of green lacewings (Neuroptera: Chrysopidae) in a mosaic ecosystem in southern France. Annali del Museo Civico di Storia Naturale di Ferrara 8: 131–138.

Trouvé C, Thierry D, Canard M. 2002. Preliminary survey of the lacewings (Neuroptera, Chrysopidae, Hemerobiidae) in agroecosytems in Northern France, with phenological notes. Acta Zoologica Academiae Scientiarum Hungaricae 48: 359–369.

Ullah Z, Sabri MA, Ahmad S, Bilal H, Hussain D, Mughal TK, Mohsin M, Aftab A, Ahmad MI. 2017. In vitro study of comparative toxicity of different insecticides against *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Journal of Entomology and Zoology Studies 5: 697–702.

Uno S, Cotton J, Philpott SM. 2010. Diversity, abundance, and species composition of ants in urban green spaces. Urban Ecosystems 13: 425–441.

Valencia-Luna LA, Romero-Nápoles J, Valdez-Carrasco J, Carrillo-Sánchez JL, López-Martínez V. 2006. Taxonomía y registros de Chrysopidae (Insecta: Neuroptera) en el Estado de Morelos, México. Acta Zoológica Mexicana 22: 17–61.

van Heezik Y, Dickinson KJM, Freeman C, Porter S, Wing J, Barratt BIP. 2016. To what extent does vegetation composition and structure influence beetle communities and species richness in private gardens in New Zealand? Landscape and Urban Planning 151: 79–88.

Villenave J, Deutsch B, Lodé T, Rat-Morris E. 2006. Pollen preference of the *Chrysoperla* species (Neuroptera: Chrysopidae) occurring in the crop environment in western France. European Journal of Entomology 103: 771–777.

Whittaker RH. 1965. Dominance and diversity in land plant communities: numerical relations of species express the importance of competition in community function and evolution. Science 147: 250–260.

Ye J, Li J, Li Z, Han S. 2017. Rearing of *Mallada basalis* (Neuroptera: Chrysopidae) on modified artificial diets. PLoS ONE 12(9): 1–9.

Zuur A, Ieno E, Smith G. 2007. Analyzing ecological data. Springer; NY. 672 p.

Received October 25, 2022; accepted December 6, 2023.
Review editor David Bowles.