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ARTICLE

Diversity of Ophioniformes wasps (Hymenoptera: Ichneumonidae) in a Central-West Brazilian Savanna area

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Abstract. This study aimed to assess the diversity, abundance and seasonal dynamics of Ophioniformes wasps collected throughout a year, as recorded in Malaise traps set at the Reserva Ecológica da Universidade Estadual do Mato Grosso do Sul, a Brazilian Savanna area in Aquidauana city, MS. A total of 621 specimens of Ophioniformes belonging to 11 subfamilies, 30 genera and 106 species were sampled. Despite the impressive number of species found, in a pattern of a few relatively abundant species and many rare ones, our data estimate even higher richness, probably between 125 to 165 species in the studied area. The genera *Diadegma, Nonnus, Diradops, Meniscomorpha, Syzeuctus, Ophiopterus* and *Thyreodon* are recorded for the first time in Mato Grosso do Sul State. Among the climatic variables evaluated, mean temperature and relative humidity were positively and significantly correlated with richness and abundance. Our data highlights the huge unknown species richness of these parasitoids in Brazil and the need of taxonomic studies efforts in the future.

Keywords. Darwin Wasps; Faunal survey; Ichneumonid; Malaise trap, Brazilian savanna.

INTRODUCTION

The Ichneumonidae (Hymenoptera), known as Darwin wasps, is a comparatively large clade of cosmopolitan parasitoid wasps (Quicke, 2015; Klopfstein *et al.,* 2019). The latest catalogue indicates 25.285 valid nominal species recorded up to 2015 making it the richest Hymenoptera family (Yu *et al.,* 2016). Despite this rich profusion of known species, there are still many taxa to be described, especially in poorly studied places mostly in the Southern Hemisphere (Sääksjärvi *et al.,* 2004; Quicke, 2012; Veijalainen *et al.,* 2014; Gómez *et al.,* 2018; Meierotto *et al.,* 2019). Within ichneumonid wasps, the clade Ophioniformes (Wahl, 1991) has been recovered as monophyletic by recent phylogenetic studies (Quicke *et al.,* 2000, 2009; Bennett *et al.,* 2019) and includes the following 18 subfamilies: Anomaloninae, Banchinae, Campopleginae, Cremastinae, Ctenopelmatinae, Hybrizontinae, Lycorininae, Mesochorinae, Metopiinae, Oxytorinae, Neorhacodinae, Nesomesochorinae, Ophioninae, Sisyrostolinae, Stilbopinae, Tatogastrinae, Tersilochinae and Tryphoninae.

Members of this group for which the host biology is known are all koionbionts and all except Tryphoninae (the sister group to all other subfamilies) are endoparasitoids (Bennett *et al.,* 2019). They parasitize larvae and pupae of a broad array of holometabolous insect orders, most commonly Lepidoptera, but also Hymenoptera, Coleoptera (Quicke, 2015 and references therein) and less commonly Raphidioptera (Spöck, 2002).

In Brazil, there are 368 described species of recorded Ophioniformes (Yu *et al.,* 2016; Fernandes *et al.,* 2020a) from almost all 18 subfamilies, except for Hybrizontinae, Sisyrostolinae, Stilbopinae and Tatogastrinae. Surveys of ichneumonid fauna including this clade, with identification of at least subfamily level, were conducted predominantly in the South (Kumagai & Graf, 2000; Kumagai & Graf, 2002) and Southeastern regions of Brazil (Guerra & Penteado-Dias, 2002; Kumagai, 2002; Sandonato *et al.,* 2010; Comério *et al.,* 2012; Tanque *et al.,* 2010). Over the last years, Darwin wasps faunistic surveys have been conducted in the Brazilian Central-West and Northeast regions (Aranda & Graciolli, 2015; Fernandes *et al.,* 2019, 2020b).

The Brazilian Savanna (known as Cerrado) is recognized as a crucial area for conservation due to its relatively high diversity and presence of

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endemic species (Mittermeier *et al.,* 2011). It occupies 1,983,017 km^2 of the Brazilian territory, extending over thirteen federation states, including most of Mato Grosso do Sul state (MS) (IBGE, 2019). Despite its significance for species conservation, deforestation rates in this biome were 2.5 times higher than in the Amazon rainforest between the years 2002 and 2011 (Strassburg *et al.,* 2017). Fast increase of agribusiness and infrastructure development combined with badly enforced environmental laws are leading to a major biodiversity collapse of this biome (Colli *et al.,* 2020).

Improvement on the knowledge of Ichneumonidae fauna is helpful to enable taxonomic studies and reviews (Klopfstein *et al.,* 2019), to use this information as a tool for environmental assessment (Mazón, 2016), and even to discover possible biological control agents (Townes, 1971; Gupta, 1991; Neto *et al.,* 2004). So, this study aimed to assess the diversity, abundance and seasonal dynamics of Ophioniformes wasps collected throughout a year using Malaise traps in the Reserva Ecológica da Universidade Estadual do Mato Grosso do Sul, from a Brazilian Savanna area.

MATERIAL AND METHODS

Study area

All Ichneumonid specimens here recorded were gathered by the project "Diptera from Mato Grosso, Mato Grosso do Sul and Rondônia states: diversity, systematics and distributional limits", which employed mass collecting using Malaise traps, from September/2011 to August/2012, completing a full year of continuously (day and night, approximately 26,300 hours) operated three Malaise traps. Each of these traps had 3.4 m^2 of catch area and contained flasks filled with ethanol 70% which were emptied every fortnight periods. The Malaise traps were placed at the Reserva Ecológica da Universidade Estadual do Mato Grosso do Sul (Aquidauana city, MS; Fig. 1A-C), each one in a collecting sites, with the following characteristics: Seasonal Deciduous Forest with closed vegetation (20°26′03.7″S, 55°39′20.8″W); Seasonal Deciduous Forest with open vegetation (20°25′59.0″S, 55°39′20.8″W); Riparian Forest (20°26′07.2″S, 55°39′32.8″W). The study area climate is classified according to the Köppen criteria as tropical Savanna climate (Aw): with mean monthly temperatures above 18°C, and a relatively dry winter, with less than 60 mm of precipitation in the driest month (Alvares *et al.,* 2013).

Specimens treatment and data analysis

Specimens were sorted, dry mounted, labelled and deposited at the Museu de Zoologia da Universidade de São Paulo (MZSP) Hymenoptera collection. Individuals were identified in subfamilies *sensu* Bennett *et al.* (2019) and those belonging to the Ophioniformes were separated into genera. Further identification was restricted to morphologically similar individuals based on characters in Gauld (1991, 2000), Gauld *et al.* (1997, 2002) and authors' experience within the group. Naming of described species was not possible because of limited knowledge of the Brazilian fauna. Henceforward, morphospecies are referred here to as species.

To characterize the assemblage, we estimated richness (S), total (At) and relative (Ar) abundances, numbers of species represented by one and two individuals (singletons and doubletons) and number found in one and two samples (uniques and duplicates). The species accumulation curve was constructed using the Mao Tau method and the estimated richness was evaluated through the estimators Chao 1, Chao 2 (classic formula option for both), Jackknife 1, Jackknife 2, and Bootstrap with 500 randomizations. These analyses were performed using EstimateS 9.1.0 software (Colwell, 2013).

A rank-abundance curve on a logarithmic scale ($\log_{10}$) was generated to evaluate dominance in the assemblage based on the abundance of species in all samples. The dominance indices of Simpson and Berger-Parker were calculated. The monthly number of collected species and individuals of Ophioniformes was correlated with meteorological data through the Coefficient of Pearson to search for possible relationships between the abiotic variables and the temporal distribution of species. The environmental data of mean temperature, relative humidity and precipitation were obtained from Instituto Nacional de Meteorologia (INMET). The data normality was assessed through the Shapiro-Wilk test and the abundance data were log transformed. These analyses were performed using PAST 4.02 software (Hammer *et al.,* 2001).

High-resolution photographs were taken using a Leica M205C stereomicroscope attached to a Leica DFC 295 camera. Multiple photographs of the subject were taken at different focal stages and combined using multiple stack methods with Leica LAS (Leica Application Suite V3.6.0) or Helicon Focus 6.7.1 software.

RESULTS

A total of 2,331 specimens of Ichneumonidae were collected in our survey. From these, 621 specimens of Ophioniformes were identified in 11 subfamilies, 30 genera and 106 species (Tables 1 and 2). Nearly 70% of the specimens captured were identified as Campopleginae (8 genera and 29 species), Cremastinae (5 genera and 21 species) and Metopiinae (4 genera and 12 species). The most abundant Ophioniformes genera were *Xiphosomella* Szépligeti, 1905 (Cremastinae) (N = 97 specimens), *Mesochorus* Gravenhorst, 1829 (Mesochorinae) (N = 96), *Casinaria* Holmgren, 1859 (Campopleginae) (N = 88), *Eiphosoma* Cresson, 1865 (Cremastinae) (N = 66) and *Stethantyx* Townes, 1971 (Tersilochinae) (N = 61).

We recorded a pattern of a few relatively abundant Ophioniformes species and many rare ones: 40

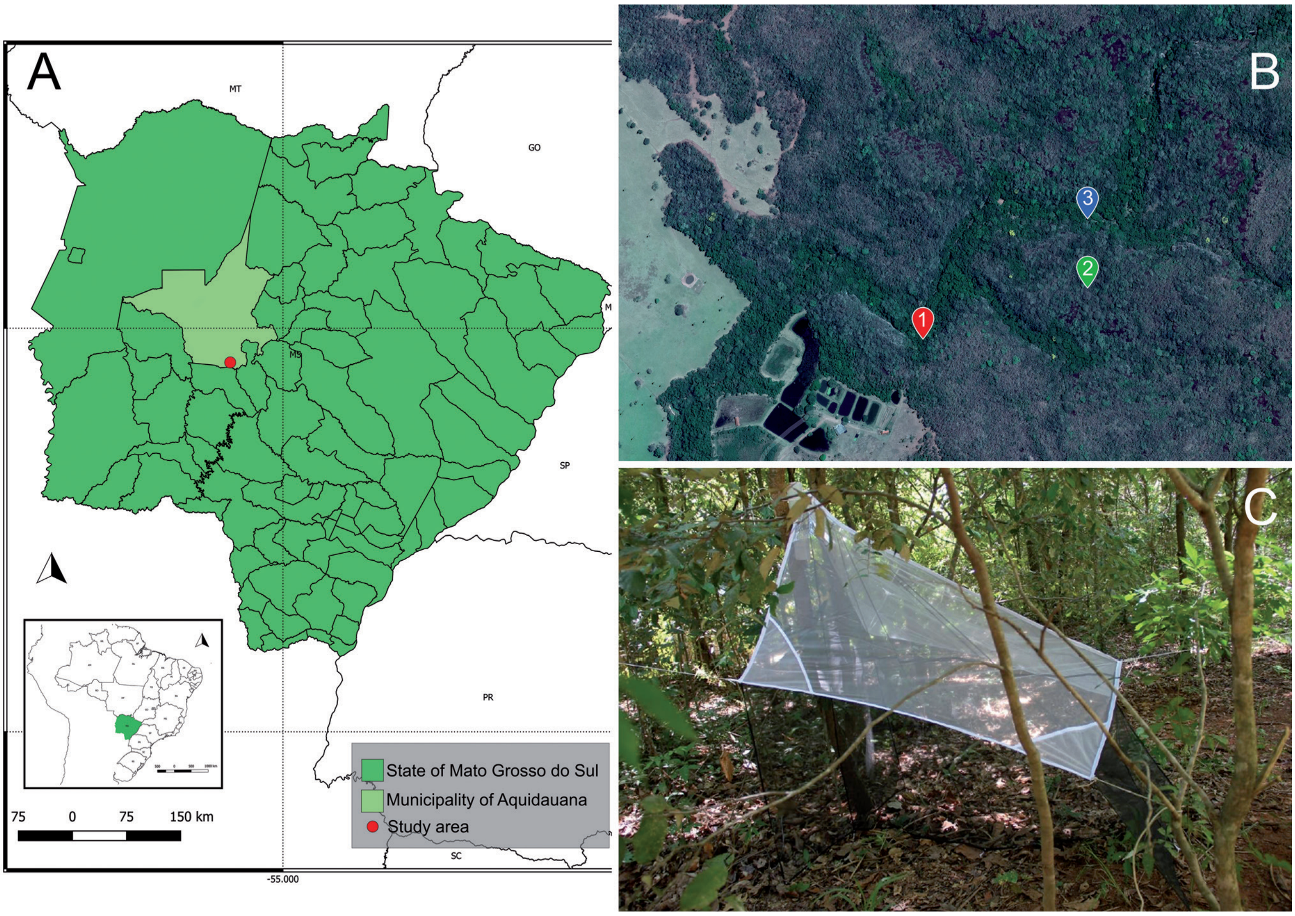

Figure 1. (A) Map illustrating the state of Mato Grosso do Sul (Brazil) emphasizing the Municipality of Aquidauana where the samples were collected. (B) Satellite image of the the Reserva Ecologica da Universidade Estadual do Mato Grosso do Sul showing the location where the Malaise traps have been deployed: 1 = Riparian Forest; 2 = Seasonal Deciduous Forest with closed vegetation; 3 = Seasonal Deciduous Forest with open vegetation. (C) Malaise trap assembled in the Seasonal Deciduous Forest with open vegetation (20°25′59.0″S, 55°39′20.8″W).

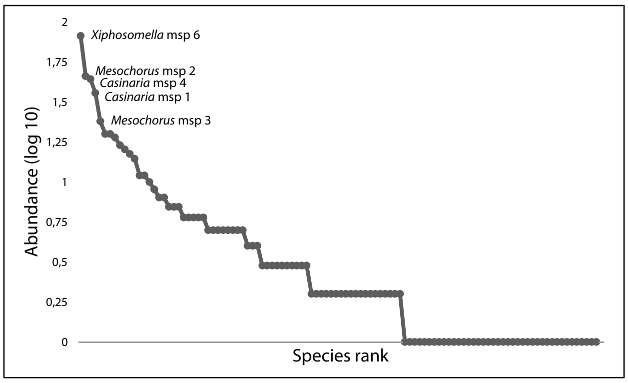

Figure 2. Rank-abundance curve and dominant species of the Ophioniformes collected in Aquidauana (MS), between September 2011 and August 2012.

singletons (37.7%), 19 *doubletons* (18%), 44 *uniques* (41.5%) and 27 (25.4%) *duplicates.* The low values obtained by the Simpson and Berger-Parker indices (0.04 and 0.13, respectively) indicate the absence of species with significant relative higher dominance. The most dominant species, however, were *Xiphosomella* sp.6 (Fig. 5A), *Mesochorus* sp.2, *Casinaria* sp.4 and sp.1, and *Mesochorus* sp.3, which together accounted for 36.5% of the sampled specimens (Fig. 2).

The richest months for Ophioniformes records were August/2012 followed by September and October/2011.

Table 1. Total and relative abundance of Ophioniformes subfamilies (Hymenoptera: Ichneumonidae) collected in Aquidauana, MS, from September 2011 to August 2012.

Ichneumonidae subfamilies	Total abundance	Relative abundance
Anomaloninae	9	0.39%
Banchinae	46	1.97%
Campopleginae	157	6.74%
Cremastinae	170	7.29%
Ctenopelmatinae	1	0.04%
Mesochorinae	96	4.12%
Metopiinae	42	1.80%
Nesomesochorinae	6	0.26%
Ophioninae	24	1.03%
Tersilochinae	61	2.62%
Tryphoninae	9	0.39%
Others ichneumonids	1710	73.36%

Mesochorus sp.3 was encountered in 11 months, followed by *Xiphosomella* sp.6 (9 months), and *Stethantyx* sp.6 (8 months) (Table 2).

The performance of species richness estimators varied, with Jackknife 2 estimating the greatest number of species (165.56) and Bootstrap being the most conservative, suggesting about 84% of the inventory of species completeness (Fig. 3, Table 3).

Table 2. Composition, abundance and sampling months of Ophioniformes (Hymenoptera: Ichneumonidae) collected in Aquidauana, MS, from September 2011 to August 2012.

Ichneumonidae subfamilies	Total abundance	Relative abundance	Ocurrence months	
			2011	2012
Anomaloninae				
Anomalon sp.1	1	0.16%	—	May
Ophionellus sp.1	1	0.16%	—	Jun
Ophiopterus sp.1	2	0.32%	Sep	Aug
Podogaster sp.1	1	0.16%	—	Aug
Podogaster sp.2	1	0.16%	—	Aug
Podogaster sp.3	3	0.48%	—	Jan
Banchinae				
Diradops sp.1	4	0.64%	Oct	Jul-Aug
Diradops sp.2	10	1.61%	Sep	Aug
Diradops sp.3	1	0.16%	—	Aug
Diradops sp.4	1	0.16%	Sep	Aug
Meniscomorpha sp.1	4	0.64%	Sep	Aug
Meniscomorpha sp.2	1	0.16%	—	Aug
Meniscomorpha sp.3	1	0.16%	—	Aug
Syzeuctus sp.1	19	3.06%	Sep-Nov	Mar, Jun-Aug
Syzeuctus sp.2	5	0.81%	Nov-Dec	Aug
Campopleginae				
Casinaria sp.1	36	5.80%	Sep-Nov	May-Aug
Casinaria sp.2	5	0.81%	—	Aug
Casinaria sp.3	1	0.16%	Sep	—
Casinaria sp.4	44	7.09%	Sep-Dec	Jun-Aug
Casinaria sp.5	2	0.32%	Oct	Aug
Charops sp.1	2	0.32%	Nov	May
Charops sp.2	1	0.16%	—	Aug
Cryptophion sp.1	1	0.16%	Sep	—
Diadegma sp.1	9	1.45%	Oct-Dec	Jun-Jul
Dusona sp.1	1	0.16%	Sep	—
Dusona sp.2	1	0.16%	Sep	—
Dusona sp.3	3	0.48%	Sep	—
Dusona sp.4	2	0.32%	—	Aug
Dusona sp.5	4	0.64%	Sep	Aug
Dusona sp.6	3	0.48%	Sep-Oct	—
Dusona sp.7	1	0.16%	Sep	—
Dusona sp.8	6	0.97%	Sep-Oct	Jun-Aug
Hyposoter sp.1	14	2.25%	Sep-Oct	Mar, May-Aug
Hyposoter sp.2	1	0.16%	—	Jun
Hyposoter sp.3	1	0.16%	—	Jun
Hyposoter sp.4	1	0.16%	—	Aug
Microcharops sp.1	1	0.16%	—	Aug
Microcharops sp.2	2	0.32%	Sep	Aug
Venturia sp.1	3	0.48%	Oct	May, Aug
Venturia sp.2	1	0.16%	Oct	—
Venturia sp.3	2	0.32%	—	Jun, Aug
Venturia sp.4	1	0.16%	Dec	—
Venturia sp.5	2	0.32%	Sep	Aug
Venturia sp.6	5	0.81%	Sep	May-Jul
Venturia sp.7	1	0.16%	—	Jul
Cremastinae				
Dimophora sp.1	1	0.16%	—	Jul
Dimophora sp.2	1	0.16%	Oct	—
Dimophora sp.3	2	0.32%	—	Aug
Eiphosoma sp.1	6	0.97%	Sep	Aug
Eiphosoma sp.2	7	1.13%	Sep	Aug
Eiphosoma sp.3	1	0.16%	—	Aug
Eiphosoma sp.4	1	0.16%	Oct	—
Eiphosoma sp.5	7	1.13%	Sep-Oct	Aug
Eiphosoma sp.6	3	0.48%	Sep	Aug
Eiphosoma sp.7	6	0.97%	—	Aug
Eiphosoma sp.8	17	2.74%	Sep-Oct	Mar, Jun, Aug
Eiphosoma sp.9	15	2.42%	Sep-Oct	Jan, May, Jul-Aug
Eiphosoma sp.10	3	0.48%	—	Jun, Aug
Pristomerus sp.1	2	0.32%	Oct	Aug
Temelucha sp.1	1	0.16%	Sep	—
Xiphosomella sp.1	1	0.16%	—	Jan
Xiphosomella sp.2	1	0.16%	—	Aug
Xiphosomella sp.3	1	0.16%	—	Aug
Xiphosomella sp.4	5	0.81%	Sep, Dec	Jun, Aug
Xiphosomella sp.5	7	1.13%	Sep-Nov	Jun, Aug
Xiphosomella sp.6	82	13.20%	Sep-Dec	Feb, May-Aug
Ctenopelmatinae				
Physotarsus sp.1	1	0.16%	Sep	—
Mesochorinae				
Mesochorus sp.1	11	1.77%	Oct-Nov	May-Aug
Mesochorus sp.2	46	7.41%	Sep-Nov	May-Aug
Mesochorus sp.3	24	3.86%	Sep-Dec	Jan-May, Jul-Aug
Mesochorus sp.4	8	1.29%	Oct-Dec	Feb, Jul-Aug
Mesochorus sp.5	2	0.32%	Oct	Feb
Mesochorus sp.6	5	0.81%	Oct-Nov	Feb, Jul
Metopiinae				
Colpotrochia sp.1	2	0.32%	Sep	—
Colpotrochia sp.2	1	0.16%	Dec	—
Colpotrochia sp.3	1	0.16%	—	Aug
Colpotrochia sp.4	2	0.32%	—	Aug
Colpotrochia sp.5	6	0.97%	Sep-Oct	Jun, Aug
Colpotrochia sp.6	1	0.16%	Sep	—
Colpotrochia sp.7	3	0.48%	—	Aug
Exochus sp.1	20	3.22%	Sep-Dec	Jun
Leurus sp.1	1	0.16%		Aug
Leurus sp.2	1	0.16%	Dec	—
Trieces sp.1	3	0.48%	Nov-Dec	Feb
Trieces sp.2	1	0.16%	Nov	—
Nesomesochorinae				
Nonnus sp.1	6	0.97%	Sep-Oct, Dec	—
Ophioninae				
Enicospilus sp.1	3	0.48%	Sep	—
Enicospilus sp.2	1	0.16%	—	Aug
Enicospilus sp.3	2	0.32%	—	Aug
Enicospilus sp.4	3	0.48%	Oct	Mar, Jun
Enicospilus sp.5	2	0.32%	Oct	Aug
Enicospilus sp.6	2	0.32%	—	Mar, Aug
Enicospilus sp.7	1	0.16%	—	Jul-Aug
Enicospilus sp.8	1	0.16%	—	Aug
Enicospilus sp.9	3	0.48%	—	Jun, Aug
Enicospilus sp.10	5	0.81%	Sep, Dec	—
Thyereodon sp.1	1	0.16%	Oct	—
Tersilochinae				
Stethantyx sp.1	16	2.58%	Oct-Dec	Jan-Feb, Apr
Stethantyx sp.2	1	0.16%	Nov	—
Stethantyx sp.3	5	0.81%	Sep	Jun, Aug
Stethantyx sp.4	11	1.77%	Oct-Dec	Jan-Feb
Stethantyx sp.5	8	1.29%	Oct-Dec	Jan-Mar
Stethantyx sp.6	20	3.22%	Oct-Dec	Jan-Apr, Jun
Tryphoninae				
Netelia sp.1	2	0.32%	—	Aug
Netelia sp.2	2	0.32%	Sep	Jul
Netelia sp.3	5	0.81%	—	Aug

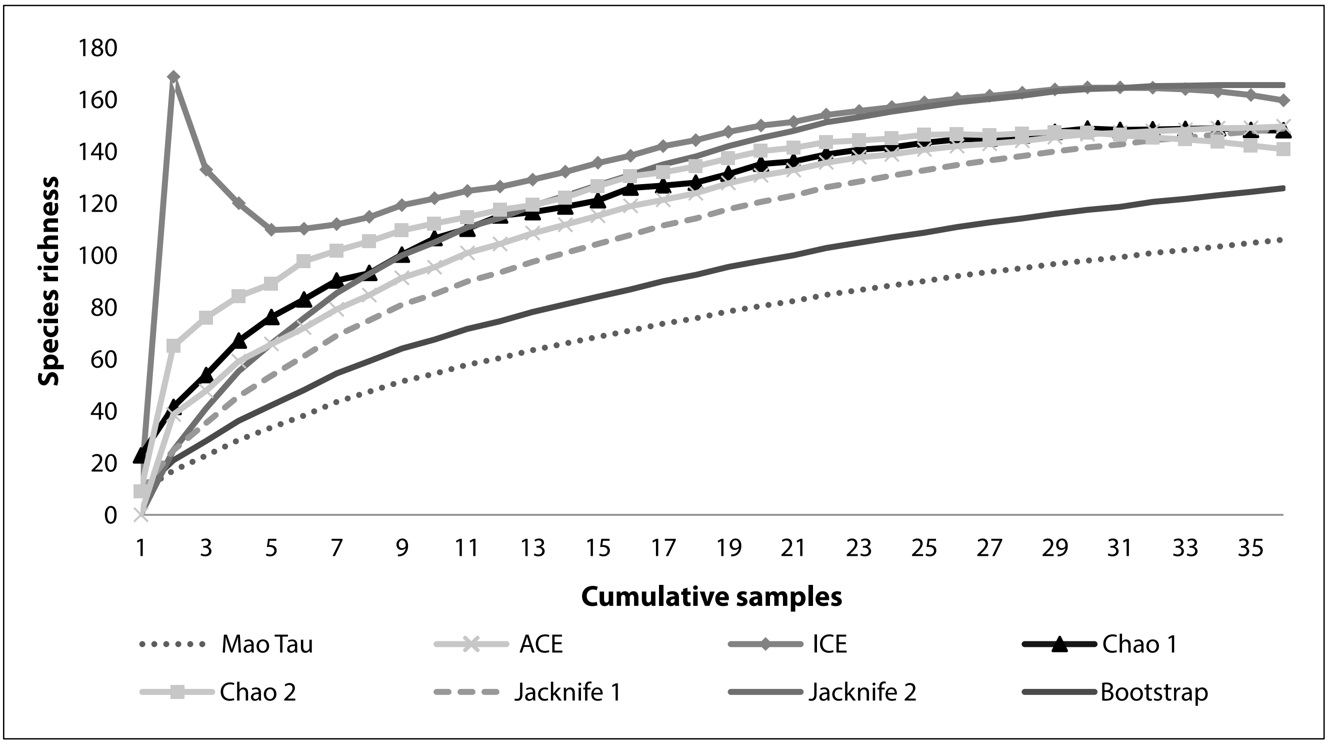

Figure 3. Observed richness and performance of the richness estimators of the Ophioniformes collected in Aquidauana (MS, Brazil), between September 2011 and August 2012.

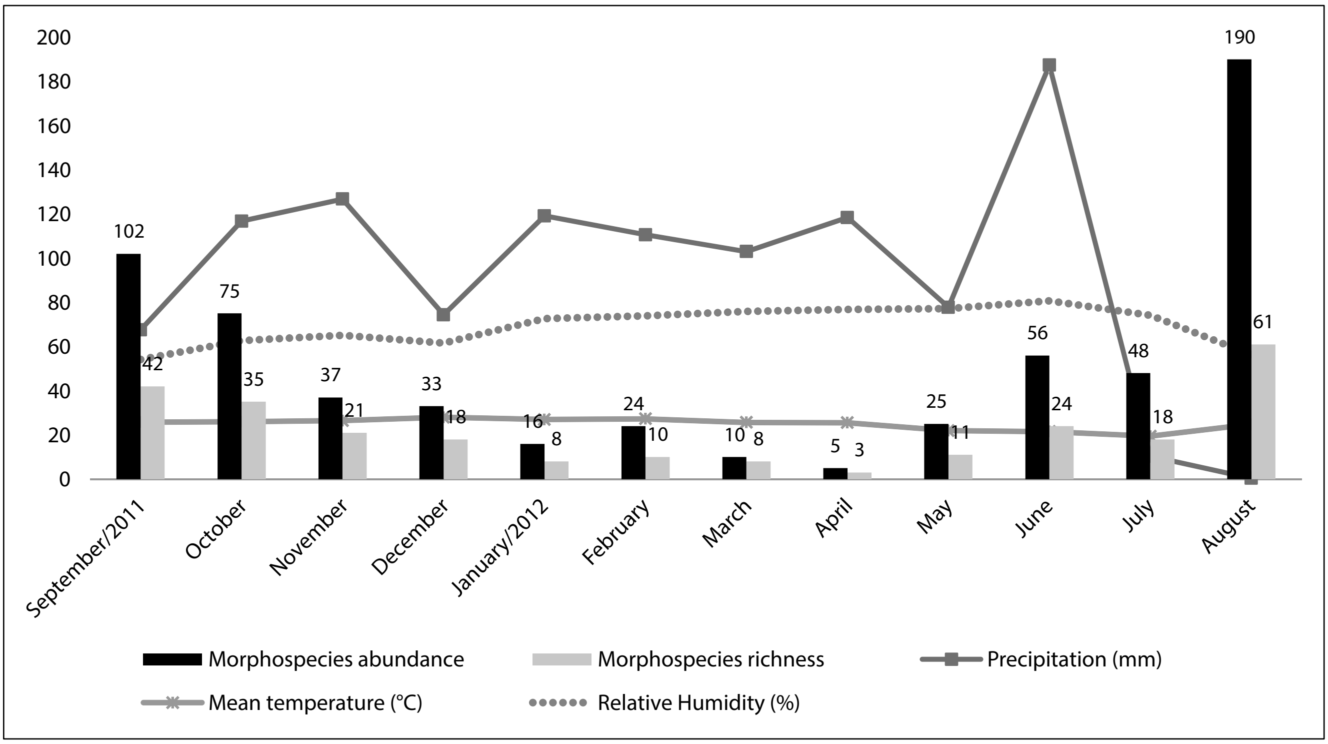

Figure 4. Distribution of environmental variables and abundance and species richness of Ophioniformes collected per month in Aquidauana (Mato Grosso do Sul, Brazil), between September 2011 and August 2012.

Among the climatic variables evaluated, relative humidity was the only variable negatively correlated with Ophioniformes abundance and richness (Table 4). The greatest richness also coincided with the period of higher abundance (Table 1 and Fig. 4) and the Pearson correlation test found a positive relation between richness and abundance variables ($RP = 0.91269$, $p < 0.05$).

DISCUSSION

In this study, Ophioniformes accounted for 26,6% of overall Ichneumonidae collected in Aquidauana. Other previous studies indicate this group may represent 16% to 50% of Ichneumonidae fauna collected in different regions of the country (Kumagai & Graf, 2000; Kumagai,

Table 3. Observed and estimated species richness of Ophioniformes collected in Aquidauana (MS), between September 2011 and August 2012.

Estimators		Estimators	
Observed	106	Chao 2	140.86 ± 13.8
ACE	149.59	Jacknife 1	148.78 ± 11.17
ICE	159.64	Jacknife 2	165.56
Chao 1	148.04 ± 17.66	Booststrap	125.81

Table 4. Pearson' linear correlation between environmental variables and abundance and richness of Ophioniformes species collected using Malaise traps in Aquidauana (MS), between September 2011 and August 2012. Asterisks (*) indicate statistical significance at level of 0.05 probability.

	Mean temperature (°C)	Precipitation (mm)	Relative humidity (%)
Abundance	-0.18915	-0.40245	-0.67064*
Richness	-0.037404	-0.44898	-0.77519*

2002; Guerra & Penteado-Dias, 2002; Kumagai & Graf, 2002; Tanque *et al.,* 2010; Comerio *et al.,* 2012; Fernandes *et al.,* 2019).

A relatively high number of Ophioniformes species were found in the present survey. Despite our efforts, rarefaction curves indicate an even greater actual richness, estimated between 125 to 165 species. The comparatively high number of singletons and uniques samples suggests the necessity of greater sampling efforts, as observed by Sääksjärvi *et al.* (2004) who recorded a relatively high local diversity of Pimplinae (Pimpliformes) in Amazonian Peru, but also represented by a relatively high number of singletons. Fernandes *et al.* (2017) pointed out the necessity of long-term sampling for the collection of rare specimens of the small family Sclerogibbidae. An interesting example can be observed in Supeleto *et al.* (2020): even after extensive collection trips, only six specimens of *Acrosnemus* Supeleto, Aguiar & Santos, 2020 (Ichneumonidae: Cryptinae) were sampled showing the importance of recurrent sampling.

Among the Ophioniformes subfamilies collected, Nesomesochorinae is for the first time recorded in a Savanna area in Center-West Brazil. Although Lycorininae has not collected in our study, Shimbori *et al.* (2017) recorded the subfamily in the municipality of Campo Grande, only 140 km distant from Aquidauana.

It is well known that temperature and humidity are important factors regulating parasitoid life (*e.g.,* Gauld, 1987; Ouedraogo *et al.,* 1996; Emana, 2007). Our figures support Aranda & Gracioli (2015) results that peak abundance in Hymenoptera in the Brazilian Savanna is from August to October (Table 2).

Anomaloninae is a subfamily currently with 25 species of nine genera recorded in Brazil (Fernandes *et al.,* 2020a). Shimbori *et al.* (2017) recorded the presence of seven of the recorded Brazilian genera of this subfamily (except for *Castrosion* Gauld & Bradshaw, 1997 and *Ophiopterus* Brullé, 1846) in the state of Mato Grosso do Sul. The genus *Ophiopterus* (Fig. 6B) is represented by two New World species: *O. cincticornis* (Cresson, 1865) known from USA to Panama and *O. coarctatus* Brullé, 1846 which is endemic to Brazil (Yu *et al.,* 2016; Fernandes *et al.,* 2020a). *O. coarctatus* has been recorded in the Amazon (Morley, 1912), Guaratuba in its south region (Brullé, 1846) and in the state of Espírito Santo (Azevedo *et al.,* 2015). The genus is recorded here for the first time in Central-West Brazil.

Five species of the cosmopolitan genus *Anomalon* Panzer, 1804 are recorded in Brazil (Yu *et al.,* 2016; Fernandes *et al.,* 2020a). Apart from the savanna this genus is also known to occur in the Amazon (Townes & Townes, 1966) and Caatinga biomes (Fernandes *et al.,* 2019, 2020b) and in coconut palm and coffee crops (Melo *et al.,* 2009; Comério *et al.,* 2012). *Ophionellus* Westwood, 1874 is a small new world genus (21 species) with three Brazilian species (Yu *et al.,* 2016; Fernandes *et al.,* 2020a). Besides the records for Mato Grosso do Sul state, this genus has been recorded in the south by Brullé (1846) and in soy crops attacking the noctuid moths *Chrysodeixis includens* (Walker, 1858) and *Heliothis virescens* (Fabricius, 1777) (Massarolli *et al.,* 2018).

The Neotropical genus *Podogaster* Brullé, 1846 with 26 known species, stands out by being relatively well documented in Brazil (Kumagai & Graf, 2000; Melo *et al.,* 2009; Azevedo *et al.,* 2015). Eight species are recorded for the country (Yu *et al.,* 2016; Fernandes *et al.,* 2020a). Brazilian host records of this genus include *Chrysodeixis includens* (Walker, 1858) (Lepidoptera: Noctuidae) in soy crops (Massarolli *et al.,* 2018) and *Hypsipyla grandella* (Zeller, 1848) (Lepidoptera: Pyralidae) in the south of Brazil (Graf, 1983).

The cosmopolitan Banchinae subfamily has 28 described species in 13 genera reported in Brazil (Yu *et al.,* 2016; Fernandes *et al.,* 2020a). All the genera found in this study are first records for the Central-West region of Brazil. Thirty-five species of *Diradops* Townes, 1946 (Fig. 5C) are restricted to the New World, two of them recorded in Brazil: *Diradops castanea* (Brullé, 1846) and *Diradops aculate* (Brullé, 1846) both occurring in the South (Brullé, 1846). The genus was well represented in our survey, with four species most frequently collected in August. Little biological information can be found in the literature, but they are known to attack Notodontidae and Noctuidae moths (Surgeoner & Wallner, 1975; Kasparyan & Ruíz, 2007; Fernandes *et al.,* 2010).

Meniscomorpha Schmiedeknecht, 1907 (Fig. 5D) is also a New World genus with 64 described species including four in Brazil (Yu *et al.,* 2016; Fernandes *et al.,* 2020a). Members of this genus were recorded attacking Gelechiidae and Oecophoridae moths in Southeast Brazil (Fernandes *et al.,* 2010; Nava *et al.,* 2005). *Syzeuctus* Förster, 1869 (Fig. 6A) is a large cosmopolitan genus comprising 127 valid nominal species (Yu *et al.,* 2016). In Brazil only *Syzeuctus minasensis* (Brèthes, 1927) has been recorded. Its occurrence was documented in the Southeast region (Brèthes, 1927) without host record.

The subfamily Campopleginae stands-out by the relatively high abundance and richness recorded. The incidence of this subfamily may be associated with the agricultural areas surrounding the study site. Campopleginae play an important role as a biocontrol agent against crop pests (*e.g.,* Moraes *et al.,* 1991; Azidah *et al.,* 2000;

Bortolotto *et al.,* 2014). All genera identified in this study were also found occurring in organic crops in the State of São Paulo by Sandonato *et al.* (2010).

Casinaria is a large genus with 100 species worldwide (Yu *et al.,* 2016) and only three of them are recorded in Brazil: *C. bonaerensis* (Schrottky, 1902), *C. brasiliensis* Brèthes, 1927, *C. plusiae* (Blanchard, 1947) (Yu *et al.,* 2016; Fernandes *et al.,* 2020a). The last species was identified attacking the noctuid moths *Rachiplusia nu* (Guenée, 1852) and *Chrysodeixis includens* (Walker, 1858) in Brazilian soy crops by Moraes *et al.* (1991).

The genus *Charops* Holmgren, 1859 represented here by two species was recently reviewed by Santos *et al.* (2019) for Brazil, with the description of seven species. Marconato *et al.* (2008) found this genus attacking geometrid moths in *Erythroxylum microphyllum* St.-Hilaire, a plant species typical of the Brazilian Savanna (Mendonça *et al.,* 1998). As rare as *Charops, Cryptophion* Viereck, 1913 was represented by only one specimen collected in September. The works of Onody *et al.* (2013) and Onody & Penteado-Dias (2016) were important contributions for the taxonomy and biogeography of this genus, showing its presence in the Atlantic forest and Savanna in the Brazilian southeast. Gauld & Janzen (1994) observed specimens reared from the sphingid moth *Erinnyis ello* (Linnaeus, 1758) in Costa Rica. Besides Sphingidae, this genus is also known to attack saturniid moths (Gauld & Janzen, 1994).

Diadegma Förster, 1869 is represented in Brazil by *D. imbecillum* (Enderlein, 1921) in the South region and *D. leontiniae* (Brèthes, 1923) in South and Central-West regions (Townes & Townes, 1966; Wagener *et al.,* 2006). *D. leontiniae* is an important biological control agent of *Plutella xylostella* (Linnaeus, 1758) (Lepidoptera: Plutellidae), one of the most damaging pests of cruciferous plants (Azidah *et al.,* 2000). This genus is recorded for the first time in Mato Grosso do Sul state.

A relatively high richness and abundance were observed for *Dusona* Cameron, 1901 in our survey. Kumagai & Graf (2000) observed four *Dusona* species occurring in rural and urban area in the South of Brazil. This genus has more than 400 described species worldwide and only four of them have been recorded in Brazil. The last Brazilian species was described in 1926 (Hancock, 1926).

Similar to Campopleginae, members of Cremastinae are parasitoids mostly of Lepidoptera, but also Coleoptera (Gauld, 2000; Quicke, 2015), including many important crop pests. For instance, Silva *et al.,* (2012) reported *Eiphosoma laphygmae* Costa Lima, 1953 attacking *Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae) in maize crops].

Eiphosoma was the most common genus of this subfamily in our survey. Onody *et al.* (2012) reported fourteen *Eiphosoma* species occurring in organic crops in the state of São Paulo. Seven species of this genus were reported in a Savanna fragment situated in the same state (Melo & Penteado-Dias, 2009). This is a medium-sized genus with 56 valid nominal species restricted to the New World, with 23 species recorded in Brazil (Yu *et al.,* 2016; Fernandes *et al.,* 2020a). Shimbori *et al.* (2017) recorded five species for the Mato Grosso do Sul state. Species of this genus are known to be endoparasitoids of Lepidoptera with host records of the families Crambidae, Noctuidae and Pyralidae in Brazil (Sauer, 1946; Lima, 1953).

Little is known about the genus *Dimophora* Förster, 1869 in Brazil. This small genus includes 19 described species, but only one from the Neotropical region: *Dimophora daschi* Gauld, 2000 described from Costa Rica (Yu *et al.,* 2016). The presence of this genus was reported by Azevedo *et al.* (2015) in Espírito Santo state. We record this genus for the first time in the Brazilian Central-West region.

Pristomerus Curtis, 1836 is a cosmopolitan, relatively large genus comprising 140 valid nominal species (Yu *et al.,* 2016). *Pristomerus spinator* (Fabricius, 1804) is the only species occurring in Brazil. Patel & Habib (1984) recorded this species attacking *Spodoptera frugiperda* (Smith, 1797) in corn crops in the Southeast region. *Temelucha* Förster, 1869 is also a cosmopolitan genus comprising 235 species with fourteen of them are known to occur in the Neotropics (Yu *et al.,* 2016). Although no described species have been previously recorded in Brazil, the genus has been documented in different regions including the Northeast (Fernandes *et al.,* 2019), Southeast (Azevedo *et al.,* 2015) and for the first time hereby in Central-West region.

The New World genus *Xiphosomella* has 54 described species (Yu *et al.,* 2016). Four species are known to occur in the North, Southeast and South Brazilian regions (Lima, 1954; Azevedo *et al.,* 2015; Fernandes *et al.,* 2020a). Biological records of this genus are scarce. Cushman (1924) recorded *X. stenomae* Cushman, 1924 attacking the Depressariidae moth *Stenoma catenifer* Walsingham, 1912 in Panama. In Brazil, the genus is recorded as a parasitoid of the concealer moth *Cerconota anonella* (Sepp, 1830) (Depressariidae) in soursop (Micheletti & Filho, 2000).

The subfamily Ctenopelmatinae was represented in our survey by only one specimen of the New World genus *Physotarsus* Townes, 1966 collected only in September. Six species are known to occur in Brazil (Zhaurova & Wharton, 2009). This genus has been recorded as parasitoid of *Trochophora lobata* (Erichson, 1848), a sawfly of the family Argidae in Costa Rica (Gauld *et al.,* 1997).

Mesochorinae are currently classified in 10 genera (Araujo *et al.,* 2018; Araujo, 2018) with 871 described species (Yu *et al.,* 2016). From these, 700 species belong to the cosmopolitan genus *Mesochorus* (Fig. 5F) with 49 species recorded in Brazil (Araujo *et al.,* 2019). Most of these species were described by Dasch in 1974 and are endemic to the Atlantic Forest, while only one is described for the Savanna biome (Araujo *et al.,* 2019). Members of this genus are hyperparasitoids mostly of Ichneumonoidea (occasionally Diptera: Tachinidae) within Lepidoptera and sawfly larvae and also in immature Hemiptera (Quicke, 2015 and references therein). The six species we found are likely undescribed since the number of *Mesochorus* species is probably underestimated, as already pointed out by Araujo *et al.* (2019).

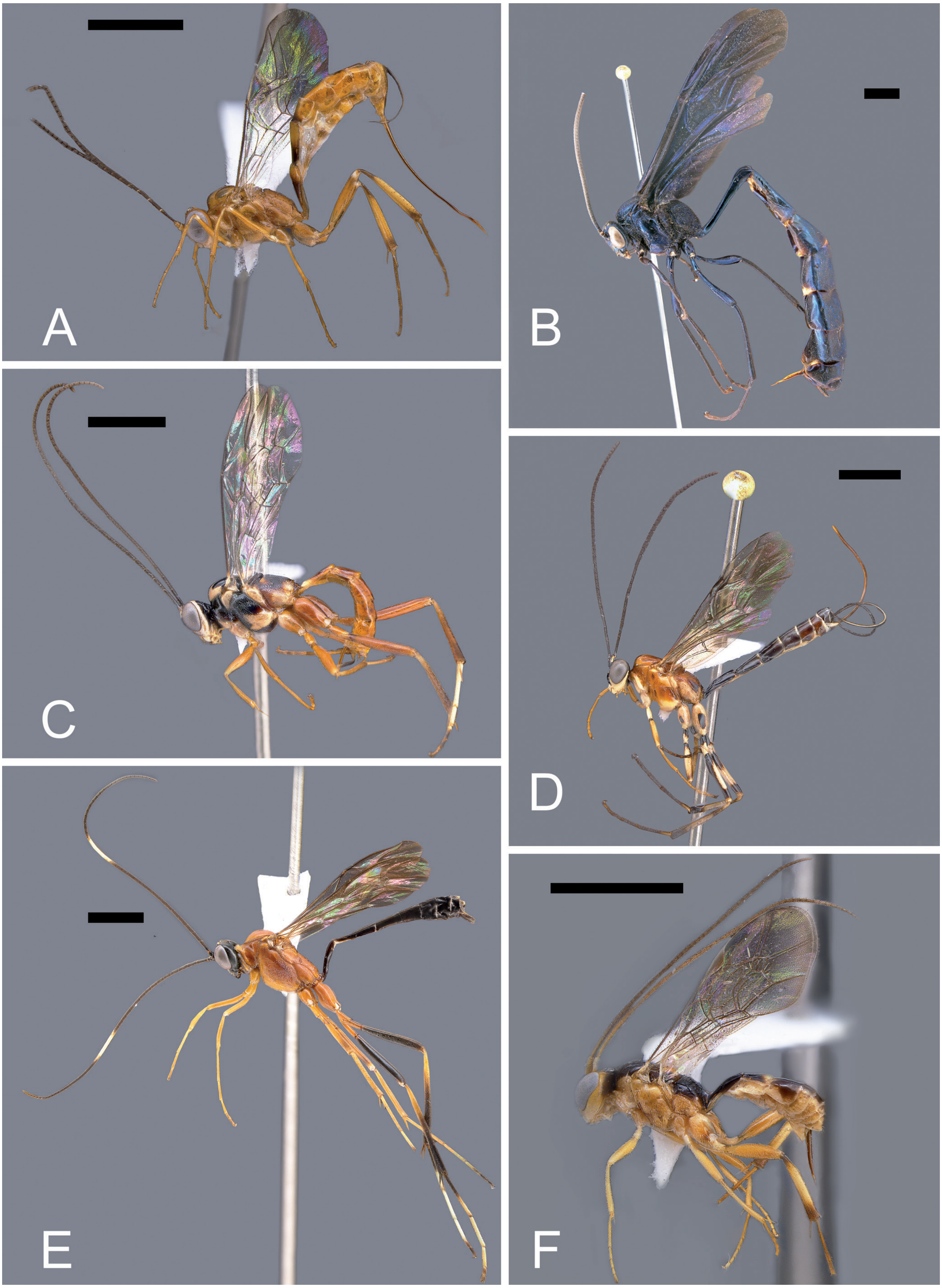

Figure 5. (A) *Xiphosomella* sp.6 (Cremastinae) female habitus, (B) *Thyreodon* sp.1 (Ophioninae) female habitus, (C) *Diradops* sp.4 (Banchinae) female habitus, (D) *Meniscomorpha* sp.1 (Banchinae) female habitus, (E) *Nonnus* sp.1 (Nesomesochorinae) female habitus, (F) *Mesochorus* sp.1 (Mesochorinae) female habitus. Scale bars: A-E: 2 mm, F: 1 mm. Specimens collected in Aquidauana, MS, between September 2011 and August 2012.

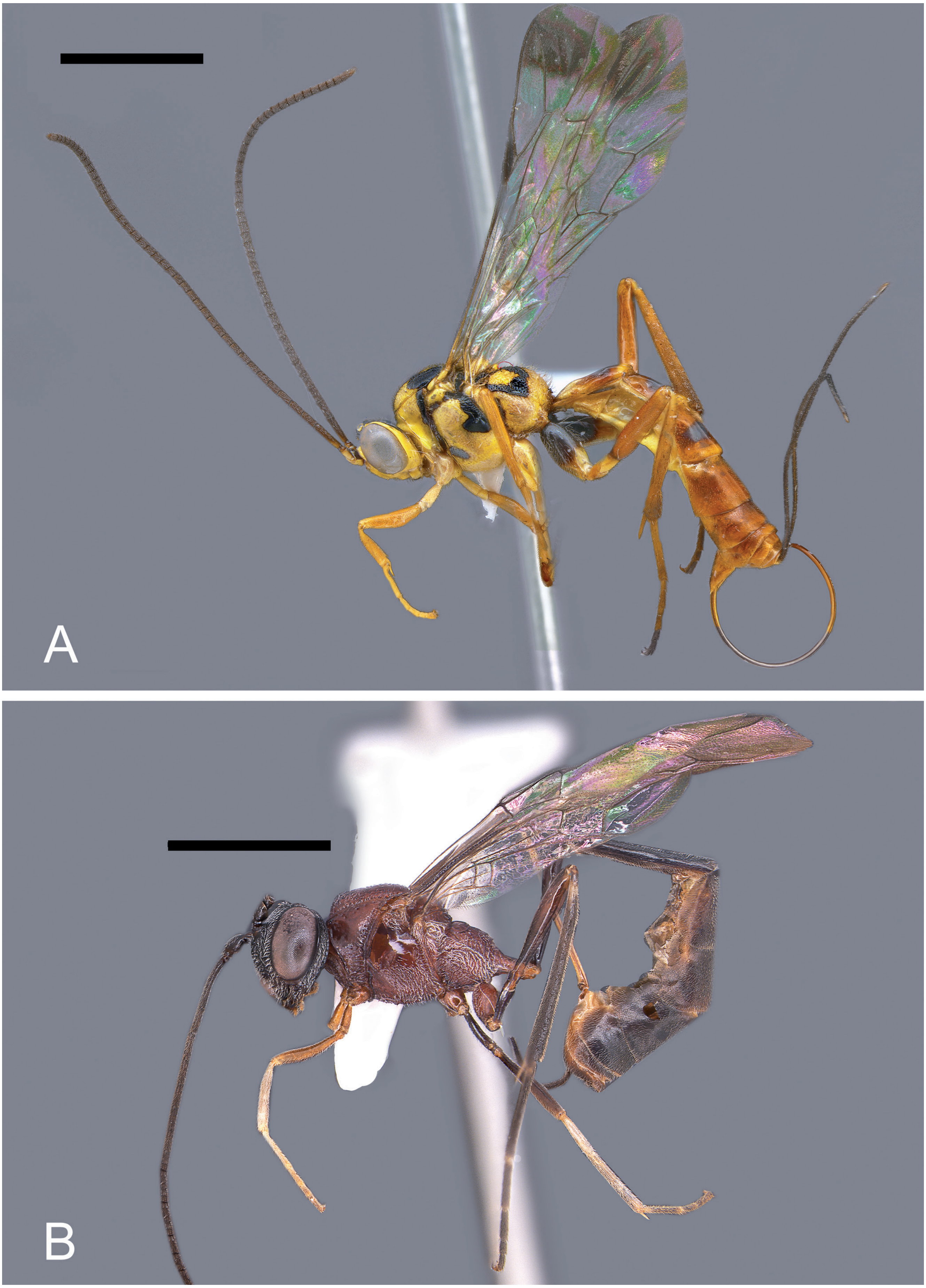

Figure 6. (A) *Syzeuctus* sp.1 (Banchinae) female habitus, (B) *Ophiopterus* sp.1 (Anomaloninae) female habitus. Scale bars: 2 mm. Specimens collected in Aquidauana, MS, between September 2011 and August 2012.

Metopiinae is a medium-sized cosmopolitan subfamily with 862 described species worldwide (Yu *et al.,* 2016). Fernandes *et al.* (2020a) registered nine genera and 29 species occurring in all regions of Brazil (apart from the Northeast) of Brazil. The genus *Colpotrochia* Holmgren, 1856 comprises 62 species with five Brazilian species. This genus was recorded parasitizing *Spodoptera frugiperda* (Smith, 1797) in Brazilian corn fields (Silva *et al.,* 2012).

Exochus Gravenhorst, 1829 is a large genus comprising 281 cosmopolitan species (Yu *et al.,* 2016). This genus was studied recently in Brazil by Melo *et al.* (2015), who described *E. atlanticus* from the Atlantic rainforest and provide new geographical records of *E. ablatus* Gauld & Sithole, 2002 and *E. izbus* Gauld & Sithole, 2002 in Savanna and semideciduous forest in southeast region.

Leurus Townes, 1946 is a small new world genus with eleven descried species (Yu *et al.,* 2016). *Leusus caeruliventris* (Cresson, 1868) is the only specie recorded from Brazil thus far. Fernandes *et al.* (2010) recorded this species attacking *Dichomeris* sp. (Gelechiidae) and *Leurus* sp. parasitizing *Olethreutinae* sp. (Tortricidae) on *Croton floribundus* Spreng in southeast region. *Trieces* Townes, 1946 is a medium-sized cosmopolitan genus with 70 valid species (Yu *et al.,* 2016). Ten species were recorded in Brazil, with most occurring in the Southeast region (Fernandes *et al.,* 2020a).

Wasps belonging to the New World genus *Nonnus* Cresson, 1874 (Fig. 5E) were the only representatives of the subfamily Nesomesochorinae in our survey. Its members are relatively large and conspicuous wasps with 20 described species (Wahl & Bennett, 2020). Nine species are recorded in the Brazilian states of Amazonas, Espírito Santo, Goiás, Mato Grosso, Rio de Janeiro, Rio Grande do Sul and São Paulo (Townes & Townes, 1966; Comério *et al.,* 2012; Azevedo *et al.,* 2015; Fernandes *et al.,* 2020a) and for the first time here for Mato Grosso do Sul state. Host records are unknown for *Nonnus,* thus the biology of this group remains a mystery (Wahl & Bennett, 2020).

Ophioninae wasps are commonly collected in Brazil due to their large size and attraction to light (Burbutis & James, 1979). This cosmopolitan subfamily comprises 32 genera and more than one thousand species (Yu *et al.,* 2016). Some species of this subfamily are parasitoids of important agricultural pests (like *S. frugiperda*), but they are not suitable for biocontrol release programmes (Quicke, 2015). Most species of this subfamily belong to *Enicospilus* Stephens, 1835 which comprises around 700 species (Yu *et al.,* 2016) with 61 of them recorded in all Brazilian regions (Fernandes *et al.,* 2020a). We record here for the first time the genus *Thyreodon* Brullé, 1846 (Fig. 5B) in the Central-West Brazilian region. This genus comprises 45 species, nine of them with Brazilian occurrence (Yu *et al.,* 2016; Fernandes *et al.,* 2020a).

Tersilochinae is a cosmopolitan medium-sized subfamily with more than 560 described species in 27 genera (Khalaim & Ruíz-Cancino, 2020). Fernandes *et al.* (2020a) registered three genera and 13 described species in the south and southeast regions of Brazil. *Stethantyx* Townes, 1971 is a Neartic and Neotropical genus with 47 species (Yu *et al.,* 2016). Recently taxonomic contributions to this genus were made by Khalaim (2017) with the description of *Stethantyx durrelli* Khalaim, 2017, increasing the recorded species in Brazil to 11 (Fernandes *et al.,* 2020a). Biological information regarding this genus is scarce but it seems to parasitize weevils (Parker *et al.,* 1950).

The subfamily Tryphoninae is a cosmopolitan group with 54 genera and about 1,300 species (Bennett, 2015). They are koinobiont ectoparasitoids of Lepidoptera larvae and pre-pupae (Konishi, 2014). In our survey this subfamily is represented by several species of the genus *Netelia* Gray, 1860, a large genus comprising more than 330 species, (Bennett, 2015), of which only nine are known to occur in Brazil (Yu *et al.,* 2016); the most recent description being *N. oeceticola* (Blanchard, 1941), but the total number of species present might be much higher (Bennett, *pers. comm.*) This genus was recorded as a parasitoid of the noctuid moth *Mocis latipes* (Guenée, 1852) in the Southeast region (Lourenção *et al.,* 1982).

In summary, this study recorded for the first time the presence of the genera *Diadegma* (Campopleginae) and *Nonnus* (Nesomesochorinae) for the Mato Grosso do Sul state and the genera *Diradops, Meniscomorpha,* Syzeuctus (all Banchinae), *Ophiopterus* (Anomaloninae) and *Thyreodon* (Ophioninae) for the Central-West region. Many genera recorded here (*e.g., Dusona, Diradops, Enicospilus, Netelia*) are relatively little-studied in the Neotropical region and the number of undescribed species in these genera highlights the huge unstudied species richness of Ichneumonidae Ophioninae wasps in Brazil and the need to study and conserve this critically important part of the world's biodiversity.

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AUTHORS' CONTRIBUTIONS

Conceived the study: A.D.S., H.C.O., C.R.F.B. Species identification and analysis: A.D.S., H.C.O. Images: A.D.S. Writing, review and editing: A.D.S., H.C.O., C.R.F.B.

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