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Checklist and New Occurrences of Odonata (Insecta) from Volta Grande do Xingu, Pará, Brazil

Anderson André Carvalho-Soares [1], Kesley Gadelha Ferreira [1], Kenned Silva Sousa [1], Ana Caroline Leal Nascimento [2], Cristian Camilo Mendoza-Penagos [3], Thiago Bernardi Vieira [4], Ana Karina Moreyra Salcedo [5], José Max Barbosa Oliveira-Junior [6], Lenize Batista Calvão [3] and Karina Dias-Silva [4,*]

1 Faculdade de Ciências Biológicas (FCB), Universidade Federal do Pará (UFPA), Rua Coronel José Porfírio, N. 2515, Bairro São Sebastião, Altamira 68372-040, Brazil; andersonxacs@gmail.com (A.A.C.-S.); kesleygadelha@gmail.com (K.G.F.); kenned272@gmail.com (K.S.S.)
2 Programa de Pós-Graduação em Biodiversidade (PPGBEES), Instituto de Ciências e Tecnologia das Águas (ICTA), Universidade Federal do Oeste do Pará (UFOPA), Santarém 68040-255, Brazil; carolineleal.bio@gmail.com
3 Programa de Pós-Graduação em Ecologia (PPGECO), Instituto de Ciências Biológicas (ICB), Universidade Federal do Pará (UFPA), Rua Augusto Correia, N. 1, Bairro Guamá, Belém 66075-110, Brazil; cristian.penagos@icb.ufpa.br (C.C.M.-P.); lenizecalvao@gmail.com (L.B.C.)
4 Programa de Pós-Graduação em Biodiversidade e Conservação (PPGBC), Universidade Federal do Pará (UFPA), Rua Coronel José Porfírio, N. 2515, Bairro São Sebastião, Altamira 68372-040, Brazil; thiagobernardi007@gmail.com
5 Centro de Ciências Naturais e Tecnologia (CCNT), Departamento de Engenharia Ambiental, Universidade do Estado do Pará (UEPA), Campus Altamira, Avenida Bom Jesus, s/n, Bairro Mutirão, Altamira 68377-078, Brazil; karina.moreyra@gmail.com
6 Programa de Pós-Graduação em Sociedade, Natureza e Desenvolvimento (PPGSND), Programa de Pós-Graduação em Sociedade, Ambiente e Qualidade de Vida (PPGSAQ), Instituto de Ciências e Tecnologia das Águas (ICTA), Universidade Federal do Oeste do Pará (UFOPA), Santarém 68040-255, Brazil; jose.mbo@ufopa.edu.br
* Correspondence: diassilvakarina@gmail.com

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Abstract: The order Odonata (Insecta) is composed of aquatic insects popularly known as dragonflies and damselflies. Members of this order are closely linked to the conservation status of their habitats; however, the Wallacean shortfall in some regions still remains high. The Volta Grande do Xingu region is known to have high endemism of some groups, such as Actinopterygii (fish), which can be applied to other groups that do not yet have their fauna known at the site, such as the order Odonata. The Wallacean shortfall and constant anthropic changes (for example, the construction of the Belo Monte Hydroelectric) have been obstacles in the preservation of these and other groups. In that regard, the main aim of this paper is to provide a checklist of Odonata (Insecta) adult species from the streams of Volta Grande do Xingu, Pará, Brazil. The collections were carried out in 19 streams in the Volta Grande do Xingu region in September 2019, corresponding to the drought period. A total of 526 specimens were collected, where two suborders, six families, 26 genera and 43 species were identified. Three species of Odonata were registered for the first time in the state of Pará: *Erythrodiplax famula* (Erichson *in* Schomburgk, 1848); *Acanthagrion chacoense* Calvert, 1909 and *Epipleoneura lamina* Williamson, 1915. These data allow us to help increase the knowledge of Odonata fauna in the streams of Volta Grande do Xingu, a region that is under intense anthropic pressure. This helps to reduce the Wallacean shortfall, with another area sampled for the state of Pará.

Keywords: aquatic insects; Anisoptera; Zygoptera; inventory; Amazon

1. Introduction

The order Odonata, belonging to the class Insecta, is composed of aquatic insects popularly known as dragonflies and damselflies [1]. Currently, the order has approximately

6322 species, with more than 600 genera and 39 families belonging to three suborders: Anisoptera, Anisozygoptera and Zygoptera, and has representatives in tropical, subtropical and temperate regions [2,3]. In Brazil, there are 862 species and 146 genera, 15 families and the suborders Anisoptera and Zygoptera registered [4]. The Zygoptera and Anisoptera suborders have high rates of endemism, about 87% and 64% of the genera groups, respectively, occur only in the Neotropical realm [5,6].

During adulthood, individuals of the suborders Anisoptera and Zygoptera can be easily distinguished by their body morphology [7]. Adult Zygoptera usually have a smaller and slimmer body; the fore and hind wings of Zygoptera are similar in terms of shape, size and venation, and, when at rest, they usually arrange their wings closed over the abdomen [7,8]. The adult Anisoptera representatives have a more robust body; the wings are widened at the base and differ in size, shape and venation, and, when at rest, generally, the wings are arranged on the sides of the body [8,9].

In addition, Odonata adults differ in their ecophysiology, they are divided into "Fliers" and "Perchers". Fliers are endothermic individuals that produce endogenous heat and are able to control the circulation of hemolymph between the chest and abdomen, and perchers are usually ectothermic using sunlight and ambient temperature [10]. Individuals classified as fliers are commonly part of the Anisoptera suborder, and perchers are mostly part of the Zygoptera suborder [11].

The thermoregulation of Odonata adults also influences their habitat preference. Most Zygoptera species are restricted to areas where canopy cover and shading are more present, while Anisoptera are present in greater abundance and richness in open areas with large sunlight inputs [12–14].

In a study by De Marco and Vianna [15] on the effort to collect Brazilian odonatofauna, they found that only 29% of the territory had data on Odonata richness, and only about 3.5% of the Brazilian area had more than 50 samples by location. In the same paper, the authors note that the main states with information are in the Southeast region and in small isolated points where there is a presence of Odonata researchers. Furthermore, the difficulty of collecting some taxa, such as Aeshnidae and Gomphidae [16], and the lack of investment in taxonomy professionals to identify individuals deposited in collections [17] interfere in the solving of the Wallacean shortfall.

In Miguel et al. [14], 12 years after the work of De Marco and Vianna [15], it was found that the north region still has a large Wallacean shortfall. Even with the growing number of studies in the field of odonatology [18–28] and recent checklists for other states in the region (Amazonas: Koroiva et al. [29]; Amapá: Garcia Junior et al. [30]), the state of Pará still does not present a checklist. In addition, many areas still have unknown biodiversity; the region of Volta Grande do Xingu is one of them. This lack of knowledge is worrisome since this area is under the impact of the reduction in the level of the Xingu River, which will modify the water functioning of its streams and generate changes in the biological communities present in these places, e.g., family Loricariidae (Siluriformes) [31], which may result in the loss of species before they are even known.

Faced with the rapid advancement of human activities on ecosystems, seeking information on the diversity and distribution of species is necessary, in order to have a basis for the planning of conservation of these species [32]. The lack of information in certain regions represents an obstacle mainly in the assessment of the conservation status of Odonata species, such as on the IUCN (International Union for Conservation of Nature) red list [33]. Therefore, this study aims to present a checklist of species of adults of the order Odonata present in streams in the region of Volta Grande do Xingu, Pará, as well as to provide the distribution of these species and the characterization of the microhabitat of new occurrences for the state of Pará, Brazil.

2. Materials and Methods

2.1. Study Area

The study was carried out by scanning in 19 streams in the region of Volta Grande do Xingu, in the municipalities of Anapu, Senador José Porfírio and Vitória do Xingu, in the southwest of the state of Pará, Brazil (Figure 1, Table 1). These streams, according to Strahler's classification [34], are considered small because they are classified as 1st to 3rd order streams (Figure 2). According to the Köppen–Geiger classification, the predominant climate in the region is Am, a tropical monsoon climate, with dry seasons usually lasting from June to November, and rainy seasons from December to May [35]. The average annual temperature in the region is 26.5 °C; the average annual rainfall is close to 2044 mm/year, and the average number of hours of sunshine per year is approximately 2453.73 h/year. In September of 2019, the monthly average number of hours of sunshine was 249 h/month (Climatedata.org, accessed on 17 May 2021) [36].

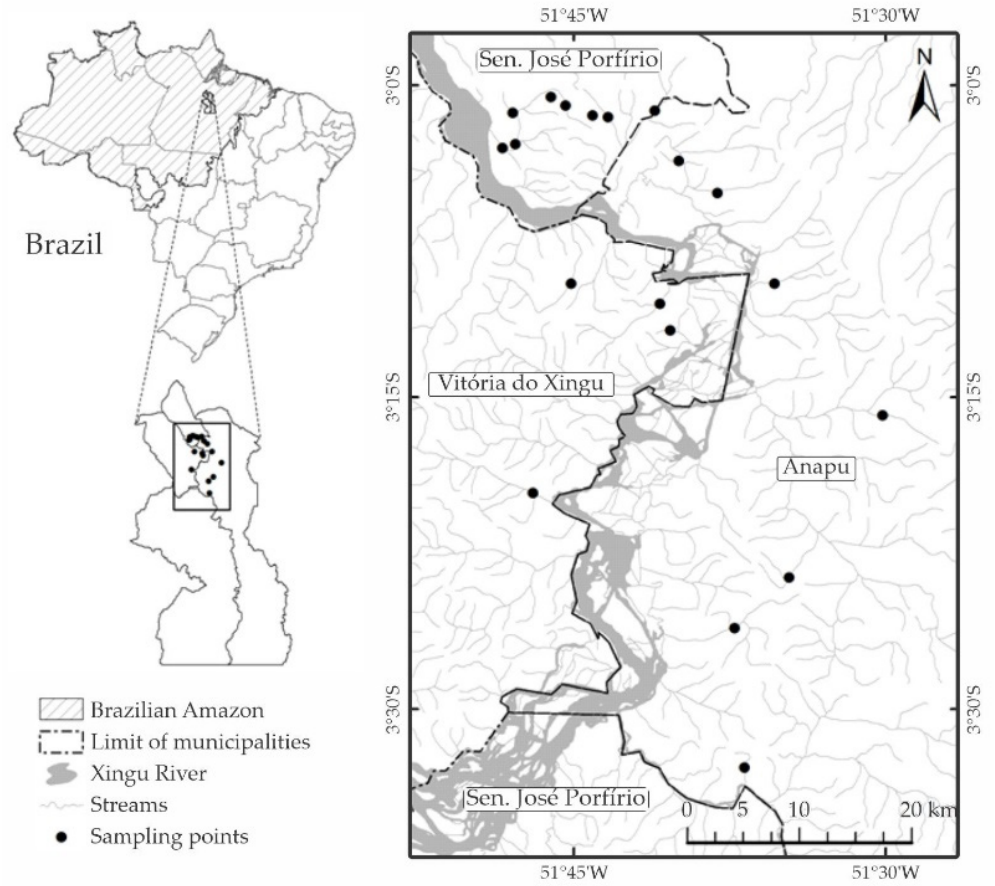

Figure 1. Location of adult Odonata collection points in Volta Grande do Xingu, Pará, Brazil (in 2019).

Table 1. Location and abbreviation of collection points (P), coordinates and their respective municipalities in the region of Volta Grande do Xingu, Pará, Brazil.

Collection Points	Cooordinates	Municipality
P1	03°19.601′ S, 051°46.967′ W	Vitória do Xingu
P2	03°05.166′ S, 051°38.097′ W	Anapu
P3	03°03.623′ S, 051°39.957′ W	Altamira
P4	03°02.993′ S, 051°48.438′ W	Senador José Porfírio
P5	03°01.315′ S, 051°47.936′ W	Senador José Porfírio
P6	03°02.818′ S, 051°47.809′ W	Senador José Porfírio
P7	03°00.953′ S, 051°45.401′ W	Senador José Porfírio
P8	03°09.530′ S, 051°35.343′ W	Anapu

Table 1. *Cont.*

Collection Points	Cooordinates	Municipality
P9	03°01.211′ S, 051°41.114′ W	Senador José Porfírio
P10	03°10.487′ S, 051°40.855′ W	Vitória do Xingu
P11	03°15.856′ S, 051°30.142′ W	Anapu
P12	03°01.428′ S, 051°44.103′ W	Senador José Porfírio
P13	03°01.511′ S, 051°43.345′ W	Senador José Porfírio
P14	03°00.549′ S, 051°46.102′ W	Senador José Porfírio
P15	03°32.798′ S, 051°36.785′ W	Anapu
P16	03°26.095′ S, 051°37.275′ W	Anapu
P17	03°23.664′ S, 051°34.643′ W	Anapu
P18	03°11.780′ S, 051°40.371′ W	Vitória do Xingu
P19	03°09.529′ S, 051°45.132′ W	Vitória do Xingu

Figure 2. Streams sampled in Volta Grande do Xingu, Pará, Brazil (in 2019): (**A**) P9; (**B**) P15; (**C**) P20; (**D**) P19; (**E**) P17; and (**F**) P18.

2.2. Data Collection

The collections were carried out in September 2019, corresponding to the dry season at the site, due to the logistics of accessing the sites. A 100-m transect was delimited in each stream, and each transect was subdivided into 20 segments of 5-m each (Figure 3). The collection was carried out using the methodology of scanning in fixed areas, with the aid of an entomological net [37,38].

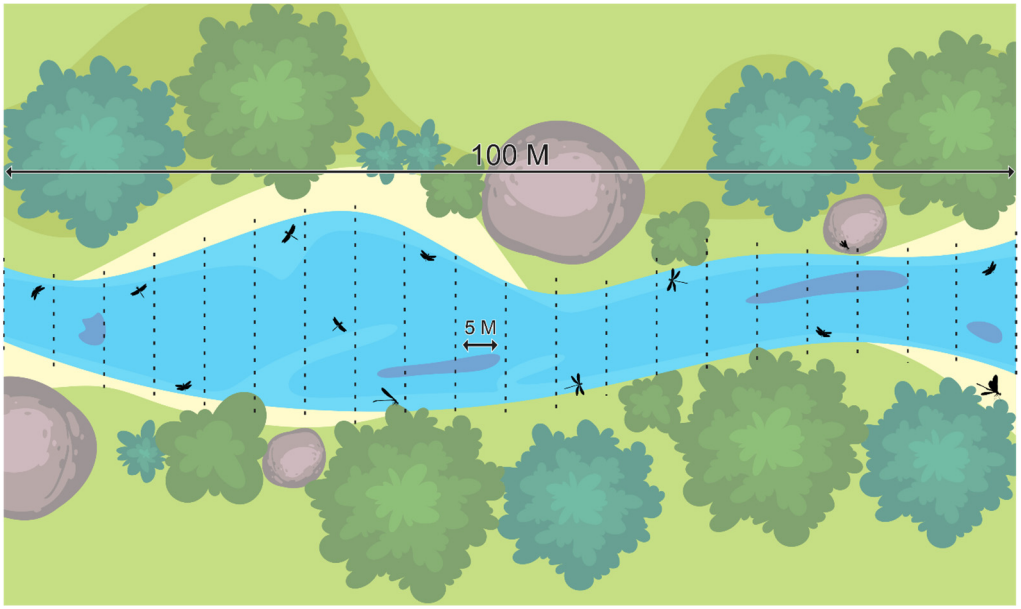

Figure 3. Representation of the division of segments after delimitation of the 100-m transect of the stream. M = meters.

After collection, the adult individuals of Odonata were placed in parchment paper envelopes, identified with the aid of taxonomic keys [7,9,39–49], and stored at the Laboratório de Ecologia—LABECO of the Universidade Federal do Pará—UFPA, Campus Altamira.

2.3. List Elaboration

For the elaboration of the list, 27 indexed publications were used, published between 1991 and 2021, on the distribution of families, genera and species, bibliographic reviews and lists of species from other Brazilian states. Additionally, the websites Fauna Taxonomic Catalog of Brazil (http://fauna.jbrj.gov.br/, accessed on 22 April 2021; Pinto [4]) and Global Biodiversity Information Facility—GBIF (https://www.gbif.org/, accessed on 13 April 2021) were used [50], and, to verify the conservation status of species on the list, we used the Red Book of the Brazilian Fauna Threatened with Extinction: Volume VII Invertebrates (Odonata) [51] (Table 2).

Table 2. References used to elaborate the distribution of adult species of Odonata from Volta Grande do Xingu (Pará, Brazil) and their numbers. GBIF = Global Biodiversity Information Facility.

Citation	References
Bastos et al., 2019	[32]
Garcia Junior et al., 2021	[30]
Dalzochio et al., 2018	[52]
Costa and Oldrini 2003	[53]
Rodrigues and Roque 2017	[33]
Ferreira-Peruquetti and Trivinho-Strixino 2003	[54]
Assis et al., 2004	[55]
Koroiva et al., 2017	[56]
Machado et al., 1991	[57]
Ferreira-Peruquetti and De Marco 2002	[58]
Storari et al., 2019	[59]
Souza et al., 2015	[60]
Oliveira-Junior et al., 2013	[61]
Pereira et al., 2019	[62]
Pessacq et al., 2012	[63]
Koroiva et al., 2020	[29]

Table 2. *Cont.*

Citation	References
Lencioni 2017	[47]
Carvalho et al., 2018	[21]
Miguel et al., 2017b	[18]
Nobre and Carvalho 2014	[64]
Lencioni 2005	[43]
Lencioni 2006	[44]
Ellenrieder 2009	[65]
Pessacq 2014	[49]
Vilela et al., 2020	[66]
Pinto 2021	[4]
GBIF	[50]
Calvão et al., 2016	[67]
Monteiro-Júnior et al., 2016	[68]

2.4. Statistical Analysis

To measure the sampling effort and the number of species collected, the non-parametric Chao 1 estimator was used. This estimator is used for abundance data, and it gives weight for rare species [69]. The accumulation curve of species was generated from the estimator. Chao 1 and the species accumulation curve were calculated using the R software [70] using the vegan package [71].

3. Results

In total, 526 individuals belonging to seven families, 26 genera and 43 species were collected. From this, a total of three species were new records for the state of Pará: two species of Zygoptera and one species of Anisoptera. Among the sampled families, Coenagrionidae had the highest species richness (n = 18), followed by Libellulidae (n = 17), Calopterygidae (n = 4), Megapodagronidae (n = 2), Dicteriadidae and Polythoridae, each with only one species (Table 3).

The suborder Zygoptera had the highest abundance (n = 374), followed by Anisoptera (n = 152). Among Anisoptera, the family with the highest number of individuals was Libellulidae (n = 151). In Zygoptera, the most abundant family was Coenagrionidae (n = 177), followed by Calopterygidae (n = 175) and Polythoridae (n = 10).

The most abundant genera were *Mnesarete* (n = 92), *Hetaerina* (n = 83) and *Erythrodiplax* (n = 71). Regarding richness, the most species-rich genera were *Argia* (n = 7), *Epipleoneura* (n = 5), *Acanthagrion*, *Erythrodiplax* and *Neoneura* with four species each. Among the species collected, *Mnesarete williamsoni* (n = 39), *Hetaerina auripennis* (n = 37), *Neoneura sylvatica* (n = 35), *Epipleoneura metallica* (n = 24) and *Mnesarete cupraea* (n = 24) presented the largest numbers of specimens collected.

Table 3. List of species recorded for Volta Grande do Xingu, Pará, Brazil. Location of collection points present in Table 1. Distribution of species in Brazilian states: AC = Acre; AM = Amazonas; AP = Amapá; BA = Bahia; CE = Ceará; DF = Distrito Federal; ES = Espirito Santos; GO = Goiás; MA = Maranhão; MG = Minas Gerais; MS = Mato Grosso do Sul; MT = Mato Grosso; PA = Pará; PB = Paraíba; PE = Pernambuco; PR = Paraná; RJ = Rio de Janeiro; RO = Rondônia; RR = Roraima; RS = Rio Grande do Sul; SC = Santa Catarina; SP = São Paulo; TO = Tocantins. References used to elaborate the distribution of species present in Table 2. Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) red book status [72], LC = Least Concern. * = New records for the state of Pará.

Suborders/Families/Species	Occurrence Points	Distribution in Brazil	References	ICMBio Status
ANISOPTERA				
Libellulidae				
Argyrothemis argentea Ris, 1909	P14	AM. MT. PA. RO.	[29,53,61,62]	LC
Dasythemis esmeralda Ris, 1910	P14	AM. CE. GO. MS. PA. RO.	[29,33,62,64]	LC
Diastatops obscura (Fabricius, 1775)	P5, P8, P9, P10, P13	AC. AM. AP. BA. ES. GO. MA. MG. MS. MT. PA. PB. PE. PR. RJ. RO. RR. RS SP. TO.	[21,29,32,52,59,61]	LC
Elasmothemis cannacrioides (Calvert, 1906)	P10, P11	BA. ES. MG. MS. MT. PA. PR. RJ. RR. SP.	[18,54,55,57,59–61]	LC
Elasmothemis williamsoni (Ris, 1919)	P9	AM. BA. MG. MS. PA.	[29,56,58,62]	LC
Erythrodiplax basalis (Kirby, 1897)	P8, P5, P7, P9	AC. AM. GO. MA. MS. MT. PA. PE. PR. RJ. AP. RO. RR. RS. SP.	[29,32,61]	LC
Erythrodiplax famula (Erichson *in* Schomburgk, 1848) *	P9	AM. AP. GO. MG. MS.	[29,30,56,58]	LC
Erythrodiplax fusca (Rambur, 1842)	P5, P9	AC. AM. BA. CE. ES. PA. PE. RJ. SP. GO. MA. MG. MS. MT. PR. RO. RR. RS. SC.	[29,32,58,61,62,64]	LC
Erythrodiplax latimaculata Ris, 1911	P9, P13	AM. CE. GO. MA. MG. MS. MT. PA. PE. RJ. RS SP.	[29,32,61,64]	LC
Micrathyria artemis Ris, 1911	P9	AM. AP. BA. ES. GO. MA. MG. MS. MT. PA. RJ. RO. RS. SP.	[29,32,52,59,62]	LC
Oligoclada walkeri Geijskes, 1931	P12, P14, P15, P16	AM. MT. PA.	[29,61,62]	LC
Orthemis attenuata (Erichson *in* Schomburgk, 1848)	P11	AM. AP. PA. RO. RS.	[29,30,52,65]	LC
Perithemis sp.	P11	SP	[50]	-
Perithemis lais (Perty, 1833)	P2, P5, P8, P11, P12, P13, P14, P18	AM. ES. MA. MS. MT. PA. RR.	[29,32,56,57,59,61,62,67]	LC
Perithemis thais Kirby, 1889	P8, P11, P15, P16	AM. AP. ES. PA. MA. MS. MT. RJ. RO. SP.	[4,29,32,67]	LC
Uracis imbuta (Burmeister, 1839)	P11	AM. BA. GO. MA. MT. PA. RR	[4,29,32,57]	LC
Zenithoptera lanei Santos, 1941	P7, P9, P13	AC. AM. BA. ES. GO. MA. MS. MT. PA. PE. RJ. RO. SC. SP. TO.	[4,29,32,62]	LC

Table 3. *Cont.*

Suborders/Families/Species	Occurrence Points	Distribution in Brazil	References	ICMBio Status
ZYGOPTERA				
Calopterygidae				
Hetaerina auripennis (Burmeister, 1839)	P1, P5, P6, P9, P11, P15, P16, P17, P18, P19	AM. BA. ES. MG. MT. PA. RO. SP.	[29,47,58,59,62]	LC
Mnesarete aenea (Selys, 1853)	P9	AM. MT. PA. RO	[18,29,61,67]	LC
Mnesarete cupraea (Selys, 1853)	P4, P6, P10, P15, P16, P19	AM. MA. MT. PA. RO.	[18,29,62]	LC
Mnesarete williamsoni Garrison, 2006	P5, P7, P9, P11, P13	PA.	[21,62]	LC
Coenagrionidae				
Acanthagrion aepiolum Tennessen, 2004	P11	GO. MA. MG. MS. MT. PA. PR. RO. SP.	[32,47,61,62]	-
Acanthagrion ascendens Calvert, 1909	P2, P8, P11, P15	GO. MG. MS. MT. PA. PR. RS. SP.	[33,47,52,62]	-
Acanthagrion chacoense Calvert, 1909 *	P9	MG. MS.	[33,43]	LC
Acanthagrion kennedii Williamson, 1916	P8, P9, P13	AM. AP. GO. MA. MT. PA.	[18,29,30,32,61]	-
Argia collata Selys, 1865	P9, P14, P15, P16, P17	AM. PA.	[18,29]	-
Argia fumigata Hagen *in* Selys, 1865	P4, P6, P9, P10, P11, P15, P16, P17, P19	AM. AP. MT. PA. RO.	[29,30,62]	LC
Epipleoneura kaxuriana Machado, 1985	P1, P4, P9, P13	AM. AP. PA. RO.	[18,29,30,63,68]	LC
Epipleoneura lamina Williamson, 1915 *	P11, P15, P16, P17, P19	AM. RO. RR.	[29,49,57]	-
Epipleoneura metallica Rácenis, 1955	P2, P4, P5, P6, P8, P9, P11, P13, P15, P19	AM. BA. DF. GO. MA. MS. MG. MT. PA. PE. RO TO.	[4,29,32,49,61–63]	LC
Epipleoneura westfalli Machado, 1986	P1, P17	MA. MT. PA. RO.	[32,61–63]	LC
Mecistogaster lucretia lucretia (Drury, 1773)	P16	AM. AP. PA.	[29,30]	LC
Neoneura bilinearis Selys, 1860	P1	AM. AP. ES. MS. PA. SP.	[29,30,33,44]	LC
Neoneura luzmarina De Marmels, 1989	P6, P9, P13	AM. MT. PA.	[29,61,62]	LC
Neoneura rubriventris Selys, 1860	P17, P19	MS. PA. RO. RR. RS	[33,57,62,63]	LC
Neoneura sylvatica Hagen *in* Selys, 1886	P1, P2, P4, P6, P8, P10, P11, P15, P17	AM. BA. CE. ES. GO. MA. MG. MT. MS. PA. PE. PR. RJ. RO.	[29,33,50,58,59,61,63,64]	LC
Phasmoneura exigua (Selys, 1886)	P12	AM. AP. MT. PA.	[29,30,61,62]	LC
Protoneura tenuis Selys, 1860	P16	AM. MG. PA. RO.	[29,62,63]	LC
Tigriagrion aurantinigrum Calvert, 1909	P11, P13, P15	ES. MG. MS.MT. PA. SP.	[18,47,56,58,61]	LC
Dicteriadidae				
Heliocharis amazona Selys, 1853	P4, P5, P16	AM. AP.GO. MG. MS. MT. PA. RO. SP.	[29,30,33,47,61,62]	LC
Megapodagrionidae				
Heteragrion icterops Selys, 1862	P4, P9	AM. GO. MT. MG. PA. SP.	[29,30,61,62,67]	LC
Oxystigma petiolatum (Selys, 1862)	P9	AM. RO. PA	[29,30,62]	LC
Polythoridae				
Chalcopteryx rutilans (Rambur, 1842)	P4, P9	AM. GO. MT. PA. RO	[4,29,43,62]	LC

The species accumulation curve (Figure 4), based on the individuals collected and the estimate, suggests that the richness of Odonata in the region has not yet been fully sampled and that in new collections it should be possible to collect more species.

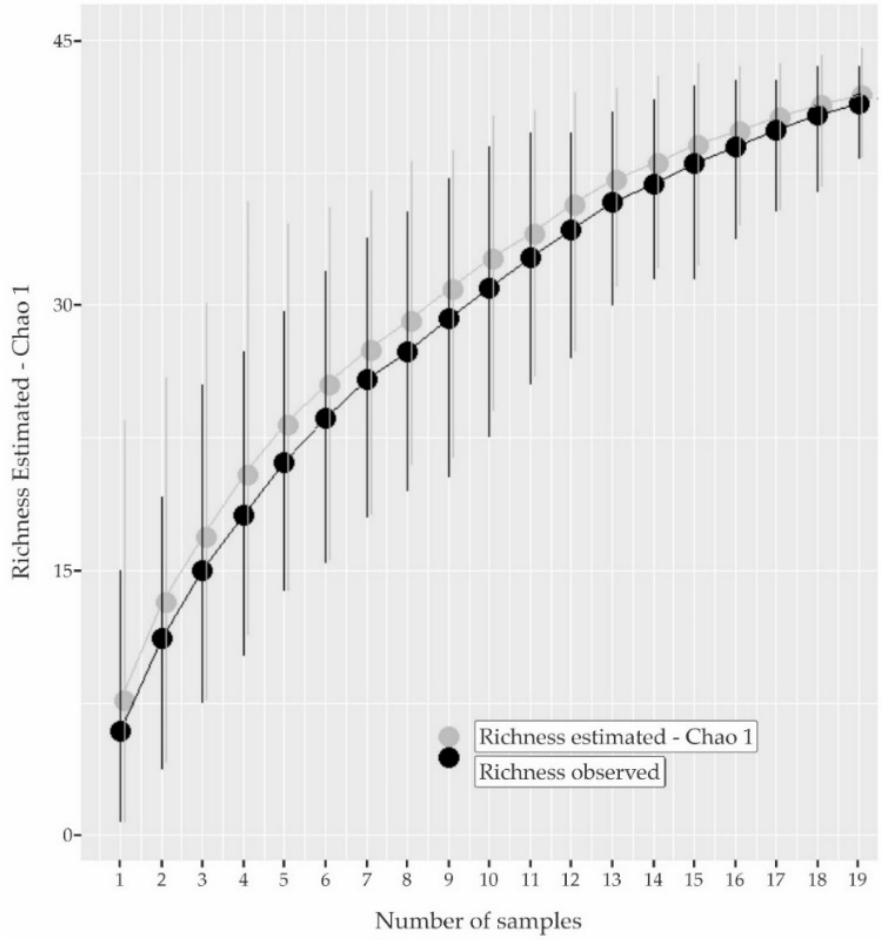

Figure 4. Accumulation curve of Odonata species collected in Volta Grande do Xingu, Pará, Brazil.

4. Discussion

A total of 43 species were identified in Volta Grande do Xingu, suggesting that the species richness in the area is similar to that found in some studies in other biomes and in the Amazon Rain Forest [30,32,73,74]. Our species accumulation curve (Figure 4) is still rising; therefore, further sampling may add more species.

About 71% of the individuals collected belonged to the suborder Zygoptera, while the other 29% were from the suborder Anisoptera. De Marco et al. [75] suggested that Zygoptera are usually predominant numerically at streams that are shaded and have well-developed riparian vegetation. The conservation of Odonata species is very important for natural aquatic ecosystems since these organisms are predators of other populations and balance the system. Many anthropic activities advance in the streams and destroy the necessary habitat for species, such as riparian vegetation and microclimatic conditions, changes in physical and chemical parameters and the presence of substrates [19,67]. Thus, many species are locally extinct without even being recorded. As our area, the number of estimated species continues to rise, and long-term and periodic monitoring are necessary to record more species.

The most diverse families in this study were Coenagrionidae (n = 18) and Libellulidae (n = 17), a fact that corroborates the work of Olaya et al. [76], where, respectively, both families are the most diverse of the Odonata order, as well as that of Lencioni [44], who states that the Coenagrionidae family is the most diverse found in Brazil. The Coenagrionidae

family presented about 33% of the total specimens collected and 47% of the total Zygoptera. In several studies, the family Coenagrionidae is sampled as the family with the greatest abundance and richness among the suborder Zygoptera and Libellulidae in the suborder Anisoptera [16,29,30,32,33,56,73,77–79].

Erythrodiplax famula (Erichson *in* Schomburgk, 1848), *Acanthagrion chacoense* Calvert, 1909 and *Epipleoneura lamina* Williamson, 1915 had their occurrences recorded for the first time in the state of Pará, thus expanding the known occurrence of these species. *E. famula* was previously registered for the states of AM, AP, GO, MG and MS, and has not yet been registered in the south and northeast regions. Even with its distribution in two states in the north region, it had not yet been registered for the state of Pará. With the record of this work, its distribution was the one with the greatest expansion, as it is the first time it has been recorded in the Brazilian Amazon Rainforest, the north region and the state of Pará. *A. chacoense* considerably expands its distribution, as it had been registered only for the states of Mato Grosso, Mato Grosso do Sul and Minas Gerais. Thus, this is the first record for the north region [33,43]. *E. lamina* has been registered in the states of AM, RO and RR already, with records for the biome and for the northern region, but it had not yet been registered in the state of Pará.

The species *E. famula* and *A. chacoense* were found only at Point 9. P9 was the point at which more individuals of the suborder Anisoptera were collected (n = 33). The stream had large areas with light entry and areas where the riparian vegetation was not the original, which suggests that the area underwent changes. This may explain the presence of species in the aforementioned suborder. *A. chacoense* was found in shaded segments of the stream where its width was smaller than the total average (6.53 m). *E. lamina* was found in several streams in the study. This species was observed only where the stream was almost entirely shaded and shallow (depth 0.17–0.56 m), with constant water flow and presence of substrate. These types of environments are conducive to oviposition and successful larval development, as observed in other Coenagrionidae species [80].

5. Conclusions

These results highlight the importance of collections in areas not sampled because each region has specific characteristics that allow for the establishment of a species, or not. There are several collection points registered in others studies in the state of Pará, and, even so, in nineteen sampling points in Volta Grande do Xingu, we have four new occurrences. Without proper knowledge of the distribution of described species, it is not possible to direct efforts towards their preservation. Therefore, inventory work such as this, the formation of research groups in the interior of the Amazon and the sampling of other areas become increasingly important to reduce the Wallacean shortfall so that we can propose effective conservation measures.

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