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LISTS OF SPECIES

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Dragonflies (Odonata) from the Taquari River valley region, Rio Grande do Sul, Brazil

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Abstract: A survey of Odonata was carried out in the central region of the state of Rio Grande do Sul: the Taquari River valley. This region was originally covered by deciduous and Semi-deciduous Atlantic Forest, which today only exist in a highly fragmented environment mainly due to agricultural activities. Our survey was conducted in 12 municipalities from this region, between March 2011 and April 2013. Aiming a general overview of the species composition, our sampling sites included lakes, bogs, small streams and river sections, all inside or surrounded by small forest fragments or forest areas. Fifty species of Odonata were collected comprising 29 genera and seven families. The dominant families were Libellulidae (40%) and Coenagrionidae (36%), while Aeshindae, Gomphidae and Lestidae each only comprise 6% of the total number of species. The findings revealed the presence of a highly diverse odonate assemblage, mainly represented by generalist species in human disturbed fragments and a few forest specialist species in the best preserved remnants only.

Key words: ecology, species richness, Neotropics, Atlantic Forest

INTRODUCTION

A large number of studies describing the diverse fauna and flora of the Neotropics have been published or are under way. Even with so intense efforts, we are still far from the knowledge levels achieved in Europe and North America, or the northern hemisphere in general. In this part of the world, questions such as "How many species are there?" still remain to be answered (May 1998; Wearn et al. 2012). Information on species diversity becomes more relevant every day, as the knowledge on the distribution of extant species richness can provide and improve conservation and management efforts, such as those with focus on human impacts on these environments (Lewis 2006). To prioritize among areas under consideration for conservation, biologists and decision makers need concise information on species diversity, especially in threatened habitats such as the Brazilian Atlantic Forest (Kerr et al. 2000).

Brazilian Odonata fauna is still poorly described since the published records cover only 29% of the territory (De Marco and Vianna 2005) and species lists are available only for São Paulo (Costa et al. 2000), Espírito Santo (Costa and Oldrini 2005) and Mato Grosso (Calvão et al. 2014). Kittel and Engels (2014) is the most recent study for Rio Grande do Sul, comprising only the suborder Zygoptera, so the knowledge on species occurrence of Southern Brazil is still limited. In this study we present a list from the Taquari River valley area, as a small piece of the puzzle towards a future state or national list of species with geographic distribution.

MATERIAL AND METHODS

Study areas

Sampling areas were distributed in twelve municipalities in the Taquari River valley region (Figure 1), the whole region covering a total area of 486,905.00 ha (Rempel et al. 2007). The climate is Temperate Subtropical, with mean temperatures varying between 15°C and 18°C, altitudes from 50 to 200 m above sea level, and mean precipitation varying between 1,300 and 1,800 mm annually (INPE 2014). The municipalities included were given the following abbreviations: Arroio do Meio (AM), Arvorezinha (AR), Bom Retiro do Sul (BR), Colinas (CO), Cruzeiro do Sul (CR), Encantado (EC), Estrela (ES), Lajeado (LA), Muçum (MU), Roca Sales (RO), Soledade (SO) and Taquari (TA). In each municipality we randomly selected two sampling sites, except CR, where we selected 15 sampling sites in order to study seasonality and regional distribution patterns, published elsewhere (Renner et al. 2013; Renner et al. submitted). In total, 37 aquatic environments were sampled.

Data collection

We sampled adult dragonflies from March 2011 to April 2013, all sampling sites were visited three times per year, once per season, excluding the winter season due to the lack of activity of adult Odonata in the low temperatures during that season. The sampling method used was hand-held insect nets by a team of two people, in sunny days, during the peak time of Odonata activity (between 09:00 h to 16:00 h). We sampled species until no new species were encountered for approximately

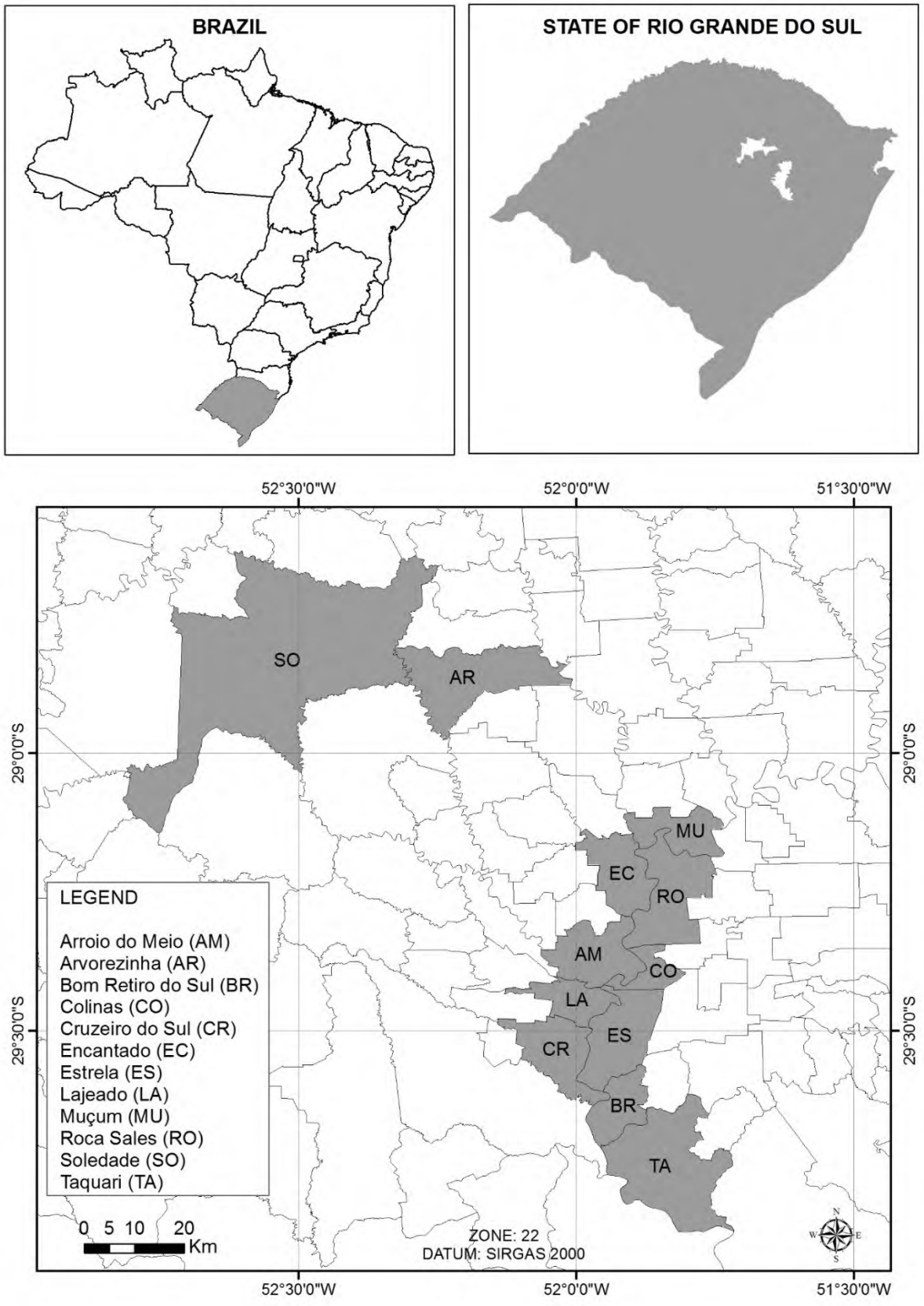

Figure 1. Map of Brazil with insets of the state of Rio Grande do Sul (RS), and the Taquari River valley region; municipalities sampled shaded.

10 minutes. This resulted in actual survey time per site ranging up to two hours; shorter at species-poor localities (~30 minutes). We focused on adults only, since many of the larvae are still unknown (e.g., Garrison et al. 2006). As adults are often dispersing long distances (Corbet 1999), we expect that some of our specimens might derive from other regions or even states, but even if the specimens have not reproduced in the region they are nevertheless found there.

All specimens collected were preserved in 96% ethanol and determined to species according to Garrison et al. (2006, 2010), Heckman (2008, 2010) and Lencioni (2006). They were later deposited in the MCNU (Museu de Ciências Naturais da Univates). The collection authorization process was issued by IBAMA, through SISBio system under the number 38928-1.

To estimate if the sampling at 37 locations gave a thorough picture of the regional richness, we used the absolute number of collected specimens for a Jackknife1 resampling in the Software EstimateS (Colwell 2009), with 1,000 repetitions. We also quantified our sampling effort by using a Jackknife estimation of total species richness according to Smith and van Belle (1984).

RESULTS

Were found 50 species belonging to 29 genera and seven families collected in the 12 municipalities of the Taquari River valley. Two specimens of *Oxyagrion* and *Micrathyria*, both newly emerged females, were impossible to determine to species but belonged to an additional species, from those encountered in the survey. Libellulidae was the dominant family (40%) followed by Coenagrionidae (36%) and, Aeshnidae, Gomphidae and Lestidae (6%), as shown in Table 1. The most common genera were *Erythrodiplax* and *Argia*, each represented by four species, *Erythrodiplax* was the most abundant genera, occurring in virtually all sampling sites. One of the rarest species in this study was *Heteragrion triangulare* Hagen *in* Selys, 1862, collected only in AR and being a typical forest species (Figure 2).

We followed the systematics according to Dijkstra et al. (2014), *Argia indocilis* Navás, 1934 was lately determined as a junior synonym of *Argia croceipennis* Selys, 1865 (pers. comm. R. Garrison). Each species is accompanied by the acronym of the municipality (or municipalities) where it was found and the collection/voucher identification number. The list of Odonata from the Taquari River Valley is presented below.

Table 1.: Number of Odonata species collected per family in the Taquari River valley region.

Suborder/Family	No.	%
Zygoptera		
Coenagrionidae	18	36
Lestidae	3	6
Calopterygidae	2	4
Heteragrionidae	1	2
Anisoptera		
Libellulidae	20	40
Aeshnidae	3	6
Gomphidae	3	6
Total	**50**	**100%**

Suborder Zygoptera

Family Calopterygidae

Hetaerina rosea Selys, 1853 (AM, AR, CO, EC, ES, LA, MU, RO, SO, TA) / ZAUMCN878

Mnesarete pruinosa Hagen *in* Selys, 1853 (SO) / ZAUMCN877

Family Coenagrionidae

Acanthagrion ascendens Calvert, 1909 (CR, LA, SO) / ZAUMCN902

Acanthagrion gracile Rambur, 1842 (AM, AR, BR, CO, CR) / ZAUMCN904

Acanthagrion lancea Selys, 1876 (CR, LA, SO, TA) / ZAUMCN889

Argentagrion ambiguum Ris, 1904 (CO, CR) / ZAUMCN895

Argia albistigma Hagen *in* Selys, 1865 (AM, BR, CO, CR, EC, RO, TA) / ZAUMCN905

Argia croceipennis Selys, 1865 (CR, SO) / ZAUMCN896

Argia indocilis Navás, 1934 (AM, AR, BR, CO, CR, EC, ES, TA, LA, MU, RO) / ZAUMCN890 [junior synonym of *Argia croceipennis*]

Argia sp. (CO, EC, ES, MU, RO, TA) / ZAUMCN903

Homeoura chelifera Selys, 1876 (CR, LA, TA) / ZAUMCN898

Ischnura capreolus Hagen, 1861 (CR, BR) / ZAUMCN901

Ischnura fluviatilis Selys, 1876 (BR, CO, CR, EC, LA, RO, TA) / ZAUMCN899

Oxyagrion basale Selys, 1876 (CR, LA, SO) / ZAUMCN893

Oxyagrion terminale Selys, 1876 (AR, CR, LA, SO) / ZAUMCN891

Oxyagrion sp. (AR) / ZAUMCN894

Neoneura leonardoi Machado, 2005 (AM, BR, CO, EC, LA) / ZAUMCN876 [formerly Protoneuridae]

Telebasis carmesina Calvert, 1909 (CR) / ZAUMCN892

Telebasis theodori Navás, 1934 (CR, SO) / ZAUMCN897

Telebasis willinki Fraser, 1948 (CR, EC, LA) / ZAUMCN900

Family Lestidae

Lestes bipupillatus Calvert, 1909 (CR, ES) / ZAUMCN881

Lestes paulistus Calvert, 1909 (AR) / ZAUMCN880

Lestes pictus Hagen *in* Selys, 1862 (CO, CR, SO, TA) / ZAUMCN879

Family Heteragrionidae [formerly Megapodagrionidae]

Heteragrion triangulare Hagen *in* Selys, 1862 (AR) / ZAUMCN882

Suborder Anisoptera
Family Aeshnidae

Anax concolor Brauer, 1865 (CR, LA) / ZAUMCN883
Rhionaeshna planaltica Calvert, 1952 (CR, LA, SO) / ZAUMCN 884
Triacanthagyna ditzleri Williamson, 1923 (LA) / ZAUMCN 885

Family Gomphidae

Aphylla producta Selys, 1854 (CR) / ZAUMCN886
Phyllocycla propinqua Belle, 1972 (AM, BR, EC) / ZAUMCN 887
Progomphus lepidus Ris, 1911 (CO, CR) / ZAUMCN888

Family Libellulidae

Dasythemis mincki mincki Karsh, 1890 (CR) / ZAUMCN915
Diastatops intensa Montgomery, 1940 (LA) / ZAUMCN911
Erythemis peruviana Rambur, 1842 (CR) / ZAUMCN912
Erythemis plebeja Burmeister, 1839 (LA, TA) / ZAUMCN 924
Erythrodiplax atroterminata Ris, 1911 (CR, RO, SO) / ZAUMCN925
Erythrodiplax fusca Rambur, 1842 (AM, AR, CO, CR, EC, ES, LA, SO, TA) / ZAUMCN906
Erythrodiplax hyalina Förster, 1907 (AM, CO, CR, EC, ES, LA, SO, TA) / ZAUMCN917
Erythrodiplax media Borror, 1942 (AR, BR, CO, CR, EC, ES, RO, SO, TA) / ZAUMCN907
Micrathyria ocellata Kirby, 1889 (BR, CO, CR, LA, MU, SO, TA) / ZAUMCN918
Micrathyria tibialis Kirby, 1897 (CR, LA, MU, SO, TA) / ZAUMCN908
Micrathyria sp. (AR, EC, RO, TA) / ZAUMCN919
Oligoclada laetitia Ris, 1911 (CR, SO) / ZAUMCN916
Orthemis discolor Burmeister, 1839 (CR, LA, SO) / ZAUMCN 922
Orthemis ferruginea Fabricius, 1775 (CR, EC, TA) / ZAUMCN 920
Pantala flavescens Fabricius, 1798 (CR, ES, BR, LA, RO, TA) / ZAUMCN923
Perithemis icteroptera Selys, 1857 (CR, EC, LA) / ZAUMCN 921
Perithemis mooma Kirby, 1889 (CR) / ZAUMCN913
Tauriphila argo Hagen, 1869 (CR) / ZAUMCN914
Tramea abdominalis Rambur, 1842 (LA) / ZAUMCN909
Tramea cophysa Hagen, 1867 (CR, EC, LA, SO) / ZAUMCN 910

Collection efforts and the number of sampled species in the 37 sites were used to estimate the richness by the mean of non-parametric estimator building the collector's curve by Jackknife1, reaching a confidence of 95% to estimate the actual number of species. The species accumulation curve (Figure 3) resulted from our Jackknife estimation, showed the total estimated richness of 61.7 ± 9.4 species (standard deviation), the lower range being similar to the number of species we observed.

DISCUSSION

We found a relatively high number of species (50), reflecting the diversity of sampling sites, including several types of aquatic systems. Most of these sites were connected with remnants or fragments of Atlantic Forest. We recorded a large number of Libellulidae (20 species), which could be the result of many widespread generalists occurring in the mosaic of forest and agriculture areas, a landscape which is known to favor the fast and agile flying dragonflies, supporting the findings by Machado (2001). In general, there are clear relations between environmental factors (biotic and abiotic) and species composition, these factors acting as determinants of presence and absence of some species due to ecological and physical restrictions (e.g., Paulson 2006; Juen et al. 2007). In preserved areas or large forested areas, it is expected to find a higher number of Coenagrionidae and Heteragrionidae, many of which have specific environmental restrictions and ecological needs (Carvalho et al. 2013). This fact can explain the occurrence of *Heteragrion triangulare* in only one locality (AR), which is a well-preserved area located in the upper basin of the Forqueta River, one of the many tributary waters of the Taquari River. These specialized forest species can function as powerful tools when distinguishing priority areas for preservation, as forest species have been shown to be good indicators of environmental quality (Clausnitzer 2003; Sahlén 2006; Koch et al. 2014).

Only a few rare species were found in the study (singletons n = 12), all having a restricted occurrence, but the finding of a high number of species of Coenagrionidae (18) can also mirror good ecological conditions, even in a highly fragmented region. This due

Figure 2. *Heteragrion triangulare*, collected in AR (Arvorezinha, RS), Brazil. Photo: C. Schmidt.

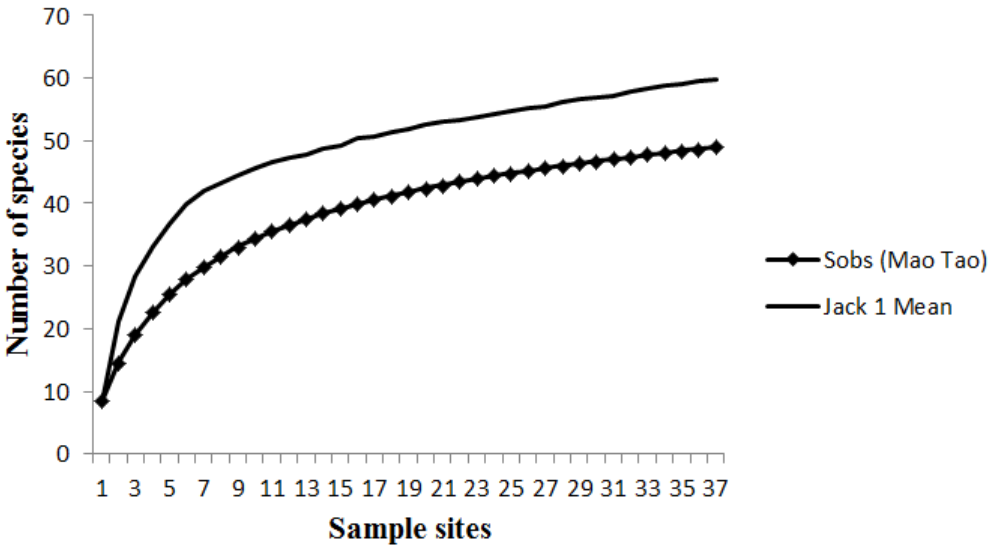

Figure 3. Number of species of Odonata collected (sobs) on 37 sampling sites in relation to the number of species expected by Jackknife1 estimator in the Taquari River valley, state of Rio Grande do Sul (RS), Brazil. The species accumulation curve is not reaching the asymptote implying the regional diversity is significantly higher than the 50 species encountered.

to some genera having ecological restrictions related to aquatic vegetation and water quality (e.g., *Homeoura*, *Argia*, *Oxyagrion*) as stated by Garrison et al. (2010).

When compared to other studies from the Neotropics (De Marco et al. 2014; Monteiro et al. 2013) our collection efficiency captured only 81% of the expected diversity, being far from reaching its asymptote, implying that the actual number of species in the region is significantly higher than 50 (Figure 3). The Taquari River valley region is relatively large area, and this study only included 12 municipalities. Future studies should include a larger selection of environments from all municipalities to obtain a more accurate number. In addition, more frequent sampling during the seasons should also improve the inventory.

The Atlantic forest is one of the most endangered ecosystems in South America, and in this context species inventories can provide valuable information for the management actions needed to preserve and restore forest environments. We made a regional survey of the Odonata, a poorly known group in southern Brazil, and show that even in such fragmented habitats, diversity remains high. This useful to know for future conservation measures.

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Authors' contribution statement:
The authors contributed to different parts of this paper: SR, GC and DMS collected the field data; SR, EP and GS identified and preserved the specimens, and wrote the manuscript.

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