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Man-made lakes form species-rich dragonfly communities in the Brazilian Atlantic Forest (Odonata)

Samuel Renner[1, 3], Eduardo Périco[1] & Göran Sahlén[2]

[1] Laboratório de Evolução e Ecologia, Centro Universitário Univates, Rua Avelino Talini, 171, Bairro Universitário, 95900-000 Lajeado, RS, Brazil; <samuelrenner@hotmail.com>, <perico@univates.br>

[2] Ecology and Environmental Sciences, Halmstad University, P.O. Box 823, 30118 Halmstad, Sweden; <goran.sahlen@hh.se>

[3] Corresponding author

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Abstract. One of the forest types occurring in Southern Brazil is the Mixed Ombrophilous Forest (MOF), a subtype of the Atlantic Forest and one of the biodiversity hotspots on Earth. We sampled adult Odonata at 30 locations in the Floresta Nacional de São Francisco de Paula (FLONA-SFP), Rio Grande do Sul, Brazil, a national reserve which is divided into several sectors of MOF, planted *Araucaria angustifolia*, *Pinus elliottii* used for sustainable and financial purposes, and open fields. There are three types of aquatic environments in the reserve: lakes, swamps, and rivers/streams. Our aim was to obtain an overview of the species' distribution patterns in the three types of aquatic environments and to evaluate the species occurring in lakes, an exclusively man-made habitat in this area. We recorded 46 species from seven odonate families; 25 species ($\overline{x} = 5.71 \pm 1.77$ SD) occurring in rivers/streams, 24 in lakes (11.57 ± 2.15) and 21 in swamps (5.22 ± 3.60). Using Non-metric Multidimensional Scaling (NmDS), we showed that the species composition differed clearly between the three types of aquatic habitats. While swamps and rivers/streams had a relatively similar and uniform species composition, species in the lakes were more varied but the total species number was almost as high as that of the rivers/streams. The lake communities also differed distinctly from those of the other habitats, and we assume that the lake species originate from other degraded areas in the vicinity, indicating that the remains of the Atlantic Forest has already been strongly altered by humans. Given the poor knowledge of the Odonata in the Atlantic Forest/MOF, we hope that our study may increase the understanding of the communities, and contribute to the development of conservation measures for this fragmented biome.

Further key words: Dragonfly, South America, Neotropics, Rio Grande do Sul, species assemblages, habitat integrity, conservation

Introduction

One of the most important forest biomes in South America is the Atlantic Forest, known for its rich biodiversity, which makes it one of the hotspots for nature conservation (Myers et al. 2000). Today, this biome is highly fragmented, mainly due to the rapidly growing human population. Formerly, Atlantic Forest covered more than 15 % of Brazil's total area. Today less than 7 % of the original area remains, and this residue is threatened by agriculture, roads, and growing urban zones (Tabarelli et al. 2010). In the southern parts of Brazil, the reduction of forest area is mostly due to the expansion of agriculture and cattle farming (Ribeiro 2009). In the state of Rio Grande do Sul, two subtypes, or formations, of this biome occur: in the highlands Mixed Ombrophilous Forest (MOF) and in the lowlands the Deciduous and Semi-deciduous Forest. The MOF covers the northern and north-eastern portions of the state (Backes 2001). The origins of this forest type are Austral-Andine and Afro-Brazilian, denoting a typical composition of dense rain forest at high altitudes, which is characterized by the occurrence of Paraná-pine or Brazilian pine *Araucaria angustifolia* (Bertol.) Kuntze (Araucariaceae) (Veloso et al. 1998).This results in a special type of dense forest with a closed canopy composed of deciduous trees belonging to the families Lauraceae, Sapindaceae, and Aquifoliaceae, constituting 60–70 % of tree cover, with *A. angustifolia* tops emerging from the fairly dense canopies. The quality of the Paraná-pine wood has led to over-exploitation and logging of the species for house-building purposes (Hueck 1972) despite its global rarity, putting the MOF at risk. In view of this, the MOF can be placed as a priority ecosystem for faunistic surveys, since it is even less known than the poorly explored Atlantic Forest as a whole (Backes 2001). Only few major fragments have remained of the MOF, and the largest ones are found today in conservation areas.

As few faunal inventories have been published from the Atlantic Forest (e.g., Kittel & Engels 2014; Renner et al. 2015), there is little information about the distribution and abundance of species, and the area as a whole is still poorly known. Faunal inventories and surveys are important, not only as representations of biodiversity, but also because they are excellent tools for conservation, ecosystem management, and environmental protection (Ward 1998) – and they may also lead to the formation of practical management strategies (cf. Finlayson et al. 1999). Schindler et al. (2003) showed that there are clear relations between environmental factors (both abiotic and biotic) and species composition, *de facto* determining the presence and absence of species due to ecological and physical restrictions (cf. Paulson 2006; Juen et al. 2007). According to Samways & Steytler (1995) and Stewart & Samways (1998), odonate communities in disturbed habitats tend to be less species rich and composed of many widespread generalist species (e.g., Machado 2001; Monteiro Júnior et al. 2013).

Dragonflies are excellent indicators of many different things, from habitat quality and integrity to the effects of forestry on general species richness (Samways & Steytler 1995; Sahlén & Ekestubbe 2001; Clausnitzer 2003; Oertli 2008; Simaika & Samways 2009; Monteiro Júnior et al. 2013; Koch et al. 2014). Due to different dispersal abilities of many species, Anisoptera and Zygoptera are reported to be differently affected by environmental characteristics (Corbet 1999). In our study, the dispersal abilities of virtually all species are unknown and we make the simple assumption that larger species are better dispersers than smaller ones.

This study has two objectives. Firstly, as the national forest reserves contain the largest pristine MOF areas, we saw an opportunity to collect more data on the odonate fauna of the Atlantic Forest, particularly in the MOF, and to analyze its community structure. Secondly, an evaluation of the differences between three aquatic environments in the study area: lakes, swamps, and rivers or streams. While the swamps and streams are natural parts of the pristine forest areas, the lakes are not. Most of the lakes are a result of impoundments and other human activities during the past 100 years. Thus, we hypothesize that the lakes as relatively late additions to the Atlantic Forest ecosystem have developed a special species composition, differing from that of the two natural aquatic systems within the area.

Material and methods

Study site

The Floresta Nacional de São Francisco de Paula (FLONA-SFP) in north-eastern Rio Grande do Sul, north of the city of Porto Alegre, is a sustainable ecological reserve, controlled by the Brazilian government. It is administered by Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), a division of the Brazilian Ministry of Environment.

In terms of aquatic resources and habitats, this region is situated in the upper basin of the Sinos River, fed by several small tributary rivers, and flowing over a basaltic plateau known as the 'Serra Geral' formation. The region is also known for the occurrence of numerous man-made lakes and dams, as well as natural wetlands, mainly in the lower parts of the topography (Teixeira 1986).

The area has its center at 29°25'22"S, 50°23'11"W (Fig. 1); it consists of 1 572 ha of forest, including 720 ha of native Mixed Ombrophilous Forest (MOF) as well as smaller areas of planted forest: *Araucaria angustifolia* (69 ha) and *Pinus elliottii* (204 ha), all under sustainable management for timber production. There are also some scattered open fields (20 ha) within the area. The elevation varies from 900 to 1 000 m a.s.l., and the climate is mesothermic humid (Cfb Köppen), with a mean temperature of 14.5°C and a mean annual precipitation exceeding 2 000 mm. Temperatures below zero often occur from April to November, with occurrence of snow and ice during cold winters (INPE 2012).

Field work

In 2014, we collected adult dragonflies at 30 sites (Fig. 1) during three seasons: summer (02–09-i-2014), autumn (10–16-v-2014) and spring (02–08--xi-2014). All sites were located inside the reserve, except two that were in the immediate vicinity. We caught flying odonates with insect nets during sunny days from 09:00–16:00 h BRST (UTC - 2 h; during autumn sampling in May: BRT, UTC - 3 h), always in proximity of water. Two persons sampled simultaneously, collecting or noting the species occurring, until no new species were encountered for approximately 10 minutes (semi-qualitative sampling). The total sampling time at each site/occasion was dependent on the number of species being active at the site. Some species were difficult to catch due to their fast flight and agility, (e.g., large aeshnids) and these were instead determined to species using binoculars and noted.

All collected specimens were preserved in 96 % ethanol and, when possible, identified to species level using Garrison et al. (2006, 2010), Heck-

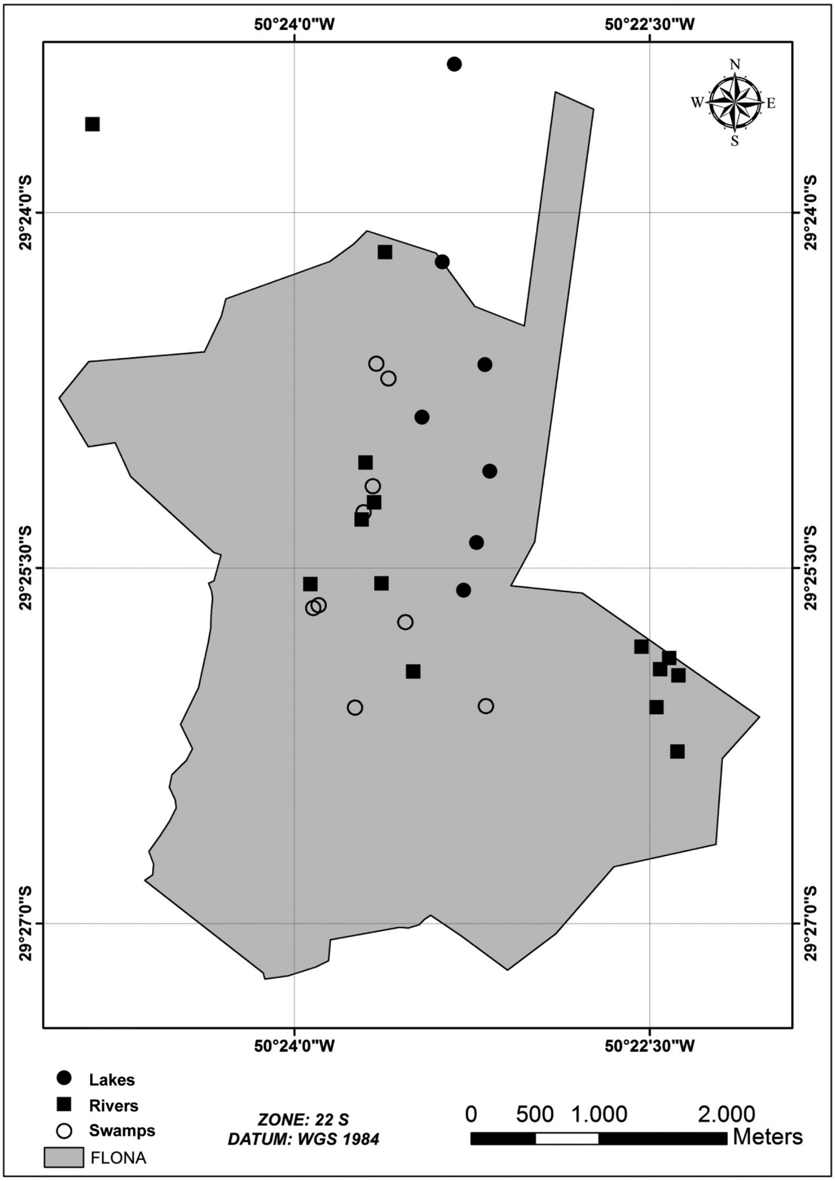

Figure 1. Map of the Floresta Nacional de São Francisco de Paula (FLONA-SFP) in Rio Grande do Sul, Brazil, with the 30 sampling localities and type of water: ● – lakes (n = 7); ○ – swamps (n = 9); ■ – rivers/streams (n = 14).

man (2006, 2010), and Lencioni (2006). Regarding the systematic order we followed Dijkstra et al. (2013, 2014). All voucher specimens were deposited in the Invertebrate Collection of the Univates Natural History Museum (MCNU), in Lajeado, Rio Grande do Sul. The collecting permission was issued by IBAMA, through SISBio system under the number 38928-1.

Categorization of sampled water bodies

Rivers and streams (n = 14): all with basaltic river beds, with rapid and highly oxygenated, cold water. Most of them were flowing through dense forest with low sun exposure, except in sun-flecks caused by tree falls (Fig. 2). The margins were mainly composed of forest vegetation, and in some cases we encountered various grasses (Poaceae). These rivers are the initial tributaries of the upper basin of the Sinos River.

Figure 2. A small sun-fleck in a river/stream habitat in FLONA-SFP in north-eastern Rio Grande do Sul, Brazil, characterized by dense tree and bush vegetation and often small amounts of running water (06-i-2014). Photo: SR

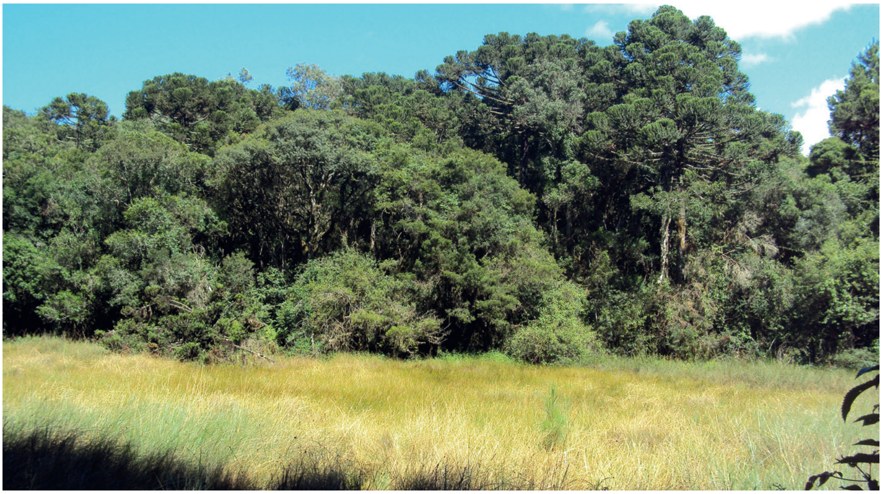

Figure 3. A swamp area in FLONA-SFP in north-eastern Rio Grande do Sul, Brazil, overgrown by sedges or grasses with very small areas of open water. Here the swamp is in an open area, but often trees are close by and sometimes numerous (05-i-2014). Photo: SR

Figure 4. A typical lake in FLONA-SFP in north-eastern Rio Grande do Sul, Brazil, with forest vegetation close to the beach, large open areas of water and only small areas of emergent vegetation along the shoreline (06-i-2014). Photo: SR

Swamps (n = 9): natural water bodies (Fig. 3) occurring in virtually all topographic depressions in the area; valleys and small ravines, most of them fed by subterranean water or small creeks. Most of the bottoms were composed of layers of mud and decomposing organic matter. All sites were characterized by very small portions of open surface water due to dense aquatic vegetation of Poaceae, Cyperaceae, and Juncaceae, as well as other structural components (i.e., dry wood, tree trunks, and rocks). In some cases the margins were shaded, depending on the time of the day.

Lakes (n = 7): man-made through impoundments/damming of running water and acting as water reservoirs in the reserve. The bottom was mainly composed of mud/clay and organic matter. Most of the lakes were surrounded by dense vegetation, as they were all located in planted or natural forest. The riparian zone often had low vegetation. The dominant/common plant families in the marginal zones were Cyperaceae, Poaceae, and Asteraceae. Lake surfaces were predominately open, except in some areas where we found stands of emergent or floating vegetation of *Eichhornia crassipes* Mart. and Solms. 1883, *Salvinia auriculata* Aubl. 1775 and *Nymphaea ampla* (Salisb. 1821) (Fig. 4).

Dragonfly assemblage comparison

We compared the average total species number per lake/river/swamp, as well as the average number of species belonging to the respective suborders. We also analyzed differences in species numbers between the habitat types using the Kruskal Wallis test. The number of sites differed between the habitat types, as can be seen in Figure 1. To verify the spatial distribution of the species in relation to the three types of aquatic habitats, we used a matrix of presence/absence data compiled from all three sampling occasions in a Non-metric Multidimensional Scaling (NmDS), through the software Past v3.06 (Hammer 2015; using an algorithm based on Taguchi & Oono 2005). We employed Euclidian distances as similarity measures, giving the precision degree by the stress, in which values below 0.2 are considered acceptable and values below 0.1 excellent, denoting »no interference« in the ordination (Clarke 1993).

Results

A total of 46 different taxa was identified, 24 of the Zygoptera and 22 of the Anisoptera, from 24 genera representing seven different families (Table 1). Eight of these taxa were determined to genus level only, as we found only female specimens and/or because no reliable, up-to-date key was available. Thus, the taxa list (Table 1) pertains to 38 identified plus eight as yet unidentified species.

We found 25 species in the streams/rivers, with an average of 5.71 ± 1.77 (SD) per site. In the swamps the number was 21 (average 5.22 ± 3.60) and in the man-made lakes we found 25 species (average 11.57 ± 2.15). Statistically significant differences existed in species numbers (H = 13.9051; $p = 0.0009$). Lakes differed from rivers/streams ($p < 0.05$) and from swamps ($p < 0.05$), but rivers/streams did not differ from swamps. Dividing the numbers found per site with the number of sites resulted in 1.79 species per site found in streams/rivers, 2.33 in swamps, with lakes adding the highest number to the species pool per site: 3.43.

Looking separately at the suborders (Anisoptera = A and Zygoptera = Z), we found that the species number was similar in two habitat types, streams/rivers A = 12 (average 3.14 ± 1.10), Z = 13 (average 2.57 ± 1.65) and swamps A = 12 (average 1.78 ± 1.39), Z = 9 (average 3.44 ± 2.74); and in lakes we found a significant difference ($p = 0.035$), A = 12 (average 6.86 ± 1.68), Z = 13 (average 4.71 ± 1.25).

In all three habitats we found a high number of specialist species occurring in only that particular habitat type (Fig. 5). In the lakes 12 such species were encountered (Table 1 – L; water-body type column); all from the families Lestidae, Coenagrionidae, and Libellulidae and, with a few exceptions, these were abundant. In the rivers we found 11 habitat-specific species (Table 1 – R), most of them Gomphidae and Calopterygidae. The smallest number of habitat-specific species was found in swamps; six species only (Table 1 – S), some of them rare (e.g., *Libellula herculea* and *Macrothemis marmorata*). Furthermore, a few species occurred in all habitats, i.e., as generalists: *Erythrodiplax* sp. 1, *E. hyalina*, *E. media*, *Rhionaeschna bonariensis*, *R. brasiliensis*, *R. planaltica*, and two zygopterans: *Oxyagrion terminale* and an unidentified *Oxyagrion* sp. (Table 1).

Table 1. Species recorded during this survey in the Floresta Nacional de São Francisco de Paula (FLONA-SFP) in north-eastern Rio Grande do Sul, Brazil, arranged in systematic order following Dijkstra et al. (2013, 2014). Occurrence in different water-body types: L – lake; R – river/stream; S – swamp; Season: Su – summer (02–09-i-2014), Au – autumn (10–16-v-2014), Sp – spring (02–08-xi-2014); Relative abundance: 1 – single record; 2 – 2-10 individuals; 3 – >10 individuals.

Taxon	Water body type	Season	Relative abundance
Lestidae			
Lestes auritus Hagen *in* Selys, 1862	S, L	Su, Sp	2
Lestes bipupillatus Calvert, 1909	L	Au	2
Lestes paulistus Calvert, 1909	L	Su, Au	2
Lestes pictus Hagen *in* Selys, 1862	L	Su, Sp	2
Calopterygidae	R, S	Su, Au, Sp	3
Hetaerina rosea Selys, 1853	R, S	Su, Sp	2
Mnesarete borchgravii (Selys, 1869)	R	Su, Sp	3
Mnesarete pruinosa (Hagen *in* Selys, 1853)	R	Su, Au, Sp	3
Coenagrionidae	L	Su, Au	2
Acanthagrion lancea Selys, 1876	S, L	Su, Sp	3
Acanthagrion sp.	R, L	Su	2
Argentagrion ambiguum (Ris, 1904)	S	Sp	2
Argia croceipennis Selys, 1865	R	Su, Au, Sp	3
Argia sp.	R	Su	1
Homeoura chelifera (Selys, 1876)	L	Su, Au, Sp	2
Ischnura capreolus (Hagen, 1861)	L	Su, Sp	3
Ischnura fluviatilis Selys, 1876	L	Su, Sp	2
Oxyagrion hempeli Calvert, 1909	R	Su, Au	2
Oxyagrion microstigma Selys, 1876	R, L	Su, Sp	2
Oxyagrion terminale Selys, 1876	R, S, L	Su, Au, Sp	3
Oxyagrion sp.	R, S, L	Su, Au	2
Peristicta gauchae Santos, 1968	R	Sp	1
Telebasis theodori (Navás, 1934)	L	Su, Sp	3
Heteragrionidae			
Heteragrion luizfelipei Machado, 2006	R, S	Su	2
Aeshnidae			
Castoraeschna sp.	S	Sp	2

Taxon	Water body type	Season	Relative abundance
Limnetron sp.	R, S	Au	2
Rhionaeschna bonariensis Rambur, 1842	R, S, L	Su, Au, Sp	3
Rhionaeschna brasiliensis Ellenrieder & Costa, 2002	R, S, L	Su, Sp	2
Rhionaeschna planaltica (Calvert, 1952)	R, S, L	Su, Au, Sp	3
Gomphidae			
Phyllogomphoides regularis (Selys, 1873)	R	Su	2
Progomphus gracilis Hagen *in* Selys, 1854	R	Su, Sp	3
Libellulidae			
Dasythemis mincki mincki Karsch, 1890	R	Su, Sp	1
Erythrodiplax atroterminata Ris, 1911	R	Su	1
Erythrodiplax fusca (Rambur, 1842)	L	Su, Au, Sp	2
Erythrodiplax hyalina Förster, 1907	R, S, L	Su, Au, Sp	3
Erythrodiplax media Borror, 1942	R, S, L	Su, Au, Sp	3
Erythrodiplax sp. 1	R, S, L	Su, Au, Sp	3
Erythrodiplax sp. 2	L	Su, Au, Sp	3
Libellula sp.	S	Su, Sp	2
Libellula herculea Karsch, 1889	S	Sp	1
Macrothemis marmorata Hagen, 1868	S	Su, Sp	1
Micrathyria artemis Ris, 1911	R	Su	1
Oligoclada laetitia Ris, 1911	S, L	Sp	2
Orthemis discolor (Burmeister, 1839)	S	Su, Sp	1
Perithemis icteroptera (Selys *in* Sagra, 1857)	L	Su, Sp	2
Perithemis mooma Kirby, 1889	L	Su	1

The NmDS analysis of the species occurrence in the respective aquatic habitats shows a clear separation between the species assemblage of the lakes and that of the natural localities (streams/rivers and swamps; Fig. 6). Although the latter two also differ slightly from each other, it is clear that the species composition of the lakes is well defined and distinctly different from that of the other habitats. The stress level found in this analysis was 0.087 (<0.1), defined as 'excellent' by the Clarke index (Clarke 1993) and indicating no interference in the analysis.

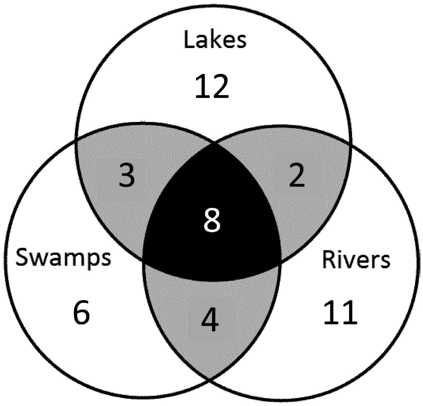

Figure 5. Venn diagram of absolute contribution to regional (here: the FLONA area) diversity (46 species) made up of the three types of aquatic environment lakes, swamps and rivers/streams (7, 9, and 14 sampled sites, respectively). Numbers in shaded areas indicate species shared by the types of environments: black – triple overlap; grey – double overlap. Numbers in white areas indicate species encountered in a single environment.

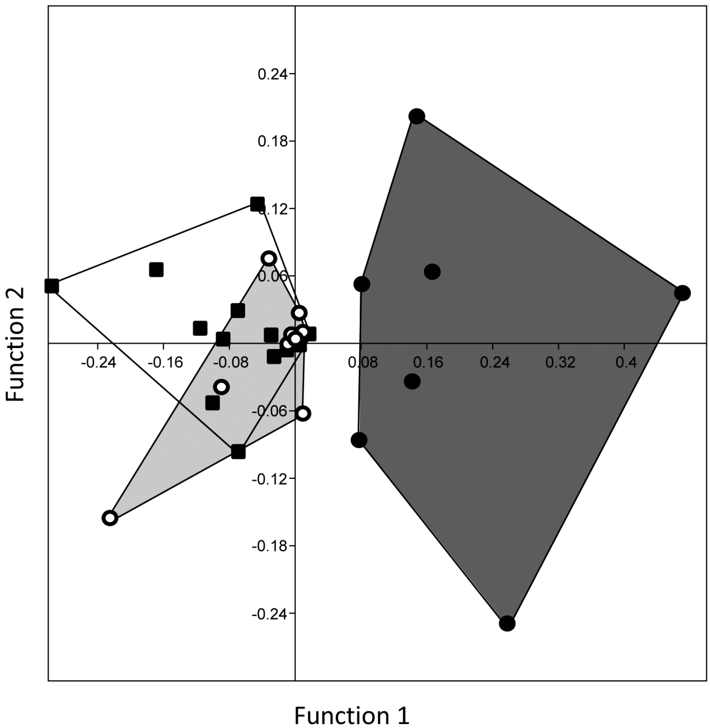

Figure 6. NmDS plot based on species occurrence at three types of aquatic environments (● – lakes; ○ – swamps; ■ – rivers/streams) in FLONA-SFP during this survey in north-eastern Rio Grande do Sul, Brazil, in 2014.

Discussion

The most interesting result of our investigation was the difference in species communities between the man-made lakes and the natural habitats streams/rivers and swamps (Fig. 6). The NmDS analysis evidences existence of difference, jointly with analysis of species occurrence corroborating studies by, e.g., Stewart & Samways (1998) and Samways & Steytler (1995), where Odonata assemblages in disturbed habitats turned out to consist of many widespread generalist species. In our study, however, looking at man-made rather than disturbed habitats, in congruence with Figure 5, only eight of the observed species may be regarded as generalists (cf. Table 1), occurring in all three habitat types sampled. We therefore assume that the large species pool of lakes only to a small extent includes widespread generalists, although the ecology of most species in the region is not well known (Machado 2001; Monteiro Júnior et al. 2013). We note that nine of the 12 habitat-specific species are zygopterans which, judging only by their size, cannot be expected to disperse over large distances (Corbet 1999). However, several studies have shown a wide range of movement capabilities, from almost sedentary (Cordero-Rivera 2016) via short and medium ranges (Keller & Holderegger 2013) to hundreds of kilometers (Rowe 1987). McCauley et al. (2014) showed that size is not an all-important factor determining the frequency of dispersal, as some species tend to disperse more than others and have larger areas of occurrence, regardless of size. Therefore, the majority of habitat-specific species in our area being zygopterans does not necessarily mean they are bad dispersers, and further studies are needed. On the other hand, only three anisopterans were encountered, in this case a surprisingly low number considering the dispersal ability of larger species (cf. Andersen et al. 2016). From this, we hypothesize that the species of the lake communities might stem from this region, unlike those of lake communities, e.g., in Namibia (Suhling et al. 2006), where also many of the species occurring in man-made lakes were large anisopterans. Thus, within the fragmented remains of the Atlantic Forest, there are nowadays so many lakes, ponds, and impoundments that lake species are already able to occur almost everywhere (Teixeira 1986).

Anthropogenic habitats are well known to affect or change the species composition in many different ecosystems (e.g., Dolný et al. 2011; Brasil et al. 2014), but the main question is what kind of species composition will develop in the changed habitat and which processes are behind it. Dolný et al. (2011) showed in Borneo that forest degradation results in a decline of species numbers, a change in species composition, and a reduction in taxonomic diversity, and Juen et al. (2014) showed that in forest clearings Anisoptera tend to dominate. In contrast, in the lake communities of our study area we see a combination of relatively high taxonomic diversity and no dominant suborder. Hence, we assume that the conditions in the Atlantic Forest differ compared to the other studied areas and it seems that species diversity in odonates can react in many ways to human alteration. We must also be aware that the lakes may be an environment created by humans, but they are in no way a degraded ecosystem.

Looking at the variation in species occurrence between sites, we noted that the standard deviation found in the river habitats was smaller than that of the swamps and lakes. We assume that this implies that the riverine species-pool is a more 'stable' set of species, occurring at several sites, whereas the opposite is true of the other two habitats, where the variation between sites is greater. Cao et al. (1998), investigating disturbed and undisturbed river sections of a river in United Kingdom, showed that rare species are easily overlooked in surveys. This is not a problem at disturbed sites, since few rare species occur there. At undisturbed sites, however, failure to sample and detect rare species will yield a lower species number, thereby making the site appear less species rich than it actually is. In our survey we see a fairly high number of riverine species, both at the individual sites and as a community. But we cannot know if this number is lower than it should be due to loss of specialist species caused by human alteration of the forest (e.g., by the addition of lakes) and/or an underestimate of the sampling time needed to detect them.

The swamps differed in their respective species composition but had a set of species occurring in only that type of habitat, such as *Argentagrion ambiguum*, *Macrothemis marmorata* and two species belonging to the genus *Libellula*. The ecology and habitat preferences of most of the swamp species are poorly known. The exception is *A. ambiguum*, which, according to Garrison et al. (2010), is related to highly vegetated waters. Likewise, larvae of *L. herculea* are known to be able to emerge from water bodies as small as tree holes (Hedström & Sahlén 2007).The lack of ecological knowledge is an overriding problem preventing detailed analysis of habitats and species pools. A more detailed survey, including odonate larvae, water chemistry, and microhabitat parameters, would therefore be rewarding.

We could note that the human made lakes added the highest number of species to the species pool per site, while our river sites added the lowest number. This is consistent with previous studies stating that small waters often are important to regional biodiversity because of greater heterogeneity in species assemblages when compared to other water body types (Oertli et al. 2002; Scheffer et al. 2006; Thiere at al. 2009). As lakes, despite being a man-made habitat, are more species-rich than the other aquatic habitats in our survey area, adding 12 species (24 %) to the regional species pool, we conclude that odonates in this part of the Atlantic Forest might have been less speciose before the human alteration and fragmentation processes started. We could speculate that there might have been a set of rare specialists in the original forest which have disappeared long ago, or that they are still present, but only very rarely and therefore unlikely to be detected. Should this be true, the original species richness in this area might even have been higher than it is today but with no lakes or lake species present (cf. Benites-Malvido & Martinez-Ramos 2003 for a study on plants).

As previously stated, dragonflies are affected by a large number of human and natural disturbances, the reactions of species can be seen as changes in abundance over time, always stronger than the 'background noise' of metapopulation dynamics (cf. Hanski 1998). In our study area, forests dominate, and we assume that the addition of lakes took place a long time ago. Since then, a steady state may have been reached with regard to habitat selection. Today we have a set of small damselflies inhabiting standing waters (e.g., Coenagrionidae: *Argentagrion*, *Ischnura*, and *Telebasis*), while the large species either show generalist behavior or occur in small numbers in certain types of water bodies (e.g., Aeshnidae: *Rhionaeschna*). At least for the river sites there is surprisingly little variation between them, indicating a homogenous habitat that hosts specialist species (Heteragrionidae and some Calopterygidae: *Mnesarete* and *Hetaerina*); which is not the case for the highly variable lakes.

In our part of the Atlantic Forest, the fragmentation process started more than a century ago, when areas were cleared and lake communities established (Hueck 1972; Backes 2001). From that point, we assume there has been a continuous reduction of the original species pool. The difference in species communities is greatest between the lakes and the original habitats, rivers/swamps. The greatest threat to the preservation of the odonate fauna of this region is an increased fragmentation of the forest. Then the number of lake communities would increase, causing a further shift away from the original state with few species and low variation in rivers/streams and few species and high variation in swamps, to a situation with dense and species-rich odonate populations at most sites. This is naturally perceived as a diverse and species-rich ecosystem even if it may have only a small portion of the original species pool. This is also a pattern resulting from biotic invasions (Mack et al. 2000) and it may be that species in our area show a similar reaction, but more conclusive evidence is needed (Symstad et al. 2003).We propose a limitation of the establishment of new lakes in the vicinity of large MOF patches in the Atlantic Forest, and we emphasize the need to explore how the remaining stream and swamp communities should be managed to prevent deterioration. To obtain up to date information, the implementation of monitoring programs should be placed high on the agenda.

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