

Effects of marginal vegetation removal on Odonata communities

Efeitos da retirada da vegetação marginal sobre a comunidade de Odonata

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Abstract: Aim: Here we assess the effects of habitat degradation on individuals of the two suborders of Odonata community of Borecaia river sub-basin. More specifically, we tested the hypothesis that Anisoptera richness would be positively affected by removal of vegetation; on the other hand, Zygoptera richness would be adversely affected by virtue of their ecophysiological requirements; **Methods:** We selected 10 streams of similar orders, six preserved and four degraded. Streams characterized as preserved had values of Index of Habitat Integrity (HII) above 0.70 (0.77 ± 0.07 , mean \pm SD) and continuous forest on both sides with a minimum width of 70 meters. Each site was sampled three times on different days. The effect of vegetation removal on richness was assessed using richness estimated by first order Jackknife; **Results:** Decreased physical integrity (measured with IHH) of streams had no significant effect on the estimated richness to Odonata in general. However, the estimated richness of Anisoptera showed an inverse relationship with the integrity ($r^2 = 0.485$, $P = 0.025$), i.e., there was a reduction in their species richness with increasing integrity; **Discussion:** As a general pattern, Anisoptera presents higher richness in an altered site; on the other hand, Zygoptera presents higher richness in a preserved one. This pattern suggests that Odonata needs to be considered at the sub-order level to access the effects of habitat degradation on these insects. Because of its restrictions ecophysiological Odonata varied widely in their composition and species richness between the two types of environments, it reinforces the potential of the order of studies and environmental monitoring also shows that Zygoptera be more affected by changes in habitat. However, further studies including more samples and different streams are need to confirm this pattern, being an interesting line of research for future works.

Keywords: environmental integrity, Anisoptera, Zygoptera, species richness, environmental changes.

Resumo: Objetivos: Com o intuito de avaliar os efeitos de mudanças na integridade ambiental sobre os indivíduos da comunidade de Odonata da sub-bacia do rio Borecaia, testamos a hipótese de que a riqueza de Anisoptera seria afetada positivamente pela remoção da vegetação; por outro lado, a riqueza Zygoptera seria prejudicada em virtude de suas necessidades ecofisiológicas; **Métodos:** Selecionamos 10 riachos de ordens similares, seis classificados como preservados e quatro como alterados. Riachos classificados como preservados apresentaram valores do Índice valores de Integridade Habitat (HII) acima de 0.70 e mata continua nas duas margens com uma largura mínima de 70 metros. Cada ponto foi amostrado três vezes em dias diferentes. O efeito de remoção de vegetação sobre a riqueza foi avaliada utilizando Jackknife de primeira ordem; **Resultados:** A diminuição da integridade física (mensurada com o IHH) dos córregos não exerceu efeito significativo sobre a riqueza estimada para a Ordem Odonata. Porém, a riqueza estimada de Anisoptera apresentou uma relação inversa com a integridade ($r^2 = 0.485$; $p = 0.025$), mostrando que com o aumento da integridade houve uma redução na sua riqueza de espécies;

Discussão: Como um padrão geral, Anisoptera apresenta maiores valores de riqueza em locais alterados; por outro lado, Zygoptera apresenta maiores valores em preservados. Devido suas restrições ecofisiológicas Odonata apresentou uma grande variação na sua composição e riqueza de espécie entre os dois tipos de ambientes, isso reforça o potencial da ordem em estudos de monitoramento ambiental e também mostra que Zygoptera será mais afetada pelas transformações de habitat. No entanto, futuros estudos incluindo mais amostras e diferentes córregos são necessários para confirmar este padrão sendo uma linha de pesquisa interessante para trabalhos futuros.

Palavras-chave: integridade ambiental, Anisoptera, Zygoptera, riqueza de espécies, alterações na vegetação ripária.

1. Introduction

Deforestation may lead to rivers degradation resulting in increases on sedimentation levels, changes in hydrological cycles, and serious decreases in water quality due to chemical effluents (Callisto et al., 2001; Pond et al., 2008). The removal of riparian vegetation may contribute to these alterations, and has a direct effect in availability of organic matter and in the input of organic matter, primary source of energy in trophic chains of rivers (Lima and Zakia, 2001). In temperate rivers, deforestation has caused changes in macroinvertebrate assemblages, due to changes in light, temperature, nutrient levels, particle size substrate, distribution and availability of food resources (Bojsen and Jacobsen, 2003).

Odonata inhabits all kinds of freshwater environments, showing high diversity in the tropics. The species composition of Odonata assemblages can vary according to the modifications of certain environmental parameters, such as, the presence of marginal vegetation (Monteiro-Júnior et al. 2013), hydroperiod, pollutants, pH, conductivity, dissolved oxygen, water temperature and water flow (Corbet, 1999).

Due to ecophysiological requirements regarding flight behavior and thermoregulation, the order Odonata can be divided into two groups: the 'perchers', which remain the most of the time perched on different types of substrate, making only short flies, between oviposition sites and foraging; and 'flyers', who remain on the wing in most of their period of activity (Corbet, 1962, 1999; May, 1976). The perchers are generally ectothermic, using directly or indirectly sunlight as the main source of heat. They can be thermal conformers or heliothermic. Thermal conformers present smaller body size and show higher conductance (high body heat exchange with the environment temperature) and body temperature varies with the environment, mainly due to heat exchange (De Marco Junior,

1998). This group is mainly composed by small zygopteran species, such species of genus *Protoneura* and *Ischnura*. Heliothermic have larger body size and consequently lower conductance, being their activities determined primarily by solar irradiation. This group is the most heterogeneous, because it includes Zygoptera and Anisoptera species. Furthermore, presents species of most representative Neotropical genus, e.g. *Erythrodiplax*, *Hetaerina*, some Gomphidae, etc. The flyers are endothermic, as they are able to produce heat by controlling the hemolymph's movement, flight and wing-whirring (Corbet and May, 2008). Endothermic group is composed only by large anisoptera (e.g. *Aeshnidae* and larger *Libellulidae* as these of *Trameinini* tribe).

The thermoregulatory strategies and ecophysiological patterns of Odonata may be associated with body size (Corbet, 1999; Corbet and May, 2008). These strategies should have an important role in dispersal capability, determining the energy expenditure and the flight capacity of the species (Corbet and May, 2008). The removal of vegetation can maximize the incidence of sunlight and alter the availability of food resources, which would lead to a process of homogenization of Odonata species, by replacement of stenotopic species by more generalist species (Remsburg and Turner, 2009). Thus, environmental changes (such as removal of riparian forest and marginal vegetation) would not influence in the same way the two Odonata suborders, because zygoptera (the small ones, thermal conformers) could be negatively affected by its ecological requirements (e.g., Loiola and De Marco 2011; Monteiro-Júnior et al., 2013); in the other hand anisoptera (and some larger zygoptera, e.g. Calopterygidae) could be positively affected, because these larger insects are adapted to environment with more light, excluding that more habitat-restricted ones (Ferreira-Peruquetti and De Marco Junior, 2002).

Here we tested the hypothesis that Anisoptera richness in Borecaia river sub-basin would be positively affected by removal of riparian vegetation; while, Zygoptera richness would be adversely affected by virtue of their requirements.

2. Material and Methods

2.1. Study area

The sub-basin of Borecaia river (located between the coordinates: 13° 56' 30" to 14° 12' 30" S and 51° 42' 30" to 51° 51' 30" W, Figure 1) is part of Mortes river basin in southwest of Mato Grosso state – MT (to the sample locations, abbreviations and accurate coordinates see Table 1). The climate of the region is tropical, with an average temperature of 24.67 °C, ranging annually from 16.7 °C and 30.4 °C. The area presents a distribution pattern typical of Cerrado biome, with two well defined seasons: a rainy season from October to March, with approximately 92% of total rainfall, and a dry period, which extends from April to September (Brasil, 1981).

2.2. Sampling

We selected 10 streams, six classified as preserved and four as altered (Figure 1). These sampling sites were selected based on the assessment of the Habitat Integrity Index (HII) (Nessimian et al., 2008). The HII index provides a quick method to evaluate the integrity of the system by quantifying

Table 1. Sample areas, abbreviations used on text and HII scores for each sample location. Scores values higher 0.7 indicates preserved areas (classified as preserved in this study).

Sample areas	Abbreviations	HII
Matrichan stream	CRMT	0.881
Tritopá stream	CRT	0.787
Paca stream	CRP	0.787
Marayatobá stream	CRM	0.731
Areia Branca stream	CRAB	0.706
Água Limpa stream	CRAL	0.706
Estrela stream	CRE	0.593
Cigano stream	CRC	0.325
Boa Esperança stream	CRBE	0.306
Goíás stream	CRG	0.262

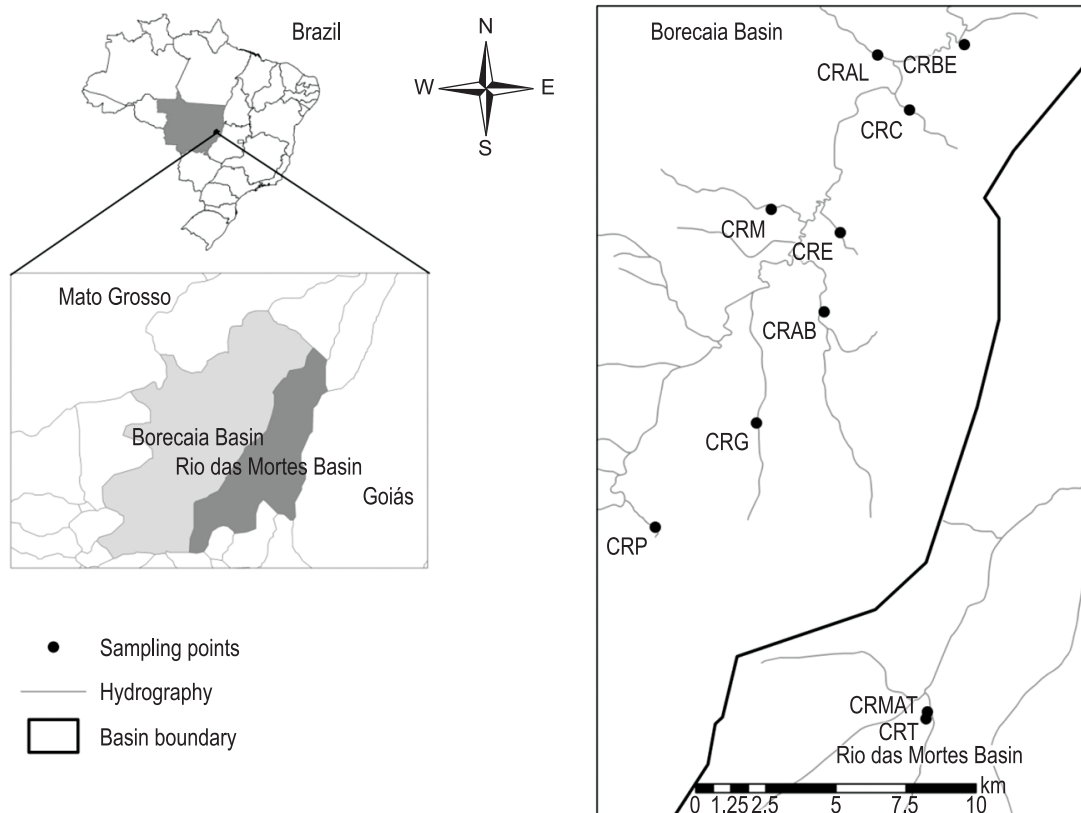


Figure 1. Study sites: 1a) Tritopá stream (CRT); 1b) Boa Esperança stream (CRBE); 1c) Marayatobá stream (CRMAT), Cigano stream (CRC), Água Limpa stream (CRAL); 1d) Areia Branca stream (CRAB), 1e) Paca stream (CRP), Estrela stream (CRE); and 1f) Matrichá stream (CRM), belonging to Borecaia river sub-basin, Nova Nazaré (MT). To classification status (altered or preserved) please refer to Table 1 (scores higher than 0.7 indicates preserved sites).

the state of preservation of riparian forest; retention and sediment in river/stream channel; appearance of stone substrate; characteristics of river flow; and aquatic vegetation. These questions were implemented in all streams; values range from zero to one, and values closer to 1 indicate more natural areas. Additionally, we run a T-test of Student (Zar, 1999) between scores to preserved and degraded areas, in order to evaluate if significant differences exist.

The specimens were collected in the months of April to July 2010, in the dry season, from 9:00 AM to 3:00 PM, with temperatures above 19 °C and open sky, being these the minimum weather conditions in which these insects are active (Marco and Resende, 2002; May, 1976, 1991). Each point was sampled three times on different days. Sampling was based on the scanning method with fixed areas (De Marco Junior, 1998), already used in other studies (Reis et al., 2011; Juen and De Marco Junior, 2011; Silva-Pinto et al., 2012). For the identification of collected specimens at species level, systematic keys were used (Borrer, 1945; Costa et al., 2002; Garrison et al., 2006; Heckman, 2006, 2008; Lencioni, 2006).

2.3. Physical-chemical variables

In each sampling site the mean width of the channel (m) was measured at five equidistant points (20 m) along of transect, using a measuring tape of 50 m. The mean depth of the channel (m) was calculated in the same locations, one in the center and one in each channel margin. The pH and conductivity ($\mu\text{s}/\text{cm}$) were determined with an electronic portable measurer (Aqua-Check™ Water Analyzer Operator, O.I. Analytical). Dissolved oxygen (mg/L) and temperature (°C) were determined with the portable oximeter/thermometer (Yellow Springs Ints., model 58), and turbidity was obtained with turbidimeter (300 TD model Instrutherm).

2.4. Statistical analysis

Richness of observed species is often a biased estimative to species richness. Therefore, we use the non-parametric first order *Jackknife* resampling estimator (Coddington and Levi, 1991; Colwell and Coddington, 1994; Heltshel and Forrester, 1983), with EstimateS Win 7.5.0 software (Colwell, 2000). This method is able to estimate the total richness summing observed richness (number of species collected) to a parameter calculated from the number of rare species. This technique produces

an approximate estimative of species richness in a community (Krebs, 1999), providing a confidence interval that allows the realization of comparisons between two or more regions sampled. These comparisons are made by confidence interval overlapping; when two or more confidence intervals are overlapping, they are no different.

To determine the relationship between richness/abundance and integrity of streams (obtained by HII) simple linear regression analyses were carried out. This procedure is one of the most used, since it provides a simple functional relationship between the variables (linear) (Zar, 1999). All assumptions were tested, and when they were not satisfied, the data were log-transformed.

3. Results

3.1. Community description

The HII scores for preserved and altered sites is presented on Table 1. Preserved areas presented scores higher than 0.7. There was a significant difference in HII scores between preserved and altered areas (t-test = 5.758; d.f. = 8; $p < 0.001$). The most representative species in altered sites were *Erythrodiplax basalis* (Kirby, 1897) (142 individuals), *Diastatops obscura* (Fabricius, 1775) (37 individuals) and *Erythemis credula* (Hagen 1861 (12 individuals)). Already by preserved sites were *Hetaerina curvicauda* Garrison, 1990 (42 individuals), *Argia reclusa* Selys, 1865 (36 individuals), *Acanthagrion apicale* Selys, 1876 (19 individuals) and *Hetaerina rosea* Selys, 1853 (19 individuals) Table 2.

The total richness of Odonata order was evaluated based on inference by confidence interval technique. The greatest richness was observed in the CRG site with 35.78 species (± 7.46) (mean \pm confidence interval), showing 10 species more than CRAB site (25.88 ± 4.94), which was the second most diverse, and was followed by CRC (9.93 ± 3.84) and CRAL sites (10.97 ± 2.76), which presented ten species less than CRAB. In other places, richness was not different, because the confidence intervals of a group overlapped the average of other (Figure 2).

Using the same technique, we can see that for Anisoptera, the site with the greatest richness was CRG, with 22.87 (± 5.22) estimated species, showing 10 species more than CRAB and CRC. CRBE and CRMT presented five species less than CRAB and CRC. The sites CRAL, CRE, CRM, CRT and CRP had lower richness (Figure 3a).

Table 2. Abundance of odonates in degraded and preserved streams in Nova Nazaré municipality, Mato Grosso, Brazil.

Suborder	Family	Species	Degraded	Preserved	Total
Anisoptera	Libellulidae	<i>Diastatops intensa</i>	3	1	4
Anisoptera	Libellulidae	<i>Diastatops obscura</i>	37	1	38
Anisoptera	Libellulidae	<i>Erythemis credula</i>	12	0	12
Anisoptera	Libellulidae	<i>Erythrodiplax paraguayensis</i>	2	0	2
Anisoptera	Libellulidae	<i>Erythrodiplax amazonica</i>	0	1	1
Anisoptera	Libellulidae	<i>Erythrodiplax amazonica melanica</i>	0	1	1
Anisoptera	Libellulidae	<i>Erythrodiplax basalis</i>	142	19	161
Anisoptera	Libellulidae	<i>Erythrodiplax basalis avittata</i>	0	1	1
Anisoptera	Libellulidae	<i>Erythrodiplax fusca</i>	2	5	7
Anisoptera	Libellulidae	<i>Erythrodiplax juliana</i>	1	0	1
Anisoptera	Libellulidae	<i>Erythrodiplax maculosa</i>	5	0	5
Anisoptera	Libellulidae	<i>Erythrodiplax paraguayensis</i>	7	0	7
Anisoptera	Libellulidae	<i>Erythrodiplax umbrata</i>	3	1	4
Anisoptera	Libellulidae	<i>Fylgia amazonica</i>	0	18	18
Anisoptera	Libellulidae	<i>Gynothemis</i> sp.	0	3	3
Anisoptera	Libellulidae	<i>Macrothemis</i> sp.	0	1	1
Anisoptera	Libellulidae	<i>Miathyria marcella</i>	6	0	6
Anisoptera	Libellulidae	<i>Micrathyria spuria</i>	1	0	1
Anisoptera	Libellulidae	<i>Micrathyria stawiaarskii</i>	1	0	1
Anisoptera	Libellulidae	<i>Nephepeltia phryne</i>	1	0	1
Anisoptera	Libellulidae	<i>Oligoclada abbreviata limnophila</i>	1	0	1
Anisoptera	Libellulidae	<i>Oligoclada limnophila</i>	1	1	2
Anisoptera	Libellulidae	<i>Oligoclada pachystigma</i>	0	1	1
Anisoptera	Libellulidae	<i>Oligoclada walkeri</i>	0	1	1
Anisoptera	Libellulidae	<i>Oligoclada xanthopleura</i>	3	0	3
Anisoptera	Libellulidae	<i>Orthemis ambirufa</i>	0	1	1
Anisoptera	Libellulidae	<i>Orthemis discolor</i>	7	0	7
Anisoptera	Libellulidae	<i>Orthemis</i> sp.	1	0	1
Anisoptera	Libellulidae	<i>Perithemis lais</i>	0	16	16
Anisoptera	Libellulidae	<i>Planiplax</i> sp	1	0	1
Anisoptera	Libellulidae	<i>Uracis reducta</i>	0	4	4
Anisoptera	Libellulidae	<i>Zenithoptera viola</i>	1	0	1
Zygoptera	Coenagrionidae	<i>Acanthagrion apicale</i>	2	19	21
Zygoptera	Coenagrionidae	<i>Acanthagrion ascendens</i>	1	9	10
Zygoptera	Coenagrionidae	<i>Acanthagrion jessei</i>	11	3	14
Zygoptera	Coenagrionidae	<i>Acanthagrion</i> sp1	5	0	5
Zygoptera	Coenagrionidae	<i>Aeolagrion flammeum</i>	0	5	5
Zygoptera	Coenagrionidae	<i>Argia mollis</i>	0	15	15
Zygoptera	Coenagrionidae	<i>Argia reclusa</i>	1	36	37
Zygoptera	Protoneuridae	<i>Epipleoneura machadoi</i>	2	12	14
Zygoptera	Protoneuridae	<i>Epipleoneura metallica</i>	0	11	11
Zygoptera	Coenagrionidae	<i>Helveciagrion obsoletum</i>	0	1	1
Zygoptera	Calopterygidae	<i>Hetaerina auripennis</i>	0	5	5
Zygoptera	Calopterygidae	<i>Hetaerina curvicauda</i>	1	42	43
Zygoptera	Calopterygidae	<i>Hetaerina laesa</i>	0	1	1
Zygoptera	Calopterygidae	<i>Hetaerina rosea</i>	1	19	20
Zygoptera	Coenagrionidae	<i>Ischnura capreolus</i>	1	0	1
Zygoptera	Calopterygidae	<i>Mnesarete lencioni</i>	0	2	2
Zygoptera	Calopterygidae	<i>Mnesarete williamsoni</i>	0	1	1
Zygoptera	Protoneuridae	<i>Neoneura sylvatica</i>	0	8	8
Zygoptera	Protoneuridae	<i>Peristicta aenoviridis</i>	0	5	5
Zygoptera	Protoneuridae	<i>Protoneura tenuis</i>	0	1	1
Zygoptera	Coenagrionidae	<i>Tigriagrion aurantigrum</i>	6	11	17

For Zygoptera, sites with greater estimated species richness were CRAB with 12.97 (± 2.76) and CRG 10.93 (± 3.84), and there was no difference among the other sites based on the confidence intervals overlap (Figure 3b).

3.2. Species richness between environments with different degrees of conservation

When we analyze all species richness (Anisoptera and Zygoptera) there was no difference between preserved and altered sites (Figure 4), based on confidence intervals. However, when we carried out the estimate of species richness separated by suborders (Zygoptera or Anisoptera), for both

Anisoptera and Zygoptera there were differences in species richness (Figure 5).

For Anisoptera in degraded areas the number of estimated species was 34.93 (± 7.74), presenting 15 species more than in the preserved areas (Figure 5a). For Zygoptera, we observed the opposite; in preserved sites the estimated number of species was 22.99 (± 4.83), presenting eight species more than degraded sites (Figure 5b). However, the estimated richness of Anisoptera decreases with increased integrity ($r^2 = 0.485$; $p = 0.025$; Figure 6).

4. Discussion

The physical classification by HII shows differences in habitat quality between disturbed and preserved sites. Observed patterns in Odonata shows that biological assessment of this area reflects the physical evaluation, suggesting that HII is a good complementary tool in Cerrado streams. Previous studies showed similar results (Nogueira et al., 2011; Shimano et al., 2010; Reis et al., 2011) although the HII has been developed to evaluate characteristics of Amazonian streamlets (Nessimian et al., 2008).

As a general pattern there is no Odonata richness difference between altered and preserved sites, except for CRG (altered) and CRAB (preserved) that presented the highest richness observed. However, when analyzed separately, Anisoptera presents higher richness in altered sites, while Zygoptera presents higher richness in preserved sites. This pattern, although it should be considered with caution, due to the reduced number of study sites, suggests that Odonata need to be considered at the sub-order level to access effects of environmental changes on these insects (Monteiro-Júnior et al., 2013). These authors discusses that, when the two

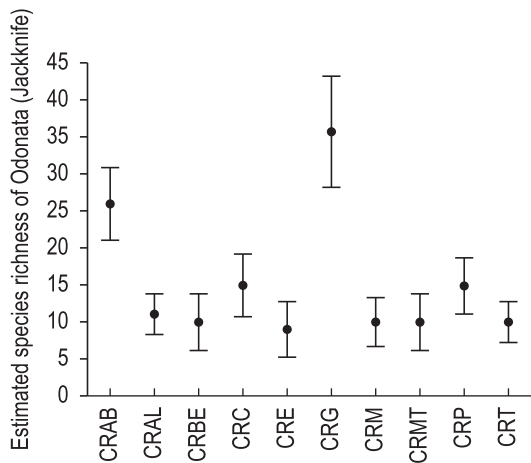


Figure 2. Estimated species richness of Odonata by Jackknife procedure, in the Cerrado streams of Nova Nazaré (MT), distributed according to sampled sites in 2010. Bars represent confidence interval of 95%. To classification status (altered or preserved) please refer to Table 1 (scores higher than 0.7 indicates preserved areas).

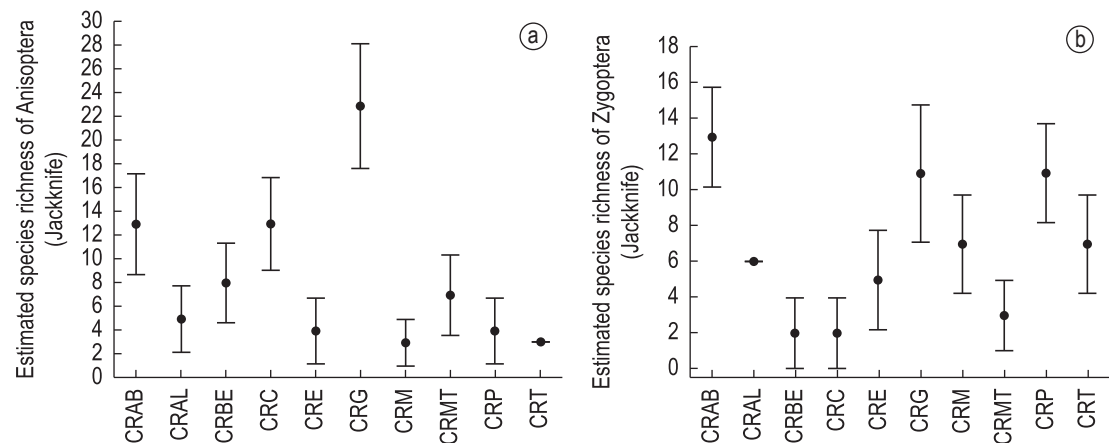


Figure 3. Estimated species richness by Jackknife procedure, in the Cerrado streams of Nova Nazaré (MT), 2010. a) Anisoptera and b) Zygoptera. Bars represent confidence interval of 95%. To classification status (altered or preserved) please refer to Table 1 (scores higher than 0.7 indicates preserved areas).

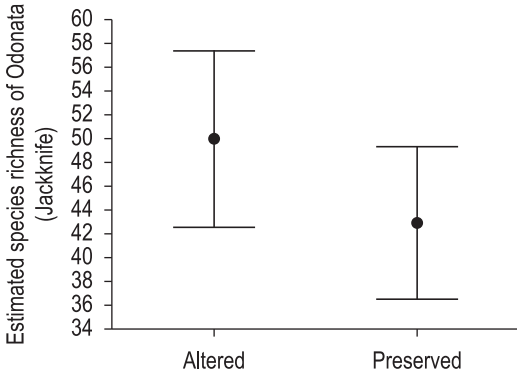


Figure 4. Estimated species richness of Odonata by Jackknife procedure, in the Cerrado streams of Nova Nazaré (MT), distributed according to conservation level, 2010. Bars represent confidence interval of 95%. To classification status (altered or preserved) please refer to Table 1 (scores higher than 0.7 indicates preserved areas).

infra-orders are considered together, direct effects of environmental alteration by human activities on species richness may be confused, causing misinterpretations of some processes and patterns. Dias-Silva et al. (2010) suggests the same pattern to Heteroptera community that suffers similar effects. Here we suggest that, in further studies, this pattern may be evaluated in others aspects and considering other types of degradation.

In the areas classified as altered we have collected most of generalist species, e.g. *Erythrodiplax fusca*, *Diastatops intensa* and *Hetaerina rosea*. In a study with similar anthropogenic effects, Ferreira-Peruquetti and De Marco Júnior (2002) have showed that some typical lentic species (e.g *Ischnura fluviatilis* and *Erythrodiplax fusca*) have increased their abundances, in consequence of deforestation and changes in water flow.

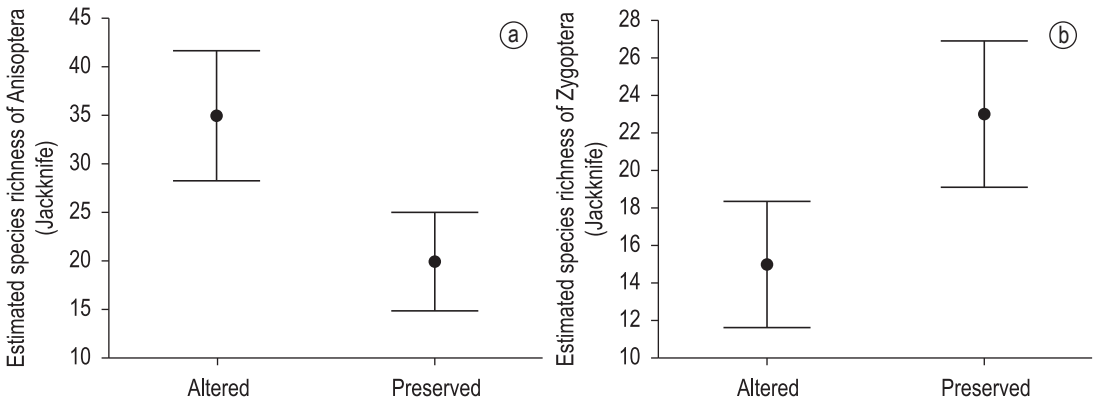


Figure 5. Estimated species richness of a) Anisoptera and b) Zygoptera by Jackknife procedure, in the Cerrado streams of Nova Nazaré (MT), distributed according to conservation level, 2010. Bars represent confidence interval of 95%. To classification status (altered or preserved) please refer to Table 1 (scores higher than 0.7 indicates preserved areas).

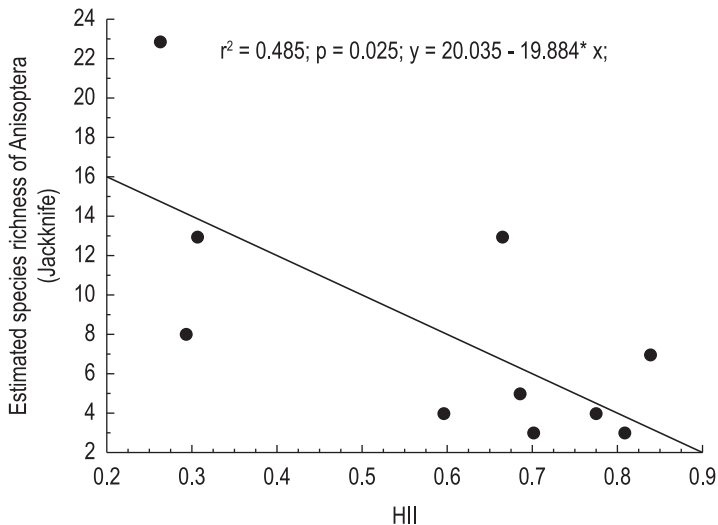


Figure 6. Relationship between estimated species richness of Anisoptera and Habitat Integrity Index (HII), sampled in Cerrado streams of Nova Nazaré (MT), 2010.

Heteragrion consors populations studied by Loiola and De Marco (2008) showed a strongly dependency to shade locals, occurring into forest, maybe relative to its capacity to exchange heat by convection. As in our study sites, the Zygoptera species observed presents the same behavior. It is possible that, with removal of riparian vegetation and an intense increase in luminosity, and strongly variation in daily temperature may exclude some small zygopteran species. On the other hand medium to large sized Zygoptera and Anisoptera may be benefited and exclude those specialists by competition.

Odonata thermoregulatory theory suggests a “continuum” between two extremes: perchers and fliers (Corbet and May 2008). Fliers present larger sizes, and can produce endogenic heat. In this way, it is expected that fliers use entire landscapes, and not necessarily only the sites where they have been collected or observed. On the other extreme, the perchers, small sized ones, mainly composed by Zygoptera species, thermoregulate by convection, and can be affected by higher temperatures. Chang et al. (2007) have demonstrated that higher temperatures are associated with disruption in development, resulting in increases in mortality of zygopteran larvae. So, we expected this group to be the first to be excluded on areas affected by riparian vegetation removal. The group that could be more benefited is that between these two extremes. This group is composed by Anisoptera and Zygoptera species, and is relatively resistant to these observed effects. They, probably have the most large temperature niche, and, although they could present some dependency of microhabitats to breeding (e.g. Guillermo-Ferreira and Del-Claro, 2012).

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