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Immature Odonata community in streams: diversity, season variation and habitat preference in different levels of degradation

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Abstract. The immature Odonata community is used to diagnose and monitor impacts on aquatic environments. Degraded environments, with a wide range of environmental variables, usually present highly resilient species. Here we present a highly diverse immature Odonata community, collect with great sample effort. In doing so, we were able to show that these altered and natural environments have similar immature Odonata communities, and pH was the only abiotic variable affecting the system and the community. The community also changes with seasonal variation, because rains modify the river flow. Furthermore, the ecological integrity of the streams was influenced by anthropogenic activities, changing the dynamics of the Odonata communities. Two genera, *Brechmorhoga* and "Unidentified genus 1", are indicators of altered environments, so they can be used as bioindicator in others monitoring environmental evaluations.

Key words: limnology, degraded environments, benthic macroinvertebrates, bioindicator.

The physical and chemical parameters of water associated with benthic invertebrate communities are used as tools of great detection potential of the causes and consequences of environmental impacts on aquatic ecosystems (Buss et al. 2008). The characteristics of the aquatic environment in relation to the physical structure, composition stability and heterogeneity of the substrate can alter abundance, distribution and structure of the macroinvertebrate community of immature Odonata (Assis et al. 2004). This relationship happens because the habitat heterogeneity increases the structural complexity and provides various niches, which favors the establishment of a more diverse immature Odonata community (Souza et al. 2015). In addition, some species require specific environmental conditions for their survival and have a substrate preference according to their habit (Carvalho & Nessiman 1998).

Immature Odonata have been used to diagnose and monitor many impacts on aquatic environments (Oertli, 2008, Oliveira-Júnior et al. 2015, Souza et al. 2015), such as the removal of riparian vegetation and different types of land uses (Ferreira-Peruquetti & De Marco Jr. 2002, Ferreira-Peruquetti & Fonseca-Gessner 2003). Nevertheless, little is known about the composition and importance of this group in tropical aquatic ecosystems due to the lack of information and the limited number of experts in the area (Saavedra, 2009). In Brazil, only 29% of the territory has data of Odonata richness (De Marco Jr. & Vianna 2005).

Given the above, this study aimed: (1) analyzing the immature Odonata community in relation to levels of degradation of lotic environments that have been altered by human activities, (2) describing and analyzing the richness, abundance, composition and the structure of the immature Odonata community; (3) analyzing the seasonal and spatial variation and (4) correlating the composition of immature Odonata with environmental variables.

It is expected that the Odonata community might change from one stream to the other because of their degradation conditions; also, that richness and abundance will be greater in less degraded streams. The composition and structure will also differ according to the levels of streams degradation because environmental variables interfere in the presence of each species.

Study area. A total of ten streams from first to third order were selected in Luminárias, São Tomé das Letras and Carrancas municipalities (21° 30'- 21° 39' S, 44° 33'- 44° 56' W), located in the south of Minas Gerais State, Brazil (Fig. 1). The climate is characterized according to the Koppen classification as Cwb (tropical). The average temperature ranges from 14 to 20 °C and the average annual precipitation is 1.517 mm, according to data from the Meteorological Station.

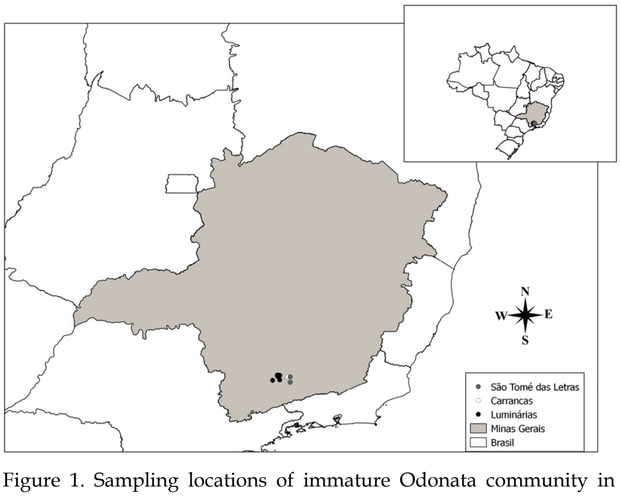

Figure 1. Sampling locations of immature Odonata community in study area in southeastern Brazil.

Sampling design. The streams were sampled in two periods: dry period (August, 2010) and rainy period (February, 2011). For each stream, four points were sampled with three replicates each. The environmental characterization was standardized according to the Rapid Assessment Protocol (RAP) proposed by Callisto et al. (2002). This protocol evaluates a set of parameters that are ranked based on environmental monitoring, considering the type of occupation, anthropogenic changes and water quality. Therefore, the stream can be classified as impacted, altered or natural.

Measurements of environmental variables. Before sampling, environmental variables were measured: water temperature, water dissolved oxygen, electrical conductivity and turbidity, using a Horiba U-22 analyzer. The current speed, depth and width of the streams were measured with rules, a measuring tape and a floating object.

Data sampling. The immature Odonata sampling was performed using a modified Surber sampler 30 x 30 cm, mesh of 225 μm in a downstream-upstream direction. The Odonata specimens were screened and identified to the lowest possible taxonomic category, using a stereoscope microscope and dichotomous keys from Carvalho et al. 2002, Costa et al. 2004, Souza et al. 2007, Neiss & Hamada 2014 and Salgado et al. 2013.

Data analysis. Curves were built to analyze the sampling effort: one for general rarefaction, one for the first order jackknife richness estimator and one for each season (dry and rainy). These curves were obtained based on 1,000 randomizations by Estimate S 9.1.0 program (Statistical Estimation of Species Richness and Shared Species from Samples) (Colwell et al. 2012).

A Two-Dimensional Non-Metric Dimensional Scaling (Clarke 1993) using the Jaccard index was created to sort the streams based on the similarity of the Odonata community structure (Clarke, 1993). The significance of this structure was analyzed by ANOSIM (Clarke, 1993) and the percentage of contribution of each genus to this divergence was calculated by SIMPER (Warwick et al. 1990; Clarke, 1993). Analyses were performed in Primer & Permanova software (Anderson et al. 2008).

The correlation between environmental variables and immature Odonata was tested by the Canonical Correspondence Analysis (CCA), using the R Platform version 3.1.3 (R Development Core Team 2015), and Vegan package (Oksanen et al. 2006). An Indicator Value analysis (IndVal -Dufrene & Legendre 1997) associated with the Monte Carlo test, using PC-ORD (McCune & Mefford 2006), was performed to verify the habitat preference of each genera. All analyses were conducted at 5% significance level.

There were 260 immature Odonata distributed in 13 genera for both studied seasons (Table 1). In the dry period, the greater abundance of Odonata was recorded in stream 5 (43 individuals) and the greatest richness was found for stream 9 (9 genera). During the rainy period, the greatest abundance of Odonata was recorded for stream 2 (48 individuals) and the greatest richness in stream 5 (6 genera). The immature Odonata were found in almost all sampled streams, with the exception of streams 1 and 4, located in Luminárias. According to the Rapid Assessment Protocol, the streams 1, 3, 5, 6, 7, 8, 9 and 10 were categorized as natural and streams 2 and 4 as altered. None of the streams studied was categorized as impacted.

Curves did not reach an asymptote (Fig. 2A and 2B). The richness and abundance were higher in the dry period (Fig. 2B). The estimated richness reached 13.98 individuals (Fig. 2A). Therefore, 92.98% of the community was sampled, according to the first order Jackknife estimator. The NMDS analysis did not show the formation of different groups in

Table 1. Immature Odonata community in streams from study area followed by abundance and and their relative frequencies.

Family	Genera	Abundance	Relative Abundance
Gomphidae Rambur, 1842	*Desmogomphus* Selys, 1854	47	18.08
	Progomphus Selys, 1854	29	11.15
	Pyllogomphoides Belle, 1970	4	1.54
	Genus not identified 1	19	7.31
Corduliidae Selys, 1850	*Neocordulia* Selys, 1882	6	2.30
Libellulidae Rambur, 1842	*Brechmorhoga* Kirby, 1894	87	33.46
	Gynothemis Calvert *in* Ris, 1909	4	1.54
	Macrothemis Hagen, 1868	5	1.92
	Genus not identified 2	29	11.15
Calopterygidae Selys, 1850	*Hetaerina/Mnesarete* Hagen in Selys, 1853 e Cowley, 1934	10	3.85
Coenagrionidae Kennedy, 1920	*Argia* Rambur, 1842	15	5.77
Megapodagrionidae Tillyard, 1917	Genus not identified 3	1	0.39
Family not identified	Genus not identified 4	4	1.54
	TOTAL	260	100%

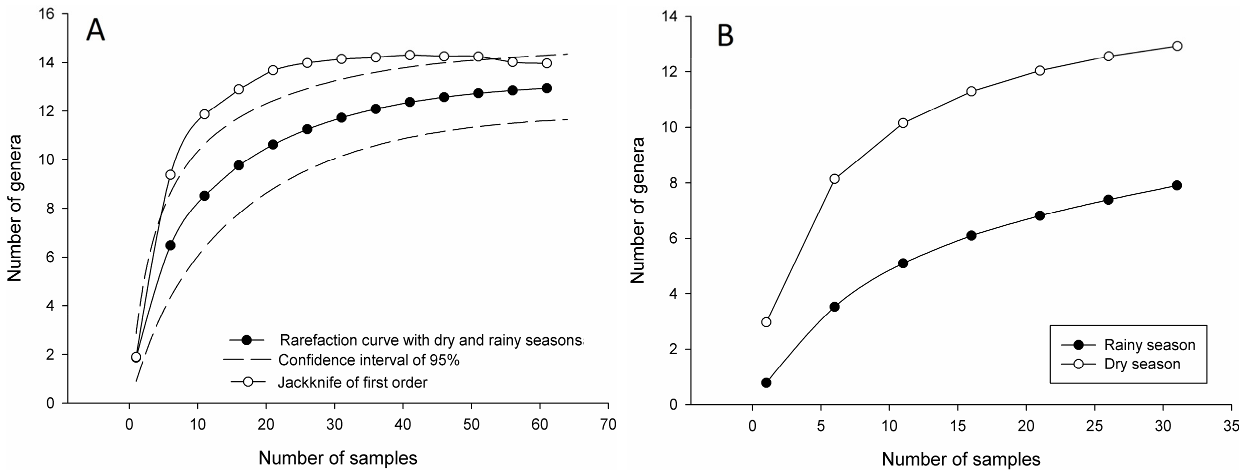

Figure 2. Rarefaction curve for the immature Odonata community in streams from study area in southeastern Brazil. Graph A represents the general rarefaction curve, with 95% confidence interval and first order Jackknife richness estimator for both periods. Graph B represents the rarefaction curves for the dry and rainy period separately.

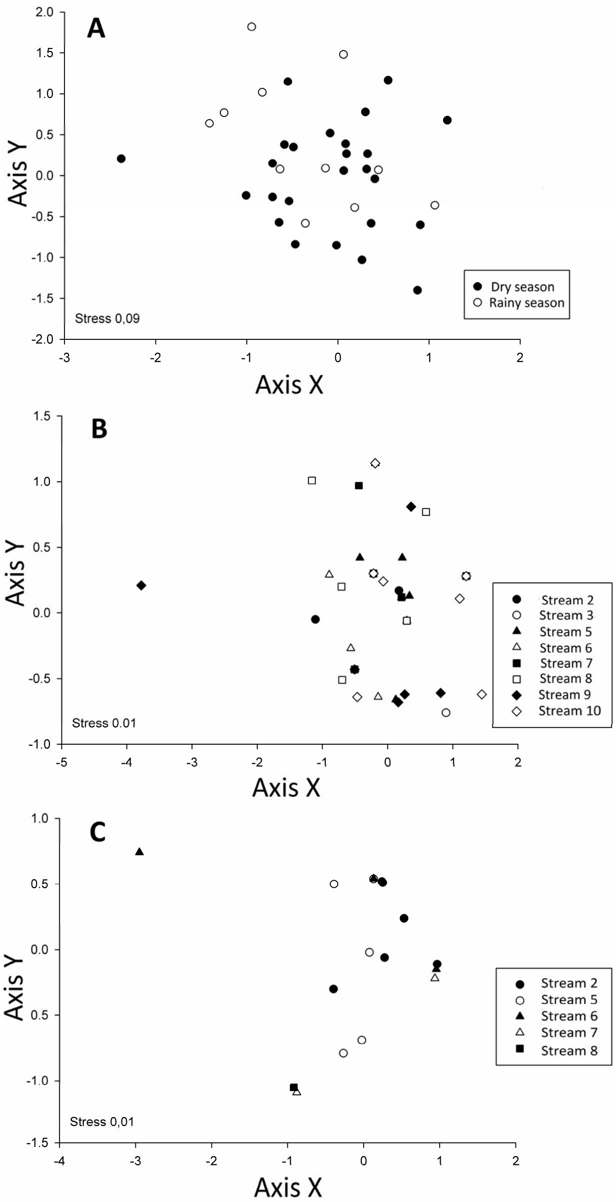

Figure 3. NMDS of immature Odonata community in streams from study area in southeastern Brazil. Map A represents the comparison between natural and altered streams. Map B represents the streams comparison for the rainy period and C is the streams comparison in the dry period.

the two-dimensional map (Fig. 3A, 3B and 3C). The analysis of similarity between seasons was not significant, however, the per-to-per ANOSIM test showed that streams 7 and 9 were statistically different in the dry period (Table 2), and streams 5 and 7 were statistically different in rainy period (Table 3).

The CCA performed for the dry period showed that genera were not influenced by abiotic variables, considering their position at the center of the graph (Fig. 4). The abiotic variables that were more correlated with the first axis, in descending order, were the width of stream, dissolved oxygen and pH. For the second axis, the electric conductivity, flow rate and turbidity were correlated. The pH was the only significant variable (Table 4).

The immature Odonata community showed high simi-

Table 2. Pairwise ANOSIM tests for the dry period. (* represents values with p<0.05)

Streams	R	P
2, 3	1	0.143
2, 5	00.034	0.533
2, 6	00.101	0.887
2, 7	00.075	0.733
2, 8	00.022	0.532
2, 9	0.13	0.091
2, 10	0.102	0.125
3, 5	0.599	0.1
3, 6	0.527	0.222
3, 7	0.589	0.091
3, 8	0.524	0.25
3, 9	0.009	0.5
3, 10	0.034	0.625
5, 6	00.118	0.982
5, 7	00.077	0.878
5, 8	00.038	0.607
5, 9	0.061	0.159
5, 10	00.017	0.509
6, 7	00.069	0.829
6, 8	00.044	0.653
6, 9	0.036	0.275
6, 10	00.03	0.542
7, 8	00.035	0.58
7, 9	0.151	0.039*
7, 10	0.054	0.228
8, 9	0.069	0.181
8, 10	0.058	0.234
9, 10	00.064	0.739

Table 3. Pairwise ANOSIM tests for the rainy period. (* represents values with p<0.05)

Streams	R	P
2, 5	0.131	0.136
2, 6	0.226	0.106
2, 7	0.509	0.055
2, 8	0.694	0.1
5, 6	0.266	0.087
5, 7	0.445	0.048*
5, 8	0.4	0.167
6, 7	00.107	1
6, 8	0.167	0.6
7, 8	00.5	1

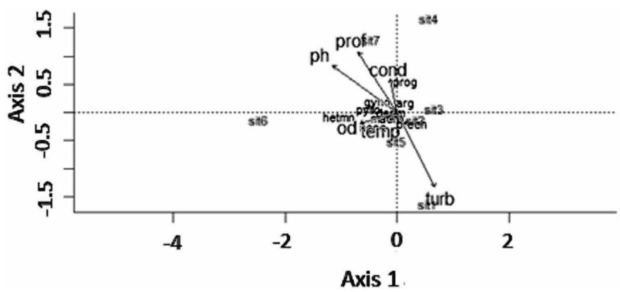

Figure 4. Canonical Correspondence Analysis (CCA) among the immature Odonata community in streams from study area in southeastern Brazil. The abbreviations represent prof = depth, pH, cond. = eletrical conductivity, od= dissolved oxygen, temp = water temperature, turb. = turbidity; brech = *Brechmorhoga*, gyno = *Gynothemis*, macro = *Macrothemis*, neoc = *Neocordulia*, desm = *Desmogomphus*, prog = *Progomphus*, pyllo = *Pyllogomphoides*, arg = *Argia*, hetmn = *Hetaerina/Mnesarete*.

Table 4. Importance of abiotic variables for the distribution of Odonata in streams for the dry period. (* Represents values of p <0.05).

Abiotic variables	Axis 1	Axis 2
Temperature	-0.633	-0.773
pH	-0.806	0.590*
Electrical conductivity	-0.211	0.977
Dissolved oxygen	-0.960	-0.278
Turbidity	0.451	-0.892
Depth	-0.540	0.841
Width	-0.964	-0.262
Current speed	-0.446	0.894

larity by the significant proportion of *Brechmorhoga* Kirby, 1894 and "Unidentified genus 1". According to the SIMPER analysis, these genera represent 98.92%, 76.62% and 53.13% for natural streams, altered and all together streams, respectively (Table 5, 6 and 7). The IndVal analysis showed that both genera, *Brechmorhoga* and "Unidentified genus 1", are indicators of altered environments (Fig. 5). The other genera presented levels of significance lower than 0.05 for the Monte Carlo test.

Regarding degradation conditions of the environments here studied, the used Protocol classified the streams as natural or altered. However, Odonata fauna presented contrasting results. It was observed a predominance of *Brechmorhoga*, which is considered an indicator of altered environments according to IndVal. This genus is found in lotic environments, preferably those affected by erosion with no vegetation coverage (Costa et al. 2004). Due to its sprawling/burrowing habits (half-buried in fine sediments, feeding on prey above the substrate), it has a preference for sandy substrates with debris.

Brechmorhoga is a genus of dragonfly in the Libellulidae Rambur, 1842 family and is mostly found in environments with human influence, such as pastures near streams and riparian areas (Soares et al. 2015). In general, abundance and richness of Anisoptera tends to be higher in areas with a less dense vegetation and higher incidence of solar radiation (Juen et al. 2014, Oliveira-Junior et al. 2013).

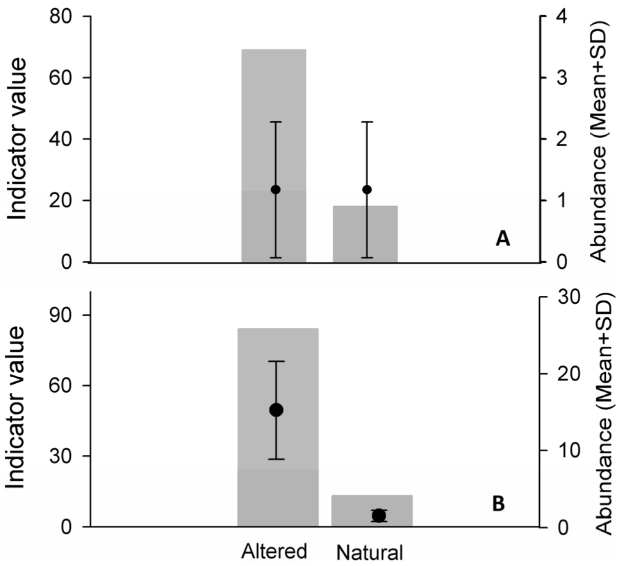

Figure 5. Indicator Value Analysis (bars) and average abundance with standard deviation for the genera related to natural and altered streams, with p > 0.05. Graph A represents "Unidentified genus 1" and B represents *Brechmorhoga.*

The richness and abundance of Odonata were lower in the rainy period, as demonstrated by the rarefaction curves. It can be explained by the increased water flow, which enhances the speed of the current, moving rocks and removing benthic invertebrates within the substrate (Ribeiro & Uieda 2005). Rarefaction curves did not reach an asymptote. Pires et al. (2013) and Souza et al. (2015), when studying immature Odonata, found similar results. This pattern is also common for rarefaction curves of benthic invertebrate communities in

Table 5. SIMPER analysis of each genus in streams characterized as natural in the dry and rainy seasons, from study area in southeastern Brazil.

Genus	% of contribution	% of cumulative contribution
Brechmorhoga	62.43	62.43
Genus not identified 1	14.19	76.62
Progomphus	12.65	89.27
Genus not identified 2	4.07	93.34

Table 6. SIMPER analysis of each genus in streams characterized as altered in the dry and rainy seasons, from study area in southeastern Brazil.

Genus	% of contribution	% of cumulative contribution
Brechmorhoga	86.91	86.91
Genus not identified 1	12.01	98.92

Table 7. SIMPER analysis of each genus in streams characterized as both natural and altered in the dry and rainy seasons, from study area in southeastern Brazil.

Genus	% of contribution	% of cumulative contribution
Brechmorhoga	40.77	40.77
Progomphus	14.05	54.82
Genus not identified 1	12.38	67.2
Genus not identified 2	8.7	75.89
Hetaerina/Mnesarete	7.11	83.01
Argia	4.48	87.49
Neocordulia	3.44	90.93

tropical streams (Melo & Froehlich 2001). However, the value of the first order Jackknife estimator was relatively high (92.98%), which allows us to make significant comparisons. The NMDS did not separate the immature Odonata community in groups. The composition among streams did not differ because of their similarity regarding the environmental characteristics. The same information was found by the SIMPER analysis, which showed high proportion of *Brechmorhoga* and "Unidentified genus 1". The streams environmental conditions favored the dominance of only two genera, reducing the diversification of the community.

The canonical correspondence analysis showed that among all the abiotic variables analyzed; only the pH significantly interfered in the composition and abundance of Odonata. This environment variable can favor the occurrence of *Brechmorhoga* and "Unidentified genus 1". Even if changes have occurred in the abiotic variables that are important for Odonata community, these changes were within the niche variation limit that each species is able to tolerate in the environment. Furthermore, little is known about the influence of these variables on the distribution of immature Odonata, which highlights the need of more research (Souza et al. 2015).

The immature Odonata community in tropical streams presented the greatest richness and abundance in streams categorized as natural, during the dry period. The composition and the structure did not differ according to the levels of degradation of the streams and the oscillations in the abiotic variables. In addition, the variables were not sufficient to interfere with the Odonata community (except pH), since they were within the range of tolerance of the genus.

It is important to emphasize that the genus *Brechmorhoga* was considered an indicator of altered environments and ought to be used in diagnostic research and monitoring water quality. Their presence in streams showed that their ecological integrity was influenced by anthropogenic activities, changing the dynamics of Odonata communities.

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