A comparative study of Odonata (Insecta) in aquatic ecosystems with distinct characteristics

Um estudo comparativo de Odonata (Insecta) em ecossistemas aquáticos com distintas características

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Resumo

O objetivo deste trabalho foi estudar comparativamente a riqueza e a densidade de larvas de Odonata em quatro ambientes distintos: lótico com grande carga de contaminantes, lótico com pouca carga de contaminantes, lêntico desconectado do rio e lêntico conectado ao rio, assim como caracterizar os quatro ambientes quanto às características físicas e químicas da água. Identificamos um total de 1.302 larvas de Odonata nos quatro ambientes. As variáveis ambientais medidas foram: oxigênio dissolvido, pH, condutividade, sólidos em suspensão, temperaturas do ar e da água, precipitação, profundidade e biomassa das macrófitas. Os ambientes lênticos mostraram uma maior densidade de larvas de Odonata em relação aos lóticos, exceto no mês de abril e dezembro de 2006. O rio Guareí mostrou uma alta condutividade devido à grande quantidade de contaminantes que recebe, no entanto, no período de junho a setembro de 2006, apresentou uma maior densidade de larvas de Odonata em comparação ao rio Paranapanema. A temperatura e oxigênio dissolvido na superfície da água foram, respectivamente, maiores e menores nos lagos em comparação aos rios. Apesar da densidade de larvas de Odonata ter sido maior nos ecossistemas lênticos em relação aos lóticos, a riqueza não se alterou durante o período estudado. Além disso, a composição de gêneros foi distinta, mostrando que alguns táxons apresentam certa preferência por determinados tipos de ecossistemas como Calopterygidae e *Neogomphus* os quais foram amostrados exclusivamente no rio Paranapanema.

Palavras-chave: larvas; lago; rio; libélulas.

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Abstract

The objective of this study was to compare the richness and density of Odonata larvae in four distinct environments: lotic with large pollutant loads, lotic with small pollutant loads, lentic disconnected from a river and lentic connected to a river, as well as to record the physical and chemical parameters of the water in the four environments. We identified a total of 1,302 Odonata larvae in the four habitats. The environmental variables measured were: dissolved oxygen, pH, conductivity, suspended matter, air and water temperature, precipitation, depth, and the biomass of the macrophytes. The lentic habitats exhibited a greater Odonata larvae density in relation to the lotic habitats, except during April and December of 2006. The Guareí River, however, presented an elevated conductivity, possibly because of a greater quantity of pollutants it received during the period between June and September of 2006, and it showed a higher density of Odonata larvae in comparison to the Paranapanema River. The temperature and the dissolved oxygen on the water surface were, respectively, greater and smaller in the lakes in comparison to the rivers. In spite of the Odonata density being higher in the lentic ecosystems in comparison to the lotic, the richness was not altered during the period studied. Nevertheless, the genera composition was distinct, showing that some taxa show a certain preference for certain types of ecosystems like Calopterygidae and *Neogomphus*, which were shown exclusively in the Paranapanema River.

Key words: larvae; lake; river; dragonflies.

Introduction

According to Chambers et al. (1991; 2008), in recent years there was an increase in the number of studies on macrophyte growth rate (AIDA et al., 2006), primary production (WETZEL; PICKARD, 1996) and decomposition (CHIMNEY; PIETRO, 2006; THULLENA et al., 2008). On the other hand, macroinvertebrates living near aquatic plants have been poorly studied due to the high density of immature insects and the difficulty in identifying them (WRIGHT et al., 2002; COSTA et al., 2004; COSTA et al., 2006; ALI et al., 2007). The macrophytes harbor one of the greatest richness and density of macroinvertabrates in the entire aquatic ecosystem, mainly because of shelters provided by the roots of plants that protect them against predators, such as fish (RANTALA et al., 2004; FULAN; HENRY, 2006). The Odonata larvae are also important predators of the macroinvertebrates in coastal areas, and because of this, we recorded high levels of density and richness in these environments (KOUAMÉ et al., 2011). The dragonflies may also use the macrophytes as substrate for deposition of eggs, as occurs in the Zygoptera species (MATUSHKINA; GORBB, 2007).

Dragonflies present distinct genera richness, depending on the kind of environment. *Hetaerina* and *Mnesarete*, for example, are more frequent in lotic habitats, and *Telebasis* are more common in lentic environments (COSTA et al., 2004). The different species composition may also occur as a function of ecosystem integrity. Several studies have shown high sensitivity in some dragonfly species to impacted ecosystems, possibly resulting in an increase in the density of resistant species and in the reduction of sensitive species (SAMWAYS, 1996; STEWARD; SAMWAYS, 1998; HOFMANN; MASON, 2005). For this reason, in recent years dragonflies have been used with success in countries such as Holland and Canada in studies about environmental monitoring (FOOTE; HORNUNG, 2005; STRIEN et al., 2010).

The objective of this study was to investigate the richness and density of Odonata larvae in four distinct habitats: lotic with a large pollutant load, lotic with a small pollutant load, lentic disconnected to a river and lentic in connection to a river, well as to record the physical and chemical parameters of the water in the four environments. At the end of this study, we will look for answers to the following questions: Are there differences in the richness and density of Odonata larvae in rivers compared to lakes? Will the Guareí River show a lesser richness of species compared to the Paranapanema River because it has a higher pollutant load?

Materials and Methods

The area of study (23º27'N, 23º30'S; 48º36'E, 48º38'W) is located in the mouth of the Jurumirim Reservoir, Brazil, which was built at the junction of the Taquari River and the Paranapanema River (Figure 1). The Paranapanema River contributes approximately 550 tons of suspended matter daily to the Jurumirim Reservoir (HENRY; NOGUEIRA, 1999). The presence of macrophytes in the Paranapanema River and lateral lakes greatly reduces the input of allochthonous material conveyed to the Jurumirim Reservoir (HENRY, 2009).

One of the lakes selected for the study, Lake Coqueiral, showed elevated connectivity with the Paranapanema River, except in severe drought such as occurred in 1999, which completely isolated the lake from the river (HENRY et al., 2005). Differently from Lake Coqueiral, Lake Cavalos is isolated from the Paranapanema River and only showed a superficial connection to the river in episodes of extraordinary flood pulses such as occurred in February of 1997 and in 2004 (PANARELLI et al., 2008). In spite of being disconnected to the river, a subterranean flow was recorded at Lake Cavalos on the lateral side (river-lake and lake-river), depending on the annual variability of hydrometric levels of the Paranapanema River (CARMO, 2007).

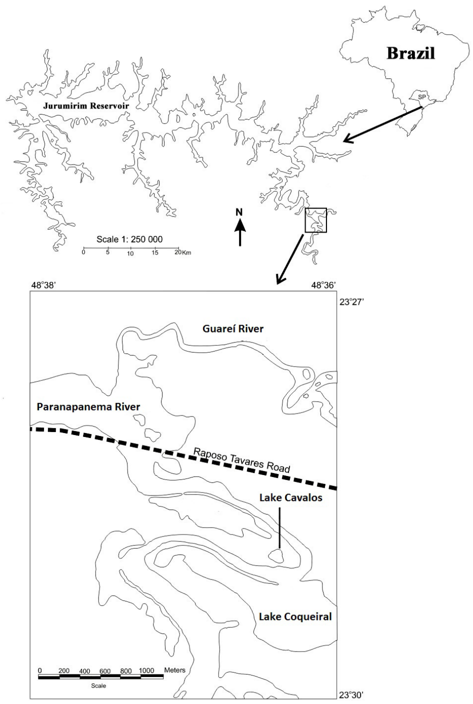
Before flowing into the Jurumirim Reservoir, the Paranapanema River receives an important contribution from the Guareí River. The headwaters of this river, 65 kilometers long, are in the city of Guareí, and pass through the county of Angatuba, receiving a large input of nutrients from agricultural activities in its drainage basin, before flowing into the Paranapanema River.

Macrophytes were sampled with a 0.25mm mesh net on a 0.07 m2 square metal frame from March 2006 to February 2007. The sampling was always performed in the morning period (8:00AM-12:00AM) and in the following sequence: Guareí River, Paranapanema River, Coqueiral Lake and Cavalos Lake. In each environment, the macrophytes were sampled nine times with mesh net. It was not possible to sample more times because macrophytes stands were smalls and the period of this work was mountly. The sampling equipment was carefully inserted below *Salvinia auriculata* Auct. in the selected area, and the plant with fauna was transferred to a plastic bag. In the laboratory, fauna was carefully removed by circular movements of the macrophyte in three buckets containing 8% and 4% formaldehyde and water, respectively. The content of each bucket was filtered through a 0.25 mm mesh net sieve. Fauna retained in the sieve was preserved in 70% alcohol. After fauna removal, the plants were dried at ambient temperature and then in an oven (60°C, 6 days) to obtain biomass (gDW.m-2). Odonata larvae were identified using an identification key (COSTA et al., 2004).

Air temperature (thermometer alcohol), water temperature (thermistor Toho Dentan - ET 3), depth (graduate thermistor cable), pH (Micronal B380), and electrical conductivity (HACH-2511) were measured at each site. The determination of suspended matter and dissolved oxygen followed the procedures described by Teixeira e Kutner (1962) and by Golterman et al. (1978), respectively. The rainfall data was obtained from the rainfall station E5-017- Department of Water and Power in Angatuba, located approximately 25 km from the study area. The raw data gathered in this study was transformed (log x + 1); normality (Shapiro-Wilk) was tested using the program Statistica version 6.0 and afterwards, a canonical correspondence analysis (CCA) was performed using the program Canoco Windows 4.5 (TER BRAAK; SMILAUER, 2002).

All specimens were deposited in the University of Estadual Paulista Júlio de Mesquita Filho.

Figure 1 - Study area: Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral



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Results and Discussion

A total of 1,302 Odonata larvae was obtained from March 2006 to February 2007: 311 from the Paranapanema River, 206 from the Guareí River, and 389 and 396 from Lakes Cavalos and Coqueiral, respectively. Calopterygidae was sampled only in the Paranapanema River. A list of all macroinvertebrates sampled and in the four environments and annual surface water temperature and pH in the four environments are shown in tables 1 and 2.

Table 1 - Taxa identified in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral

Taxa	Paranapanema	Guareí	Cavalos	Coqueiral
	Odonata			
Acanthagrion Selys, 1876	+	+	+	+
Calopterygidae	+	-	-	-
Coryphaeschna Williamson, 1903	+	+	-	+
Cyanallagma Kennedy, 1920	+	+	+	+
Erythemis Hagen, 1861	+	+	+	+
Erythrodiplax Brauer, 1868	+	+	+	+
Homeoura Kennedy, 1920	-	-	-	+
Leptagrion Selys, 1876	-	-	-	+
M. marcella Selys, 1857	-	+	+	+
Micrathyria Kirby, 1889	-	+	+	+
Neogomphus Selys, 1858	+	-	-	-
Oxyagrion Selys, 1876	+	-	+	+
***Telebasis* Selys, 1875**	+	+	+	+
	Other macroinvertebrates			
Ceratopogonidae	+	+	+	+
Chironomidae	+	+	+	+
Coleoptera	+	+	+	+
Culicidae	+	+	+	+
Ephemeroptera	+	+	+	+
Gastropoda	+	+	+	+
Hemiptera	+	+	+	+
Oligochaeta	+	+	+	+
Orthoptera	+	+	+	+
Ostracoda	+	+	+	+
Pupa de Diptera	+	+	+	+

Font: Authors (2012).

Note: Presence (+) and absence (–) of macroinvertebrates

Table 2 - Annual surface water temperature (°C) and pH in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

Sites	Surface water temperature (ºC)		pH	
	Average	Range	Average	Range
Paranapanema	21,21	17,10-24,13	7,1	6,62-7,40
Guareí	21,17	17,96-24,00	7,08	6,75-7,37
Cavalos	23,23	15,20-27,70	6,29	4,43-6,70
Coqueiral	24,15	19,13-30,80	6,35	6,05-6,75

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Average dissolved oxygen was higher in the Paranapanema River from March 2006 to February 2007, except in September 2006 and January 2007. Lake Cavalos showed low oxygenation in March, June, August, November, December of 2006 and in January 2007 (Figure 2). Lake Cavalos exhibited higher average surface water temperatures in March, May, July, August, October 2006, and February 2007; Paranapanema River averaged lower surface water temperatures in March, May to September, December 2006 and January and February 2007 (Figure 3). The average depth was higher in the Guareí and Paranapanema Rivers (Figure 4). The Guareí River showed higher average values of electrical conductivity in all study, except in January and February 2007 (Figure 5). The average hydrogenic potential (Ph) modified from 4.43 in Lake Cavalos, November 2006, to 7.40 in the Paranapanema River, August 2006 (Figure 6). The highest average of suspended matter was recorded in Paranapanema River in January of 2007 (Figure 7). The highest average biomass of *S. auriculata* was recorded in Paranapanema River, July 2006, and Lake Cavalos, March 2006 (Figure 8). A high diversity of Odonata larvae was recorded in the Guareí River in the months of March, July and September to December 2006 (Figure 9). In Lake Coqueiral, a high Odonata larva density was noted in April to June, August, September and November 2006, and February 2007 (Figure 10). Relative abundance in the four enviroments is showed in the figures 11 and 12.

Figure 2 - Average surface water dissolved oxygen (mg. L^{-1}) in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

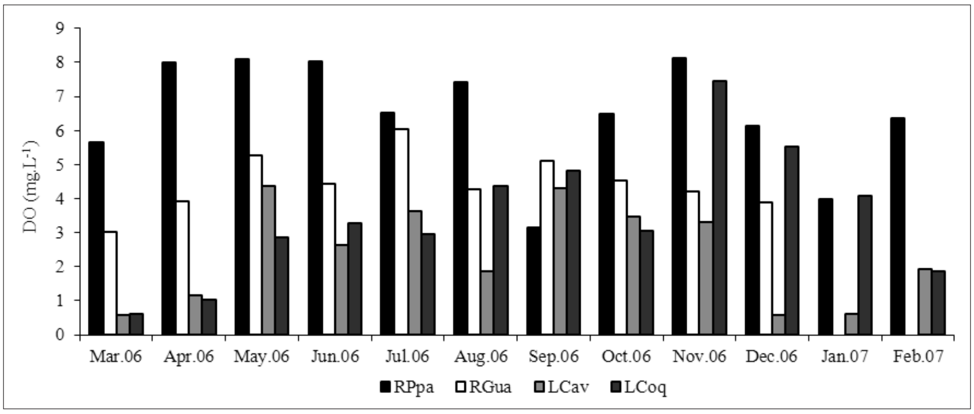

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Figure 3 - Average surface water temperature (°C) in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

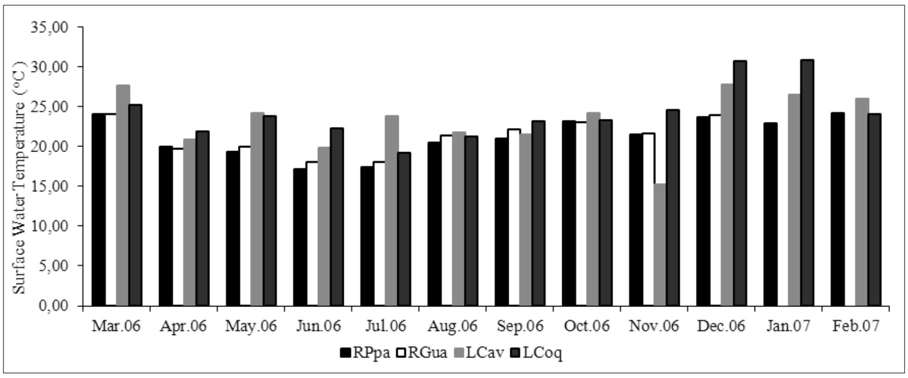

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Figure 4 - Average depth (meters) in Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

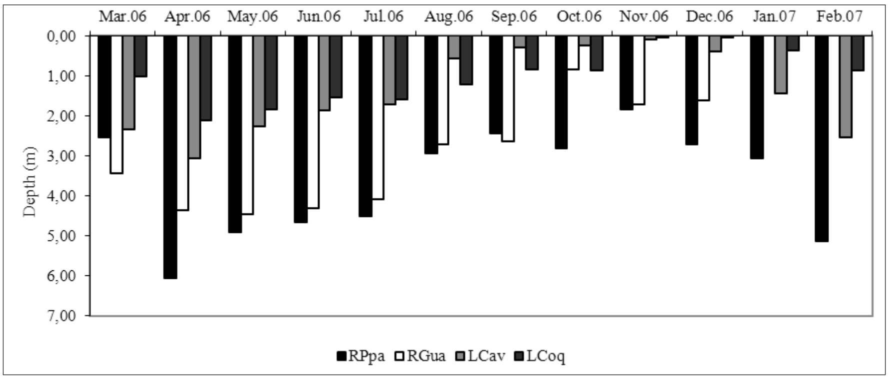

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Figure 5 - Average surface water electric conductivity in (μS.cm^{-1}) in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

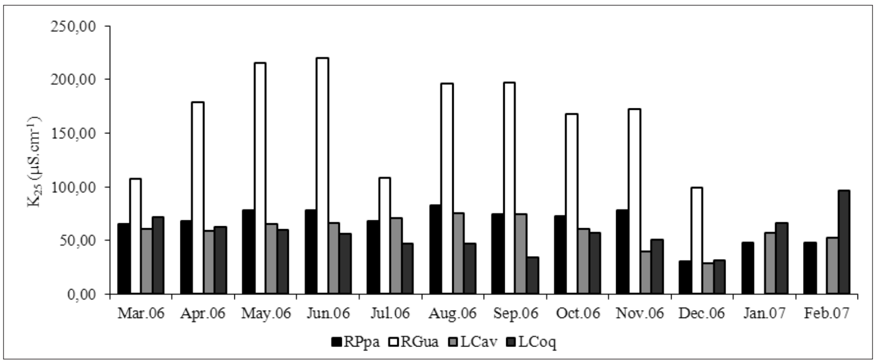

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Figure 6 - Average pH in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

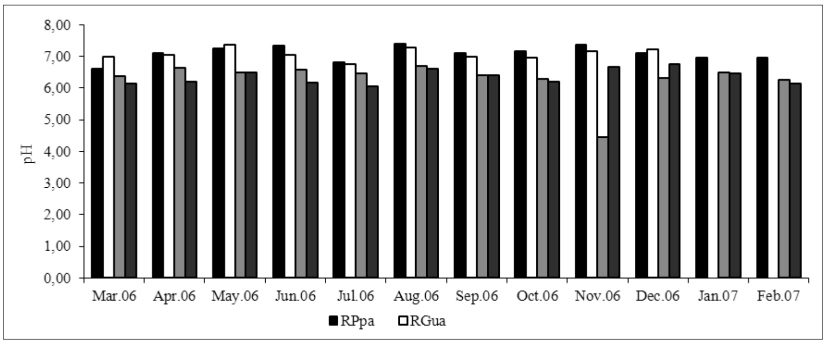

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Figure 7 - Average surface water suspended matter (mg.L^{-1}) in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

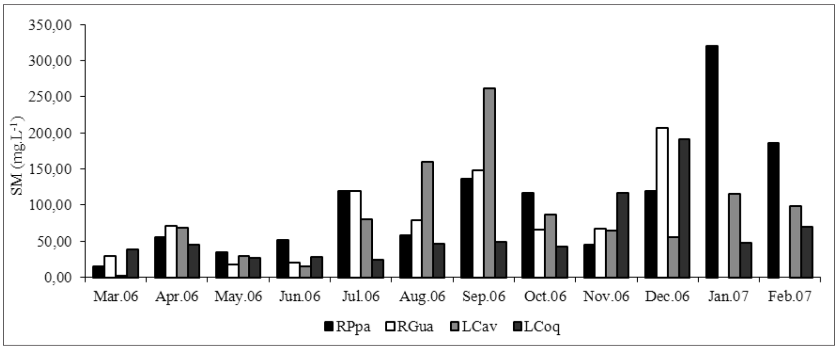

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Figure 8 - Average *S. auriculata* biomass (gDW. m^{-2}) in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

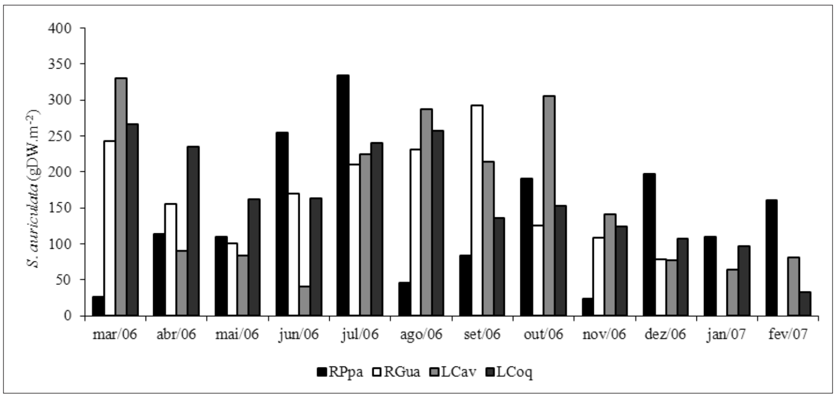

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Figure 9 - Shannon diversity índex larvae Odonata in Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

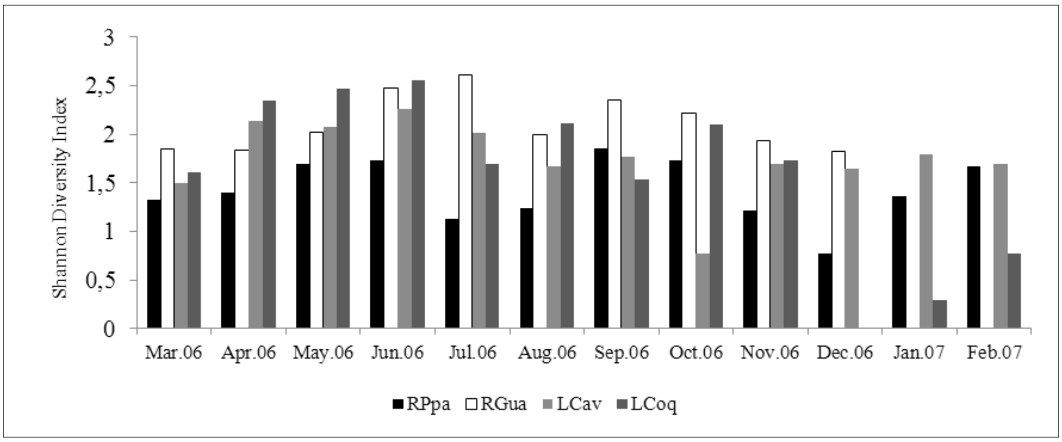

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Figure 10 - Average Odonata density (number of individuals.m-2) sampled near macrophyte in the Paranapanema River, Guareí River, Lake Cavalos and Lake Coqueiral from March 2006 to February 2007

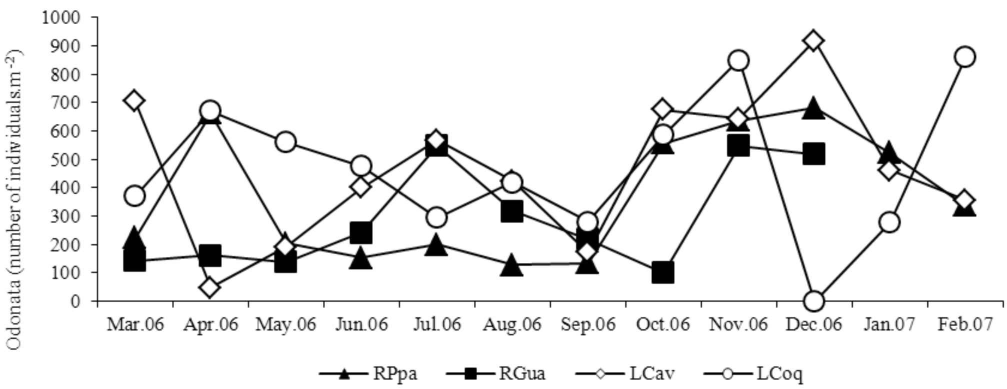

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Figure 11 - Relative abundance (%) sampled near macrophyte in the Paranapanema River and Guareí River from March 2006 to February 2007

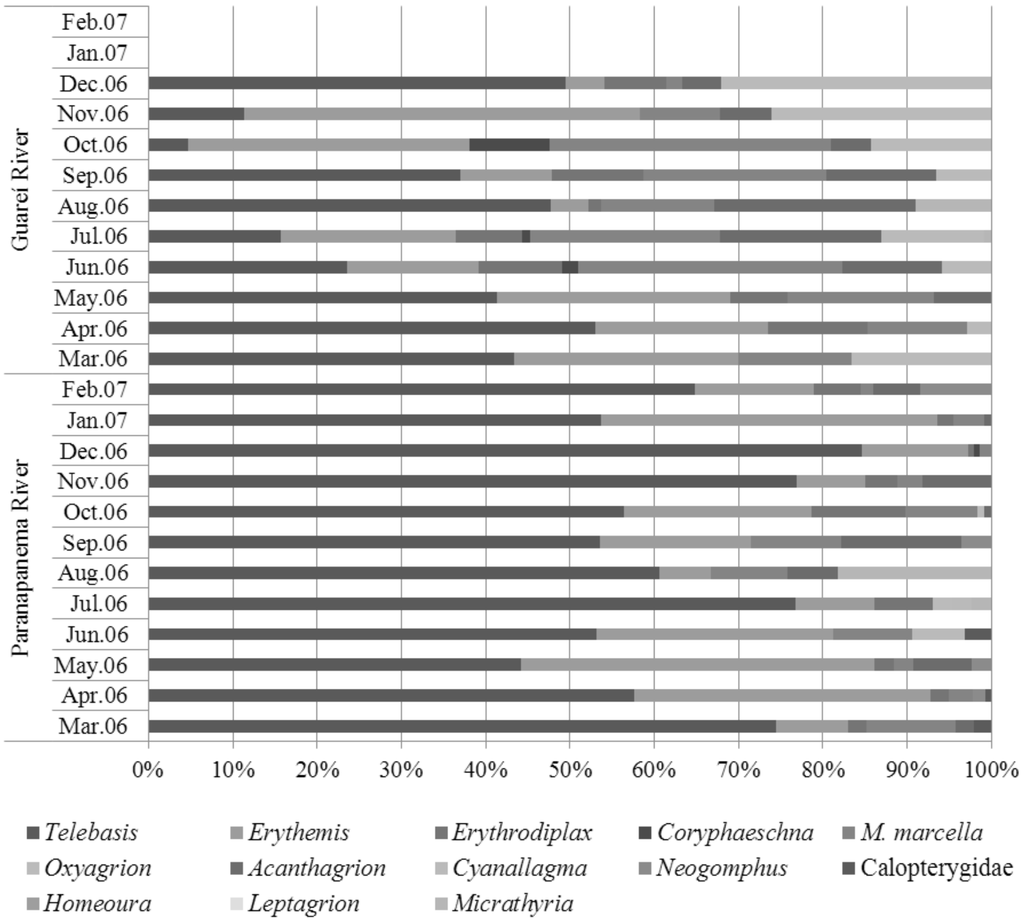

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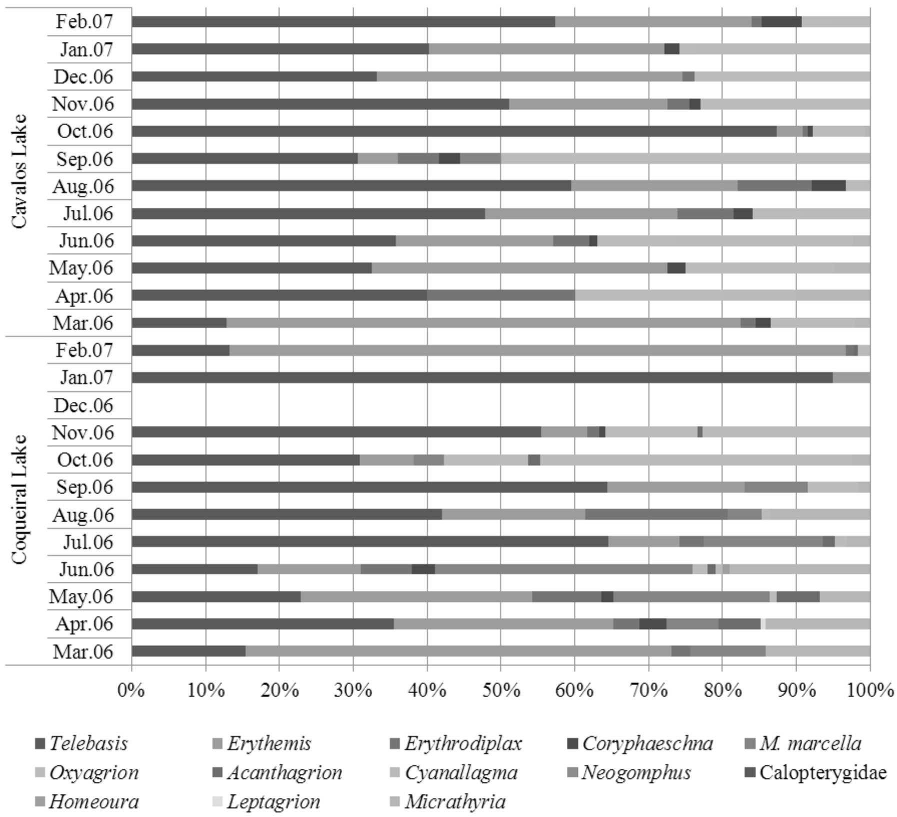
Figure 12 - Relative abundance (%) sampled near macrophyte in the Lake Cavalos and Lake Coqueiral from March 2006 to February 2007



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Two environments are easily recognizable in aquatic ecosystems: lotic and lentic ecosystems. Rivers and lakes can be distinguished by physical and chemical characteristics of the water, such as turbidity, organic matter, pH (MISHRA; YADAV, 1978), nutrients (ESSINGTON; CARPENTER, 2000) and dissolved oxygen (BRANCO; NECCHI, 1997; ODUM, 2004). In rivers, there was usually a higher oxygenation due to the turbulence that the diffusion of oxygen from air to water provides (CLOSS et al., 2004).

The results showed that dissolved oxygen concentration in the rivers were higher than in the lakes. In this study, lower dissolved oxygen concentrations in the lakes may have occurred for other reasons, such as a high density of macrophytes. In Lake Coqueiral and Lake Cavalos, more than 50% of the surfaces of the lakes were covered with *S. auriculata*. The high density of the aquatic plant reduces the oxygen in the water because of the nocturnal respiration processes (ESTEVES, 1998; LORENZI, 2000). The dissolved oxygen concentration in the water can strongly affect the composition of the Odonata larvae (CORBET, 1999).

The distinct composition species of Odonata recorded in lentic and lotic environments is related to ways of obtaining oxygen observed in the two major suborders of Odonata: Anisoptera and Zygoptera. In Anisoptera, the larva has a breathing system that consists of a specialized rectal tissue which removes oxygen from the water (CORBET, 1999). This system, according to the author, can be simple and wavy in both families of Cordulegastridae and Petaluridae, or it can be in the form of papillae, as in Gomphidae. It can also be double foliaceus, as in Aeshnidae, or double lamellar as in Cordulidae and Libellulidae (CORBET, 1999).

According to the author, in the suborder Zygoptera, breathing is accomplished by driving water through the epithelium, wich is richly irrigated by the tracheal. Under conditions of low dissolved oxygen, some species of Zygoptera as *Calopteryx splendens* (HARRIS, 1782) can compensate for the low amount of oxygen available by increasing the frequency and range of rectal motion (CORBET, 1999). Therefore, species composition can be distinguished depending on the structures responsible for obtaining oxygen and the behavior of the larvae in the different Odonata families.

The density of the Odonata larvae in lentic environments was greater than in the lotic environments during the study period, except in April and December of 2006. However, the richness of the genera throughout the study period was the same, eleven genera, only with different compositions. Calopterygidae, for example, was registered only in the Paranapanema River. In Brazil, two genera are described for Calopterygidae: *Hetaerina* Hagen, 1853, and *Mnesarete* Cowley, 1934 (COSTA et al., 2004). It is very difficult to identify these two taxa due to a lack of knowledge about their life cycles, and for this reason, identification keys for *Hetaerina* and *Mnesarete* did not allow for their distinction. Nevertheless, *Hetaerina* and *Mnesarete* show common characteristics, such as habitating in lotic environments (COSTA et al., 2004). In this study, Calopterygidae showed a clear preference for lotic environments because it was found only in the Paranapanema River. Like Calopterygidae, *Neogomphus* presents larvae with a total length of 20.1 to 23.7 mm that live buried in sandy substrate in areas with low water velocity such as ponds (COSTA et al., 2004). *Neogomphus* was recorded in the months of April, May and September of 2006, and in February, 2007. Except for September 2006, these were the months with the greatest depths and highest precipitation. Therefore, it's possible that *Neogomphus* was carried in by the current of some lateral lake.

The high level of anthropic impact in the Guareí River was evidenced by greatly elevated conductivity values registered during the entire study. Although the Guareí River displayed an obvious pollutant load, such as sewage, between June and September of 2006, it showed a greater density of Odonata larvae in comparison to the Paranapanema River. The number of genera identified in the Guareí River was slightly lower, eight, since the Paranapanema River recorded nine genera; however, the composition of the genera was distinct. *Oxyagrion, Leptagrion, Neogomphus, Homeura and* Calopterygidae, recorded in the Paranapanema River, were not found in the Guareí River. Yet, *Miathyria marcella* and *Micrathyria,* recorded in the Guareí, were not found in the Paranapanema. *M. Marcella* and *Micrathyria* are larvae of small to medium size are found in temporary lagoons and are associated with aquatic plants (COSTA et al., 2004).

In this work, rivers showed a lower surface water temperature in comparison to lakes. These results were similar to those recorded in river and lakes in India (MISHRA; YADAV, 1978) and in Brazil (GRANADO; HENRY, 2008). Lake Cavalos is a shallow lagoon with a maximum depth of 3.07 meters, and from June 2006 to January 2007, its depth was less than 2 meters; from August to December of 2006, it was less than one meter. In the first one meter depth, 50% to 60% of the radiation is effectively converted in heat (ESTEVES, 1998). Therefore, the high water temperature can be explained by the shallow depth recorded in Lake Cavalos from August to December of 2006.

Granado e Henry (2008) recorded a similar water temperature in Lake Coqueiral connected to the Paranapanema River. In eight months of the study (March, April, July, August, September, October and November of 2006, and February, 2007), temperatures of water surface in Lake Coqueiral were similar to those recorded in the Paranapanema River. The influence that the Paranapanema River exerted on Lake Coqueiral was significant when compared to the data of November 2006. In this month, the average surface water temperature in Coqueiral Lake (24.5 ºC) was very similar to the Paranapanema River (21.5 ºC) and was very distinct from Lake Cavalos (15.2 ºC), disconnected from a river.

The effects of water temperature on the density and the development of the Odonata larvae were acknowledged (CORBET, 1999; SUHLING et al., 2004). Sites with high water temperature exhibited low density and richness species (CORBET, 1999; FULAN; HENRY, 2006). In Lake Cavalos, a direct relationship between surface water temperature and density of Odonata was observed. A high water temperature was recorded at Lake Cavalos during the months of March, July, October and December of 2006. During this same time period, a high density of Odonata larvae was also recorded.

The Guareí River showed a high electrical conductivity. This result was expected due to its geological characteristics of drainage and the introduction of high loads of sewage from the water current. The electrical conductivity was very important in explaining the variance in the density of macroinvertebrates located in lakes in Italy (ROSSARO et al., 2007) and in England (PAINTER, 1999). On the other hand, some species, for example, *Macromia splendens,* showed low sensitivity to electrical conductivity (RIVERA, 2000). In this study, the high electrical conductivity recorded in Guareí River did not affect the Odonata larvae distribution.

In conclusion, the densities of the Odonata larvae in the lentic ecosystems were greater than those in the lotic; however, the richness was not altered. Nevertheless, the genera composition was distinct, showing that there is some preference for certain genera in some types of ecosystems. The Guareí River, despite receiving an important contribution of pollutants, showed richness only slightly smaller than in the Paranapanema River, but with different composition genera, indicating that some genera may be more resistant to pollutants.

Conclusion

In spite of the Odonata density being higher in the lentic ecosystems in comparison to the lotic, the richness was not altered during the period studied. Nevertheless, the genera composition was distinct, showing that some taxons show a certain preference for certain types of ecosystems like Calopterygidae and *Neogomphus*, which were shown exclusively in the Paranapanema River.

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