OPEN ACCESS

RESEARCH

Diversity and Spatiotemporal Distribution of Larval Odonate Assemblages in Temperate Neotropical Farm Ponds

Mateus Marques Pires,[1,2] Carla Bender Kotzian,[3] and Marcia Regina Spies[4]

[1]Programa de Pós-graduação em Biologia, Escola Politécnica, Universidade do Vale do Rio dos Sinos, Avenida Unisinos, 950, CEP 93022-000, São Leopoldo, Rio Grande do Sul, Brazil
[2]Corresponding author, e-mail: marquespiresm@gmail.com
[3]Departamento de Biologia e Programa de Pós-graduação em Biodiversidade Animal, Universidade Federal de Santa Maria, campus Sede, Avenida Roraima, 1000, CEP 97105-900, Santa Maria, Rio Grande do Sul, Brazil
[4]Universidade Federal do Pampa, campus São Gabriel, Avenida Antônio Trilha, 1847, CEP 97300-000, São Gabriel, Rio Grande do Sul, Brazil

ABSTRACT. Farm ponds help maintain diversity in altered landscapes. However, studies on the features that drive this type of property in the Neotropics are still lacking, especially for the insect fauna. We analyzed the spatial and temporal distribution of odonate larval assemblages in farm ponds. Odonates were sampled monthly at four farm ponds from March 2008 to February 2009 in a temperate montane region of southern Brazil. A small number of genera were frequent and accounted for most of the dominant fauna. The dominant genera composition differed among ponds. Local spatial drivers such as area, hydroperiod, and margin vegetation structure likely explain these results more than spatial predictors due to the small size of the study area. Circular analysis detected seasonal effect on assemblage abundance but not on richness. Seasonality in abundance was related to the life cycles of a few dominant genera. This result was explained by temperature and not rainfall due to the temperate climate of the region studied. The persistence of dominant genera and the sparse occurrence of many taxa over time probably led to a lack in a seasonal pattern in assemblage richness.

Key Words: dragonfly, reservoir, aquatic insect, spatial distribution, seasonality

Artificial ponds have recently been recognized as biodiversity hosts in freshwater environments (Ruggiero et al. 2008, Williams et al. 2008, Chester and Robson 2013). These systems not only fulfill their primary role in agriculture but they also serve as refuge for threatened species and maintain regional diversity in altered landscapes (Williams et al. 2008). The importance of farm ponds for benthic macroinvertebrate diversity has already been studied (Della-Bella et al. 2005, Davies et al. 2008, Ruggiero et al. 2008). However, features that improve and maintain diversity in these habitats are still poorly understood (Williams et al. 2008).

In general, macroinvertebrate assemblages in natural ponds are influenced by factors such as area, hydroperiod, and vegetation structure (Heino 2000, Oertli et al. 2002, Della-Bella et al. 2005). Environmental factors that affect freshwater assemblages are subject to changes across time and space (Spencer et al. 2002). For instance, photoperiod, and air and water temperatures (WTs) are highly seasonal in temperate areas (e.g., Corbet et al. 2006). Thus, knowing how much temporal features contribute to local environmental factors that affect macroinvertebrate assemblages is indispensable for interpreting these assemblages (Borcard et al. 1992, Hutchinson 1998).

Odonate larvae are common members of macroinvertebrate assemblages in many lentic environments such as wetlands, lakes, and ponds (Schindler et al. 2003, Niba and Samways 2006, Suhling et al. 2006). The size and age of an area, aquatic and riparian vegetation structure, and water chemistry (e.g., dissolved oxygen and nitrogen levels) are important drivers of odonate assemblages in these environments (Oertli et al. 2002, Kadoya et al. 2004, Carchini et al. 2007, Dibble and Thomaz 2009, Remsburg and Turner 2009). These factors affect both adult oviposition and larval survival rates. However, studies approaching simultaneously temporal and spatial features at natural ponds and wetlands (Ellenrieder 2000, 2009; Maltchik et al. 2010), and especially at water bodies on farms (Hamasaki et al. 2009) are lacking. Consequently, how time and space influence odonate larval assemblages is also poorly understood (McCauley 2006, Hamasaki et al. 2009).

Farm ponds are common features of the landscape throughout southern Brazil. Land in Rio Grande do Sul state (RS) has traditionally been used for cattle raising and agriculture, which requires the construction of artificial reservoirs (regionally named "açudes"). Thus, small reservoirs are widespread, especially in small properties, where they provide water supply services. Information about odonate diversity in Brazilian farm ponds and other reservoirs is restricted to few larval inventories conducted in small reservoirs (De Marco et al. 1999, Fonseca et al. 2004, Pires et al. 2013) and generally conducted in warmer climate (tropical–subtropical) regions of the country. Additionally, ecological studies concerning the spatial and temporal structure of these assemblages remains largely unknown. Thus, this study aims to analyze both the spatial and temporal drivers of odonate larval assemblages in small farm ponds, in a temperate region in the Neotropics.

Materials and Methods

Study Area. The study area is located in central RS (Fig. 1), between the plateau (~500 m in height) and the central depression (~50 m in height), in a mountainous region, the Northeastern Lower Slope (Pereira et al. 1989). This area is occupied by the middle course of the Jacuí River, which lies within a deep and narrow valley, and exhibits numerous rivers and streams with predominantly gravel beds (boulders and cobbles). Lentic environments such as marshes and lakes are absent, macrophytes are scarce, and few backwaters are found only downstream, near the lowlands of the lower course of the river (Pires et al. 2013). The middle course of the Jacuí River is dammed at its downstream end by a hydroelectric station (UHDF: Usina Hidrelétrica Dona Francisca; Dona Francisca Power Station (Agudo and Nova Palma municipalties, Rio Grande do Sul State, Brazil); Fig. 1).

Small fragments of Seasonal Deciduous Forests remain in the region, and second-growth and riparian forests are also present and distributed sparsely along rivers and on mountain slopes. The region is unfavorable for large agricultural areas, and land use consists mainly of
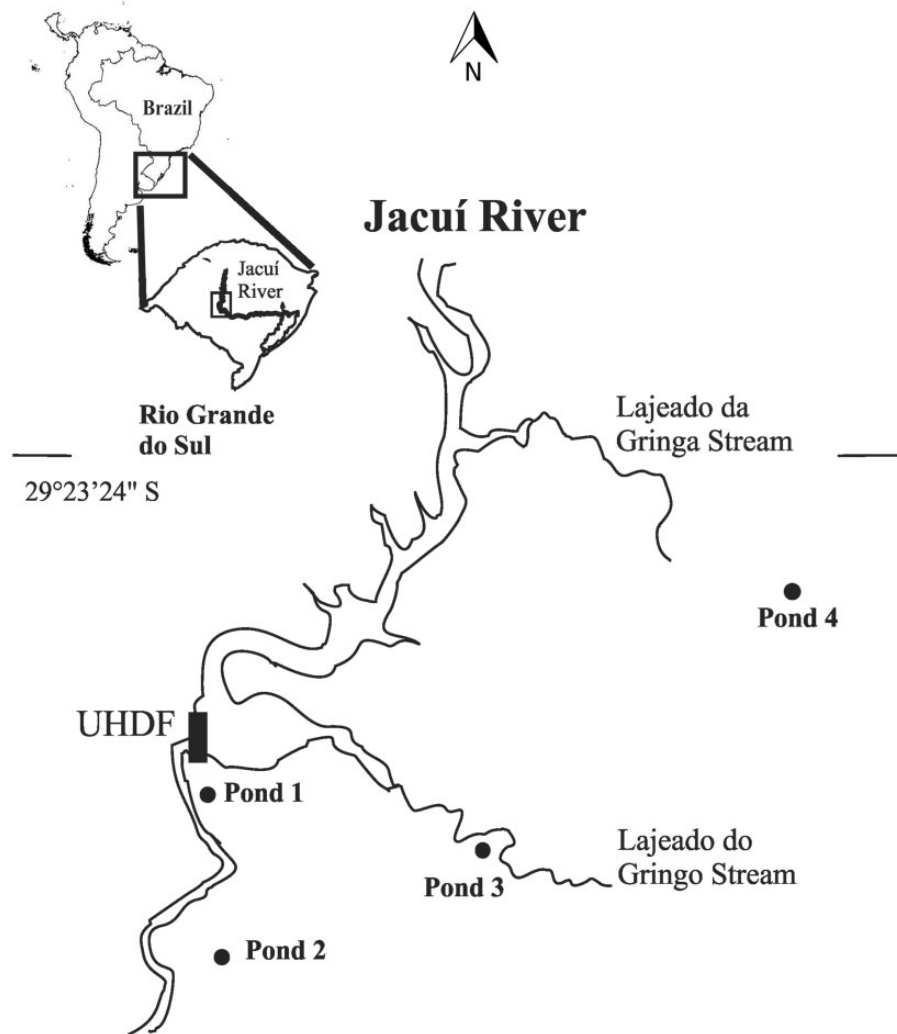
Fig. 1. Map of the area of study indicating the location of the four farm ponds studied (UHDF: Dona Francisca hydroelectric power station).

small farms used for livestock, some fruits and vegetables, and maize and tobacco crops (Marchiori et al. 1982). Thus, small reservoirs and artificial farm ponds are common and constitute the lentic freshwater environments of the area. The climate of the region is Cfa, humid subtropical, according to the Köppen classification system (Maluf 2000). The mean annual temperature ranges from 18 to 22°C (Maluf 2000), and the rainfall is distributed evenly throughout the year, with the total annual precipitation ranging from 1,500 to 1,750 mm (Pereira et al. 1989). Recently, some authors have considered the climate of the region as temperate because the mean temperature can near 13°C during the coldest period of the year (IBGE 1986, Maluf 2000).

Site Characterization and Sampling Methods. Sampling was conducted monthly at four farm ponds, from March 2008 to February 2009 (Fig. 1). These sites are described in Table 1. All ponds have a muddy bottom and are used for watering cattle, and casually, for domestic purposes (Pond 2). Except for occasional events (see Results), pond depth showed little variation during most part of the year (~1 m), because they are connected to different water supplies.

Samples were taken with hand sieves (mesh = 1 mm), with a sampling effort of 1 h by one person. The specimens collected were fixed and preserved in 70% ethyl alcohol. Larvae were identified to genus level using a specialized key (Costa et al. 2004) and the help of specialists (see Acknowledgments). Voucher specimens are deposited in the Coleção de Invertebrados, Departamento de Biologia, Universidade Federal de Santa Maria (UFSM), RS, Brazil.

Local Environmental Factors. The following abiotic factors were measured at each sampling site: WT (alcohol 0–50°C thermometer), dissolved oxygen (DO; mg/liter oxymeter), and pH (pH meter). Regional values for monthly rainfall data (Prec) and mean monthly temperature (MMT) for the study area were obtained at the Plant Science Department (Departamento de Fitotecnia), UFSM. Pond age and surface area were obtained by means of interviews with local dwellers and examination of satellite images, respectively. Percentage of marginal vegetation cover of each pond was visually determined, and structure of dominant vegetation and macrophyte richness at each pond were also measured (Table 1).

Data Analysis. A two-way analysis of variance was used to compare the abiotic factors among ponds and months. This analysis was complemented by a Tukey's test. All statistical tests followed the significance level of 5% (Zar 1999).

Rarefaction curves were constructed to compare genera richness among the farm ponds studied. Through this method, the estimated richness is compared at the largest comparable abundance level among the assemblages (Gotelli and Colwell 2001). The mean rarefaction curves were estimated based on 1,000 iterations, using the program EcoSim version 7.72 (Gotelli and Entsminger 2006).

Similarity among farm pond assemblages was calculated with a Bray–Curtis similarity index, posteriorly ordinated through nonmetric multidimensional scaling (NMDS). The quality of the representation of the ordination was measured by the stress value, usually <0.2 (Clarke and Warwick 2001). These analyses were carried out in the software PrimerE version 6.0 (Clarke and Gorley 2006).

Table 1. Location and characterization of the sampling sites of the odonate larval assemblages (MC% = % of marginal vegetation cover at each pond; MR = macrophyte richness; DV = dominant vegetation structure)

Site	Coordinates	MC%	MR	Area (m²)	Age (yr)	Origin	Hydroperiod	DV
Pond 1	29° 27′30″ S 53° 17′30″ W	—	0	50	—	Natural	Permanent	—
Pond 2	29° 29′41″ S 53° 16′54″ W	50	10	230	6	Artificial	Permanent	Floating, Emergent
Pond 3	29° 28′6″ S 53° 13′23″ W	100	1	560	10	Artificial	Permanent	Emergent
Pond 4	29° 25′27″ S 53° 09′01″ W	100	10	600	12	Artificial	Nonpermanent	Emergent

Table 2. Regional values of monthly accumulated rainfall and mean monthly air temperature (MMT) during the study period (March 2008 to February 2009) in the study area

| Season	Month	Rainfall	MMT
Summer	Mar.	106	22.9
Autumn	April	131.9	18.4
Autumn	May	131.7	15.9
Autumn	June	157.7	11.9
Winter	July	176.8	15.9
Winter	Aug.	99.8	14.3
Winter	Sept.	120.8	15.1
Spring	Oct.	255.3	19.1
Spring	Nov.	143.1	22.6
Spring	Dec.	147.9	23.7
Summer	Jan.	162.1	23.5
Summer	Feb.	131.7	22.7

Table 3. Composition, number of individuals (N) and richness (S) of larval odonate genera at each farm pond studied

Sites	Pond 1	Pond 2	Pond 3	Pond 4	Total
Coenagrionidae					
Acanthagrion Selys, 1876	312	285	52	144	793
Ischnura Charpentier, 1840	2	7	7	10	26
Oxyagrion Selys, 1876	7	159	108	47	321
Telebasis Selys, 1865	0	0	1	0	1
Lestidae					
Lestes Leach, 1815	10	12	205	409	636
Aeshnidae					
Anax Leach 1815	0	1	1	30	32
Coryphaeschna Williamson, 1903	0	14	0	4	18
Rhionaeschna Förster, 1909	3	0	11	94	108
Gomphidae					
Aphylla Selys, 1854	0	0	1	1	2
Libellulidae					
Elasmothemis Westfall, 1988	1	0	0	0	1
Erythemis Hagen, 1861	2	0	0	0	2
Erythrodiplax Brauer, 1868	37	104	218	41	400
Gynothemis Calvert in Ris, 1909	5	0	0	0	5
Micrathyria Kirby, 1889	0	15	4	3	22
Oligoclada Karsch, 1890	2	0	0	0	2
Orthemis Hagen, 1861	1	0	1	33	35
Pantala Hagen, 1861	0	0	3	11	14
Perithemis Hagen, 1861	0	0	0	4	4
Tauriphila Kirby, 1889	1	0	0	0	1
Tramea Hagen, 1861	5	0	138	8	151
N	388	597	750	839	2,574
S	13	8	13	14	20

Circular statistics (Zar 1999) was used to verify the occurrence of seasonality in abundance and richness of odonates, using the program ORIANA 3.21 (Kovach 2010). The vector length is given by the abundance and richness values recorded in each month throughout the study. The average vector *r* measures data concentration around the mean. Rayleigh's uniformity test (Zar 1999) was performed to test whether the data were distributed uniformly along the sampled months.

Results

Local Environmental Factors. No significant variation in pH and DO was detected either among ponds or among months ($P > 0.05$). WT varied among ponds ($F_{3,33} = 4.49$; $P < 0.05$; Pond 2 differed from Pond 4) but not through time ($P > 0.05$). MMT values were higher in spring and summer months, and lower in autumn and winter months (Table 2). Rainfall was similar throughout the study period (~ 100–150 mm), except for October 2008, when extreme high values were recorded (>250 mm) (Table 2). Thus, variations in pond depth were recorded for Pond 1, after a flooding event in October 2008, and for Pond 4, which completely dried in January 2009, due to higher mean temperatures.

Macrophyte richness differed among ponds (Table 1), and percentage of marginal vegetation coverage remained stable along all the study period. However, the dominant vegetation structure differed among ponds (Table 1). Emergent macrophyte species dominated Ponds 3 (*Eleocharis interstincta* [Vahl] Roem. & Schult. [Cyperaceae]) and 4 (mainly *Rhynchospora aurea* Vahl [Cyperaceae] and *Juncus densiflorus* Kunth [Juncaceae]), whereas Pond 2 had showed both floating and emergent macrophytes (mainly *Hydrochotyle* (L.) sp. [Araliaceae] and *R. aurea* Vahl [Cyperaceae], respectively). Pond 1 had no macrophytes.

Composition and Assemblages' Spatial Structure. In total, 2,574 larvae distributed among 20 genera, and five families were recorded in the four farm ponds (Table 3). *Acanthagrion* Selys, 1876 (30%), *Lestes* Leach, 1815 (24.7%), *Erythrodiplax* Brauer, 1868 (15.5%), and *Oxyagrion* Selys, 1876 (12.4%) were the dominant genera. Eight genera were rare and represented by no more than five individuals (Table 3). *Acanthagrion* was the dominant genera at Pond 1, *Acanthagrion* and *Oxyagrion* dominated Pond 2, and *Erythrodiplax* and *Lestes* predominated in Pond 3, whereas *Lestes* and *Acanthagrion* dominated Pond 4 (Table 3).

Richness and abundance varied among farm ponds. Richness was similar among Ponds 1, 3, and 4 (Table 3). Pond 2 had the lowest richness (8). Abundance in Pond 4 was more than twice the abundance of Pond 1 (Table 3). The estimated richness comparing the four ponds, for a sample of 389 individuals, confirmed the highest and similar richness of Ponds 4, 3, and 1, which was evidenced by the overlapping of their confidence intervals (Fig. 2). Pond 2 had the lowest estimated richness (7.63). The NMDS diagram showed that pond samples were spatially structured in two groups, which were formed by the segregation of samples of Ponds 3 and 4 from samples of Ponds 1 and 2 (stress value 2D = 0.14) (Fig. 3).

Temporal Structure. Richness data did not appear to be strongly concentrated around the mean (low Z values), except for Pond 4 ($P > 0.05$; Fig. 4; Table 4). On the other hand, abundance distribution was significantly seasonal (high Z values; $P < 0.01$), and peaks of abundance occurred in spring months at all farm ponds (Fig. 5; Table 4).
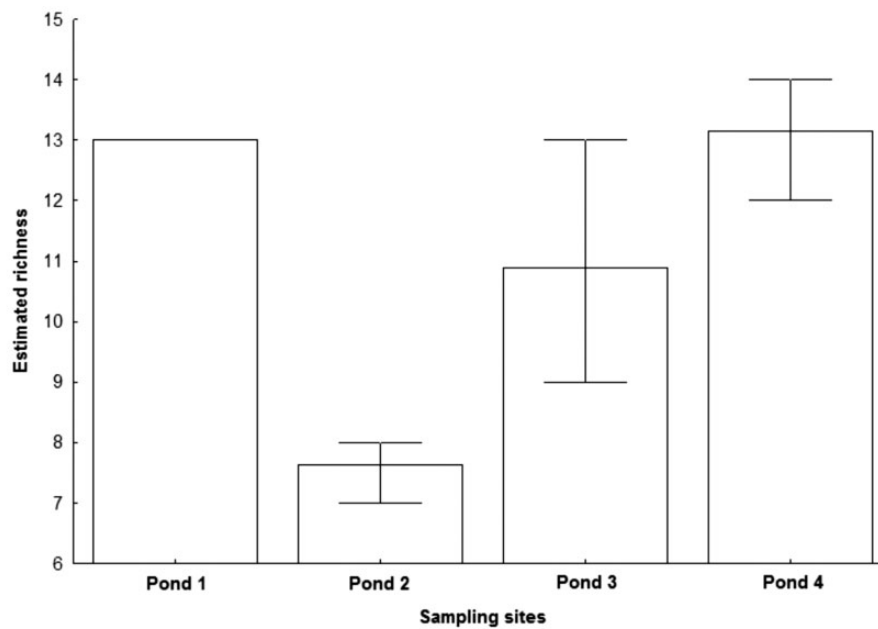
Fig. 2. Comparison of the estimated richness of odonate larval assemblages among the sampled farm ponds for a subsample of 388 randomly drawn specimens. Error bars indicate standard errors.
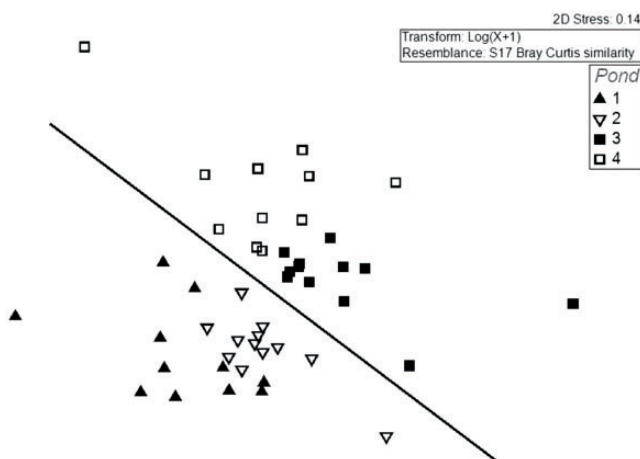
Fig. 3. NMDS Ordination Diagram of the samples of larval odonate assemblages in the farm ponds throughout the study period.

Discussion

Composition and Assemblages' Spatial Structure. In general, the dominant genera were coenagrionids, libellulids (*Acanthagrion* and *Oxyagrion*, and *Erythrodiplax*, respectively), and lestids (*Lestes*). The dominance of these families in farm ponds was expected because both groups have been documented in artificial and lentic water bodies from tropical areas of the Neotropics (De Marco et al. 1999, Fonseca et al. 2004). The overall richness recorded in the study area was lower than that of some natural lentic systems of tropical South America (Ferreira-Perquetti and Gessner 2003, Juen et al. 2007) but also higher than others (De Marco and Latini 1998, De Marco et al. 1999, Franco and Takeda 2002, Fonseca et al. 2004). Also, about 50% of the genera found in this study have already been recorded in natural lentic systems of southern Brazil (Maltchik et al. 2010). Thus, artificial ponds show significant potential for hosting a large portion of odonate biodiversity.

Differences among local environmental factors of the ponds studied accounted for most of the results concerning the composition of dominant genera and the spatial distribution and structure of the assemblages. Additionally, the overall dominance of zygopteran genera (Coenagrionidae and Lestidae) was related to the dominant vegetation structure in each farm pond. Although Pond 2 had higher macrophyte richness, Ponds 3 and 4 were fully covered by marginal vegetation and were dominated by more complex macrophyte species (emergent; according to classification of macrophyte types [Cronk and Fennessey 2001]; Table 1). Vegetation diversity and density can favor both the endophytical oviposition by adult zygopterans and the climbing habit of their larvae (Carvalho and Nessimian 1998, De Marco et al. 1999, Gibbons et al. 2002, Kadoya et al. 2004). The fully marginal vegetation cover of the shoreline in Pond 3 accounted for the dominance of *Erythrodiplax* and *Lestes* larvae because they are well adapted to vegetated substrates (Carvalho and Nessimian 1998, De Marco et al. 1999, Maltchik et al. 2010).

The dominance of *Acanthagrion* at Ponds 1 and 2 determined the high similarity between the assemblages of these sites. *Acanthagrion* larvae are known to be successful in many freshwater environments, including natural and artificial lentic ones (De Marco et al. 1999, Maltchik et al. 2010). Pond 2 also had the lowest odonate richness, even though the macrophyte richness was high. The low area, the less complex vegetation structure, and scarce marginal vegetation at this site negatively influenced the assemblage diversity. Furthermore, Pond 2 differed from other ponds in local abiotic factors. For instance, Pond 2 is the site most affected by anthropogenic disturbance because it is used for domestic sewage, grazing, and pasture, which could lead to artificial eutrophication. All these features likely contributed to the lower odonate larvae richness recorded. Lower odonate richness has also been reported in highland areas subject to anthropogenic pollution (Carchini et al. 2007).

The higher estimated richness and higher abundance values of the odonate assemblages of Ponds 3 and 4 were responsible for the higher similarity between these assemblages. This result is probably related to pond size and vegetation structure. Ponds 3 and 4 had larger surface areas, fully covered shorelines, and emergent dominant vegetation. Larger areas tend to have higher habitat diversity in permanent environments than smaller ones (Oertli et al. 2002, Williams et al. 2008). Additionally, the vegetation structure of each of these sites is probably
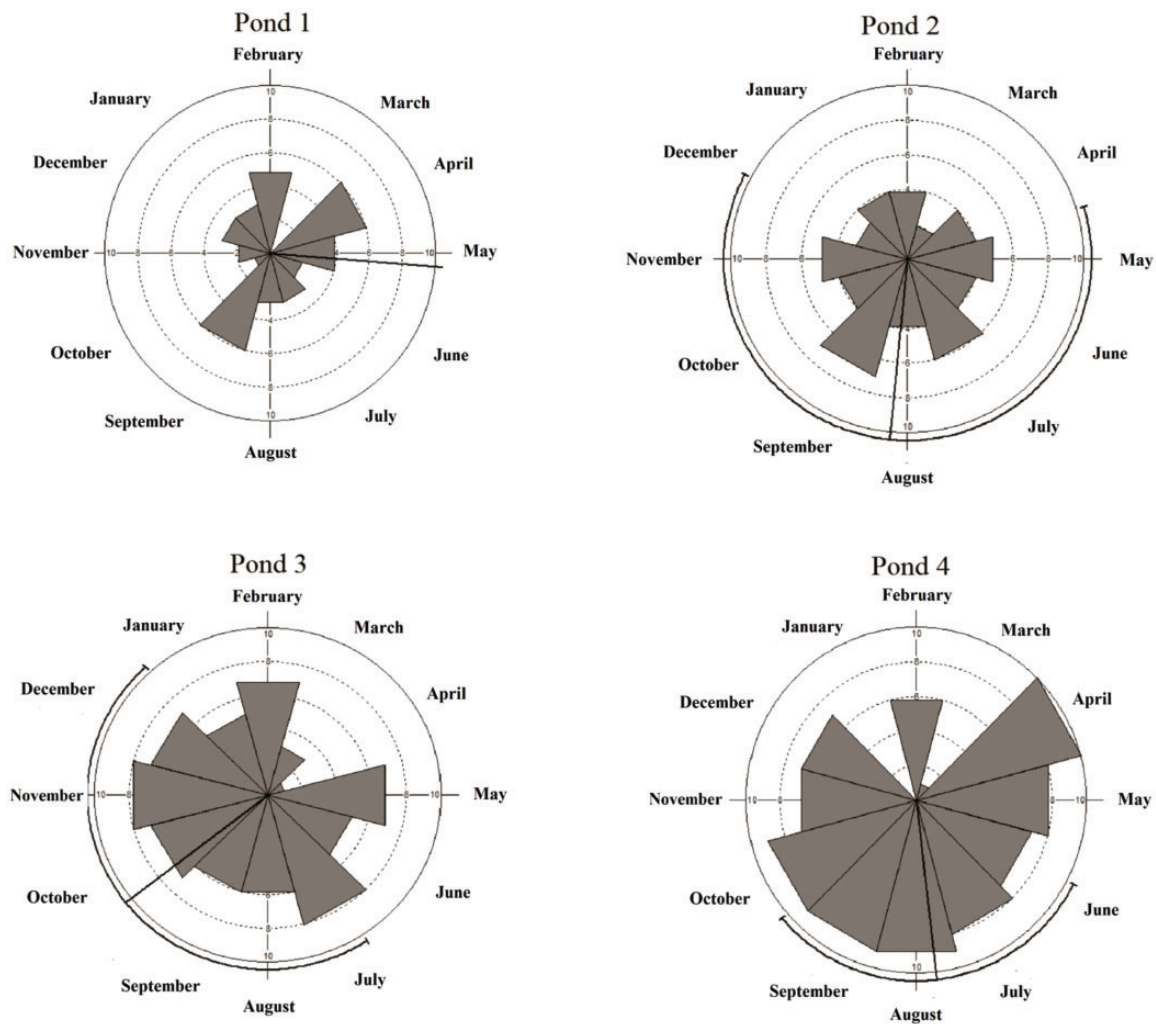
Fig. 4. Temporal distribution of odonate larval assemblage richness in the farm ponds studied.

Table 4. Circular Analysis of the abundance (A) and richness (R) of odonate larval assemblages in farm ponds studied.

Site	Pond 1		Pond 2		Pond 3		Pond 4	
	A	R	A	R	A	R	A	R
Mean vector angle (μ)	302.95°	139.55°	233.85°	230.51°	244.46°	276.99°	248.70°	218.49°
Mean vector length (r)	0.27	0.06	0.18	0.12	0.28	0.14	0.52	0.2
Circular SD*	92.71°	133.66°	105.13°	116.12°	91.17°	112.51°	64.74°	101.91°
Rayleigh's test (Z)	28.29	0.16	20.55	0.85	59.62	1.14	233.75	3.42
Rayleigh's test (P)	<0.01	0.85	<0.01	0.42	<0.01	0.22	<0.01	0.03

*Circular SD: circular standard deviation.

related to pond age. Older ponds tend to have more developed marginal vegetation, which influences odonate communities (Kadoya et al. 2004). Thus, the effects of vegetation on the fauna may be linked to pond age too. On the other hand, the environmental heterogeneity yielded by more complex vegetation structure influences food availability and provides odonate larvae with protection against predators, which leads to assemblages with higher richness and abundance (Oertli et al. 2002, Ruggiero et al. 2008, Dibble and Thomaz 2009, Remsburg and Turner 2009). The dominance of *Lestes* in Pond 4 may be related to the pond's nonpermanent hydroperiod. Previous studies (Ellenrieder 2000, Schindler et al. 2003) observed *Lestes* larvae living in intermittent settings because its eggs are resistant to drought (Corbet 1980).

It is important to discuss the differences between Pond 1 and the other ponds, because it is the only natural water body in the study.

Pond 1 is the only site without marginal vegetation cover and has the smallest size. Its odonate assemblage is more similar to that of Farm Pond 2 (NMDS, Fig. 4), but its estimated richness is higher. The higher richness is probably due to its permanent contact with the large and main course of the Jacuí River, which provides its permanent hydroperiod and prevents strong variations in abiotic factors and casual colonization events (Juen et al. 2007). In fact, the dominant genus in this site (*Acanthagrion*) is successful in both lentic and lotic water bodies. Thus, although the absence of macrophyte hinders the occurrence of higher richness, such as those of Ponds 3 and 4, the connectivity and cleaner waters of Pond 1 constitute important environmental features for maintaining diversity of odonate assemblages in farm ponds.

Temporal Distribution. The temporal structure of the assemblages studied showed no seasonal peak in richness. Few genera predominated
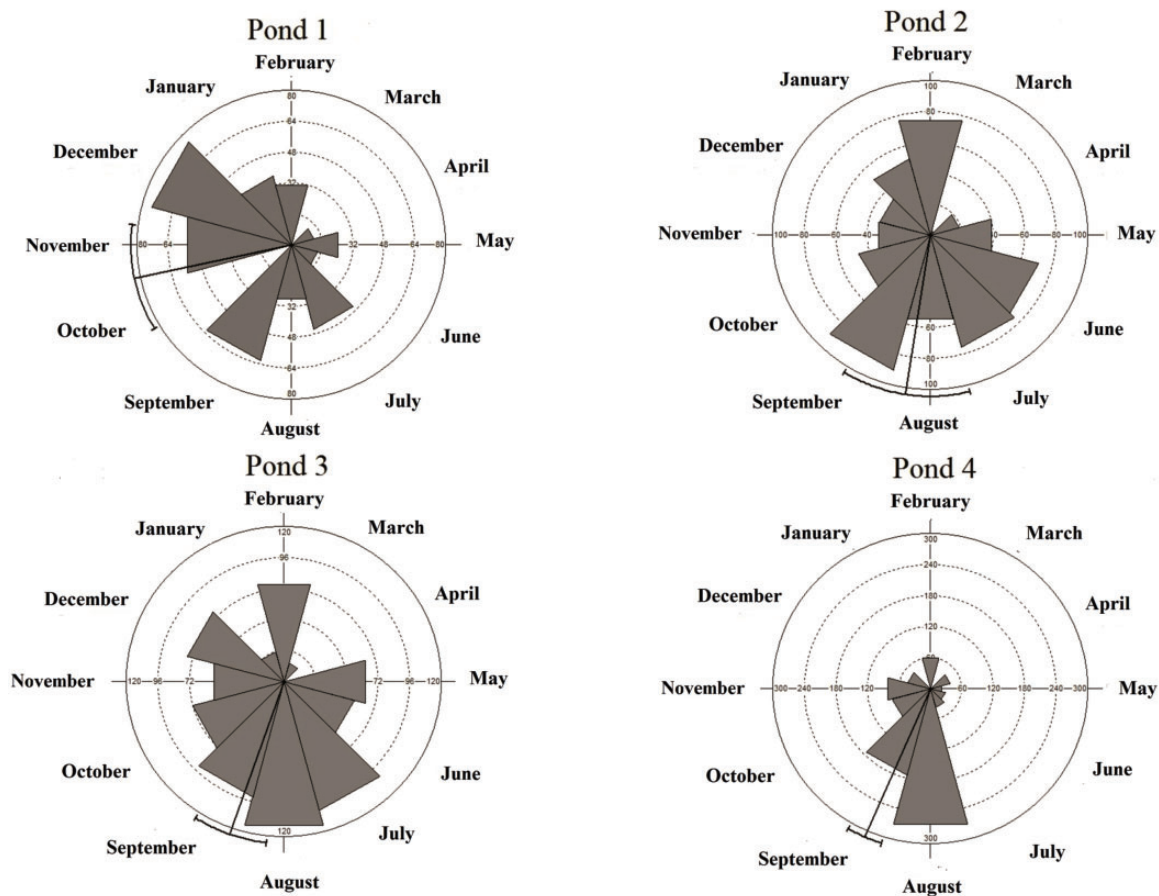
Fig. 5. Temporal distribution of odonate larval assemblage abundance in the farm ponds studied.

in each pond throughout the study period (Table 4), and most of the assemblages were composed of accidental and low frequent genera. For instance, *Acanthagrion*, *Erythrodiplax*, *Lestes,* and *Oxyagrion* were collected almost every month of the study period. Pond permanence and water level fluctuation are likely related to these results, because there tends to be less drastic changes in the community richness of permanent sites, which stabilizes their composition (Shurin 2007). One pond (Pond 4) had a nonpermanent hydroperiod, and its importance in driving odonate assemblages is discussed below. Water level in Pond 1 is highly influenced by the water level of the Jacuí River, which frequently oscillates due to the functioning of the UHDF (<2 km upstream). Variability of water permanence in lentic habitats has been shown to affect odonate richness in ponds and wetlands in other areas (Ellenrieder 2000, Della-Bella et al. 2005, Whiles and Goldowitz 2005).

On the other hand, there were seasonal peaks in the odonate assemblages in each pond, and these peaks were concentrated in the spring months. This seasonal pattern is probably related to the life cycle of the dominant genera cited above. Larval abundance peaks during the spring have been recorded in subtropical region ponds (Shieh and Chi 2010). This pattern contrasts with odonate assemblage seasonality in tropical areas (de Marmels 1998, Delgado 2002, Franco and Takeda 2002, Fulan and Henry 2007), which is related to rainfall cycles. In RS, rainfall has historically been distributed regularly throughout the year due to the humid temperate climate of the region (IBGE 1986, Maluf 2000) and therefore does not influence odonate assemblages. Most temperate odonate species tend to have only one generation per year, which differs from tropical species and reveals a latitudinal gradient in voltinism (Corbet 1980, 1999; Corbet et al. 2006). Therefore, the pattern here observed reflects the role of temperature in influencing the

seasonal regulation of life cycles of odonates from temperate Neotropical regions.

The slight displacement of the abundance vector from Pond 1 in November is related to the absence of larvae in October 2008. There was an intense environmental disturbance during this month, particularly in Pond 1. Intense and sudden flood pulses caused by heavy rain affected the Jacuí River and the backwater forming Pond 1 a few days before sampling. Some studies have already shown the negative role that these environmental events cause on diversity and the structuring of benthic macroinvertebrate freshwater assemblages (Flecker and Feifarek 1994, Ward 1998). The absence of specimens in Pond 4 during the summer months (March 2008 and January 2009) is explained by the complete drought that occurred at the site.

Final Remarks. Small farm ponds can sustain a diverse odonate larval assemblage if they possess specific environmental conditions. As in natural areas, factors such as area, hydroperiod, and vegetation structure drive the spatial distribution and structure of the assemblages, and the dominance of certain genera. Some human activities can also play an important role and concur to avoid the occurrence of richer assemblages, even in vegetated ponds. Seasons also play an important role because temperature and precipitation can modulate important drivers, such as hydroperiod, which affect seasonal patterns in assemblages. However, extreme oscillations in hydroperiod may affect odonate assemblage structure, suggesting that climatic changes altering rainfall distribution in southern Brazil (Junk 2013) could have negative influence on ponds' odonate diversity of the region.

Schmidt Dalzochio Unisinos (Universidade do Vale do Rio dos Sinos); for their aid in larvae identification and to MSc. Elzira Cecília Serafini Floss and biologist Edson Pinheiro Bachinski in field sampling.

References Cited

Borcard, D., P. Legendre, and P. Dapreau. 1992. Partialling out the spatial component of ecological variation. Ecology 73: 1045–1055.

Carchini, G., V. D. Bella, A. G. Solimini, and M. Bazzanti. 2007. Relationships between the presence of odonate species and environmental characteristics in lowland ponds of central Italy. Annales de Limnologie – International Journal of Limnology 43: 81–87.

Carvalho, A. L., and J. L. Nessimian. 1998. Odonata do estado do Rio de Janeiro, Brasil: hábitats e hábitos das larvas, pp. 3–28. In J. L. Nessimian and A. L. Carvalho (eds.), Ecologia de Insetos Aquáticos. Series Oecologia Brasiliensis, vol. V. PPGE–UFRJ, Rio de Janeiro, Brazil.

Chester, E. T., and B. J. Robson. 2013. Anthropogenic refuges for freshwater biodiversity: their ecological characteristics and management. Biol. Conserv. 166: 64–75.

Clarke, K. R., and R. N. Gorley. 2006. User manual/tutorial. PRIMER-E, Plymouth, United Kingdom.

Clarke, K. R., and R. M. Warwick. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd ed. PRIMER-E Ltd, Plymouth Marine Laboratory, Plymouth, United Kingdom.

Corbet, P. S. 1980. Biology of Odonata. Annu. Rev. Entomol. 25: 189–217.

Corbet, P. S. 1999. Behaviour and ecology of Odonata, Comstock Pub Association, Great Horkesley, United Kingdom.

Corbet, P. S., F. Suhling, and D. Soendgerath. 2006. Voltinism of Odonata: a review. Intl. J. Odonatol. 9: 1–44.

Costa, J. M., L. O. I. Souza, and B. B. Oldrini. 2004. Chave para as famílias e gêneros das larvas de Odonata citadas para o Brasil: comentários e registros bibliográficos. Publicações Avulsas do Museu Nacional 99: 1–43.

Cronk, J. C., and M. S. Fennessey. 2001. Wetland plants: biology and ecology. Lewis Publishers, New York, NY.

Davies, B., J. Biggs, P. Williams, M. Whitfield, P. Nicolet, D. Sear, S. Bray, and S. Maund. 2008. Comparative biodiversity of aquatic habitats in the European agricultural landscape. Agric. Ecosyst. Environ. 125: 1–8.

De Marco, P., Jr., and A. O. Latini. 1998. Estrutura de guildas e riqueza de espécies em uma comunidade de larvas de Anisoptera (Odonata), pp. 101–112. In J. L. Nessimian and A. L. Carvalho (eds.), Ecologia de Insetos Aquáticos. Series Oecologia Brasiliensis, vol. V. PPGE–UFRJ, Rio de Janeiro, Brazil.

De Marco, P., Jr., A. O. Latini, and A. P. Reis. 1999. Environmental determination of dragonfly assemblage in aquaculture ponds. Aquaculture Res. 30: 357–364.

de Marmels, J. C. 1998. A five year survey of an odonate community inhabiting a North Venezuelan mountain stream. Odonatologica 27: 189–199.

Delgado, C. 2002. Spatial and temporal distribution patterns of Odonata larvae in the streams of a terra firma forest of the Central Amazon, Brazil. J. Freshw. Ecol. 17: 555–561.

Della-Bella, V., M. Bazzanti, and F. Chiarotti. 2005. Macroinvertebrate diversity and conservation status of Mediterranean ponds in Italy: water permanence and mesohabitat influence. Aquat. Conserv. Mar. Freshw. Ecosyst. 15: 583–600.

Dibble, E. D., and S. M. Thomaz. 2009. Use of fractal dimension to assess habitat complexity and its influence on dominant invertebrates inhabiting tropical and temperate macrophytes. J. Freshw. Ecol. 24: 93–102.

Ellenrieder, N. V. 2000. Species composition and temporal variation of odonate assemblages in the subtropical-pampasic ecotone, Buenos Aires, Argentina. Odonatologica 29: 17–30.

Ellenrieder, N. V. 2009. Odonata of Argentinian Yungas cloud forest: distribution patterns and conservation status. Odonatologica 38: 39–53.

Ferreira-Perquetti, O. S., and A.A.F. Gessner. 2003. Comunidade de Odonata (Insecta) em áreas naturais do cerrado e monocultura no nordeste do estado de São Paulo, Brasil: relação entre o uso do solo e a riqueza faunística. Rev. Bras. Zool. 20: 219–224.

Flecker, D. S., B. Feifarek. 1994. Disturbance and the temporal variability of invertebrate assemblages in two Andean streams. Freshw. Biol. 31: 131–132.

Fonseca, A. R., N. M. Sanches, M. C. Fonseca, D. M. Quintilhiano, and E. S. Silva. 2004. Levantamento de espécies de Odonata associadas à tanques de piscicultura e efeito de Bacillus thuringiensis var. israelensis sobre ninfas de Pantala flavescens (Fabricius, 1798) (Odonata: Libellulidae). Acta Sci. Biol. Sci. 26: 25–29.

Franco, G. M. S., and A. M. Takeda. 2002. Spatial and temporal variation of Odonata larvae associated with macrophytes in two floodplain lakes from the upper Paraná River, Brazil. Acta Sci. Biol. Sci. 24: 345–351.

Fulan, J. A., and R. Henry. 2007. Variação anual da biomassa de Telebasis (Odonata: Coenagrionidae), junto à Eichhornia azurea (SW.) Kunth na Lagoa do Camargo (lateral ao rio Paranapanema, São Paulo). Estudos de Biologia 30: 117–23.

Gibbons, L. K., J. M. Reed, and F. S. Chew. 2002. Habitat requirements and local persistence of three damselfly species (Odonata: Coenagrionidae). J. Insect Conserv. 6: 47–55.

Gotelli, N. J., and R. K. Colwell. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4: 379–391.

Gotelli, N. J. and G. L. Entsminger. 2006. EcoSim: null models software for ecology, version 7. Acquired Intelligence Inc. & Kesey-Bear. (http://home pages.together.net/~gentsmin/ecosim.htm) (accessed 29 June 2010).

Hamasaki, K., T. Yamanaka, K. Tanaka, Y. Nakatani, N. Iwasaki, and D. S. Sprague 2009. Relative importance of within-habitat environment, land use and spatial autocorrelations for determining odonate assemblages in rural reservoir ponds in Japan. Ecol. Res. 24: 597–605.

Heino, J. 2000. Lentic macroinvertebrate assemblage structure along gradients in spatial heterogeneity, habitat size and water chemistry. Hydrobiologia 418: 229–242.

Hutchinson, J. J., K. Chung, and B. Wallace. 1998. Temporal variability of stream macroinvertebrate abundance and biomass following pesticide disturbance. J. North Am. Benthol. Soc. 17: 518–534.

IBGE. 1986. RADAMBRASIL, Levantamento de Recursos Naturais. IBGE, Rio de Janeiro, Brazil.

Juen, L., H. S. R. Cabette, P. De Marco, Jr. 2007. Odonate assemblage structure in relation to basin and aquatic habitat structure in Pantanal wetlands. Hydrobiologia 579: 125–134.

Junk, W. 2013. Current state of knowledge regarding South America wetlands and their future under global climate change. Aquat. Sci. 75: 113–131.

Kadoya, T., S. Suda, and I. Washitani. 2004. Dragonfly species richness on man-made ponds: effects of pond size and pond age on newly established assemblages. Ecol. Res. 19: 461–467.

Kovach, W. 2010. Oriana 3.21. Kovach Computing Services, Anglesey, Wales.

Maltchik, L., C. Stenert, C. B. Kotzian, and M. M. Pires. 2010. Responses of odonate communities to environmental factors in southern Brazil wetlands. J. Kans. Entomol. Soc. 83: 208–220.

Maluf, J. R. T. 2000. Nova classificação climática do estado do Rio Grande do Sul. Rev. Bras. Agrometeorol. 8: 141–150.

Marchiori, J. N. C., S. J. Longhi, and M. A. Durlo. 1982. A vegetação de capoeira na região do curso médio do rio Jacuí, RS. Ciência e Natura 4: 141–150.

McCauley, S. J. 2006. The effects of dispersal and recruitment limitation on community structure of odonates in artificial ponds. Ecography 29: 585–595.

Niba, A. S., and M. J. Samways. 2006. Remarkable elevational tolerance in an African Odonata larval assemblage. Odonatologica 35: 265–280.

Oertli, B., D. A. Joye, E. Castella, R. Juge, D. Cambin, and J. B. Lachavanne. 2002. Does size matter? The relationship between pond area and biodiversity. Biol. Conserv. 104: 59–70.

Pereira, P. R. B., L. R. G. Netto, C. J. A. Borin, and M. G. B. Sartori. 1989. Contribuição à geografia física do município de Santa Maria: unidades de paisagem. Geografia: Ensino e Pesquisa 3: 37–68.

Pires, M. M., C. B. Kotzian, M. R. Spies, and D. B. Neri. 2013. Diversity of Odonata (Insecta) larvae in streams and farm ponds of a montane region in southern Brazil. Biota Neotrop. 13: 259–267.

Remsburg, A. J., and M. G. Turner. 2009. Aquatic and terrestrial drivers of dragonfly (Odonata) assemblages within and among north-temperate lakes. J. North Am. Benthol. Soc. 28: 44–56.

Ruggiero, A., R. Céréghino, J. Figuerola, P. Marty, and S. Angélibert. 2008. Farm ponds make a contribution to the biodiversity of aquatic insects in a French agricultural landscape. Comptes Rendus Biologie 331: 298–308.

Schindler, M., C. Fesl, and A. Chovanec. 2003. Dragonfly associations (Insecta: Odonata) in relation to habitat variables: a multivariate approach. Hydrobiologia 497: 169–180.

Shieh, S. H., and Y. S. Chi. 2010. Factors influencing macroinvertebrate assemblages in artificial subtropical ponds of Taiwan. Hydrobiologia 649: 317–330.

Shurin, J. B. 2007. How is diversity related to species turnover through time? Oikos 116: 956–967.

Spencer, M., S. Schawartz, and L. Blaustein. 2002. Are there fine-scale spatial patterns in community similarity among temporary freshwater pools? Glob. Ecol. Biogeogr. 11: 71–78.

Suhling, F., G. Sahlén, A. Martens, E. Marais, and C. Schütte. 2006. Dragonfly assemblages in arid tropical environments: a case study from western Namibia. Biodivers. Conserv. 15: 311–332.

Ward, J. V. 1998. Riverine landscapes: biodiversity patterns, disturbance regimes, and aquatic conservation. Biol. Conserv. 83: 269–278.

Whiles, M. R., and B. S. Goldowitz. 2005. Macroinvertebrate communities in Central Platte river wetlands: patterns across a hydrologic gradient. Wetlands 25: 462–472.

Williams, P., M. Whitfield, and J. Biggs. 2008. How can we make new ponds biodiverse? A case study monitored over 7 years. Hydrobiologia 597: 137–148.

Zar, J. H. 1999. Biostatistical analysis, 4th ed., 663 pp. Prentice-Hall, Inc., New Jersey, USA.