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article

Diversity and distribution of riffle beetle assemblages (Coleoptera, Elmidae) in montane rivers of Southern Brazil

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Abstract: The diversity and spatio-temporal distribution of Elmidae (Coleoptera) assemblages in montane rivers and streams of southernmost Brazil (Rio Grande do Sul state) were studied. Six genera were found, represented mostly by larval specimens. *Austrolimnius* and *Macrelmis* are new occurrences in the region. Assemblages' genera composition and dominance were related to the presence of the macrophyte *Podostemum*. Also, water temperature and stream depth and velocity were the most important drivers related to the assemblages' distribution. Richness and abundance were positively related to high water velocity and negatively to stream depth. Temporal patterns were detected especially in assemblage abundance, yet a slight pattern in richness was also observed. The seasonal structure was related to warm temperatures, but temporal distribution of Elmidae assemblages appears to be related to the dominant genera life cycles. The studied area shows an overall Elmidae richness similar to that found in some tropical areas and the role of mountainous environments in sustaining high rates of regional diversity in the Neotropics is stated.
Keywords: *aquatic insects, streams, Neotropical region.*

BRAUN, B.M., SALVARREY, A.V.B., KOTZIAN, C.B., SPIES, M.R., PIRES, M.M. **Diversidade e distribuição de comunidades de Elmidae (Coleoptera) em rios montanhosos do sul do Brasil.** Biota Neotropica. 14(2): e20130001. http://dx.doi.org/10.1590/1676-060320140615183046

Resumo: A diversidade e a distribuição espaço-temporal de comunidades de Elmidae (Coleoptera) em rios e riachos de uma área montanhosa no sul do Brasil (estado do Rio Grande do Sul) foram estudadas. Sete gêneros foram encontrados, representados principalmente pelo estágio larval. *Austrolimnius* e *Macrelmis* são novas ocorrências no estado. A composição e a dominância dos gêneros estiveram relacionadas com a presença da macrófita *Podostemum*. Além disso, a temperatura da água, a velocidade da corrente e a profundidade dos riachos foram os fatores mais importantes relacionados à distribuição das comunidades. A riqueza e a abundância foram positivamente relacionadas com a velocidade da corrente e negativamente com a profundidade. Não foram detectados fortes padrões temporais na riqueza, mas certa sazonalidade na abundância das comunidades foi observada. A distribuição temporal não esteve relacionada a um fator abiótico específico. Assim, a distribuição temporal das comunidades de Elmidae parece estar relacionada aos ciclos de vida dos gêneros dominantes. Por fim, ressalta-se que a área de estudo apresenta uma riqueza total Elmidae semelhante à de algumas áreas tropicais e o importante papel dos riachos montanhosos na manutenção de altas taxas de diversidade regional na região Neotropical.
Keywords: *insetos aquáticos, riachos, região Neotropical.*

Introduction

Riffle beetles (Elmidae Curtis 1830) are coleopterans whose larvae and adults live especially in lotic environments with high oxygen concentration (Merritt & Cummins 1996, Domínguez & Fernández 2009) and strong water current, in stony bottoms containing leaves (Passos et al. 2003a, b, Elliot 2008, Fernandes 2010). Although abundant in rivers and streams, riffle beetles can also be found in ponds and lakes (Passos et al. 2003a). Their feeding habit is herbivorous (Cummins 1973, White & Brigtam 1996) or herbivorous-detritivorous (Seagle Jr. 1982). Functionally, they are considered scrapers, collectors or shredders (Cummins 1973, White & Brigham 1996), and adults and larvae obtain food scraping rocks, roots, leaves, and woods, or consuming detritus and periphyton (Seagle Jr. 1982). Elmids are also considered important environmental indicators, because they are sensible to physical and chemical changes in the aquatic environment (Jäch & Balke 2008) and, consequently, have low tolerance to pollutants (Brown 1987). Thus, anthropic activities, such as agriculture and domestic and industrial waste, influence their occurrence (Merritt & Cummins 1996). The temporal distribution is associated to life cycle, which is few studied in the adult stage, but better known for the larvae (Kodada & Jäck 2003). The larval stage lasts from six to 36 months, and is affected by temperature and food availability (Brown 1987). Periods of low precipitation also drive the temporal distribution because water depth and velocity become stable (Passos et al. 2003a).

Until now, 1,330 species of Elmidae were described in the world, but estimates indicate that almost 520 species remain unknown (Jäch & Balke 2008). Their diversity is higher in tropical regions (Jäch & Balke 2008), but in South America the family is little studied. Approximately 350 species have been assigned to the Neotropics, and in Brazil, which comprehends ca 40% of the Neotropical region, only ca. 150 species were recorded (Segura et al. 2013). Besides, the knowledge about riffle beetles is restricted to few Brazilian regions. Most taxonomic studies deal with species of Southeastern and Northern regions (e.g., Passos & Felix 2004a,b, Passos et al. 2007, Passos et al. 2009, Passos et al. 2010, Fernandes 2010, Fernandes et al. 2011, Sampaio et al. 2011, Miranda et al. 2012, Sampaio et al. 2012, Segura et al. 2012). Ecological aspects such as spatial distribution, substrate influence and life cycles were studied especially in Southeastern region (Passos et al. 2003a, b, Segura et al. 2007).

The Southernmost Brazil (Rio Grande do Sul state, RS) has environmental characteristics that favor the occurrence of riffle beetles. The escarpment of the Serra Geral Formation is ca. 450 km east-west extension (Pedrón & Dalmolin 2011), and presents numerous rivers and streams with stony substrate (Simões 2002). The humid temperate climate (Maluf 2000) allows the occurrence of a rich drainage net, with well oxygenated waters. However, the diversity and ecology of elmids in Rio Grande do Sul remains poorly known (Hinton 1972, Benetti et al. 1998, Salvarrey 2011). In general, the spatial distribution of these beetles has been registered especially at family level, in studies of freshwater macroinvertebrates (e.g., Wiedenbrug et al. 1997, Bueno et al. 2003, Pereira & De Luca 2003). The occurrence of 14 genera in Santa Catarina state (Segura et al. 2013) and of 19 genera in Argentina (Archangelsky & Manzo 2006) suggests that the diversity of elmids genera in Rio Grande do Sul could be greater than it is known so far.

This study presents an inventory of the Elmidae genera in the middle course of the Jacuí River. Previous studies show that this region contains a very diversified macroinvertebrate assemblage (Neri et al. 2005, Spies et al. 2006, Siegloch et al. 2008, Floss et al. 2012), due to its location in a transitional relief area, and also to the occurrence of the incrusting aquatic macrophyte *Podostemum* A. Michaux, 1803 (Floss et al. 2012). Besides, the middle Jacuí course has part of its marginal areas protected by a state park, Parque Estadual da Quarta Colônia (PEQC). An analysis of the spatial and temporal distribution of the assemblages, according to some environmental factors along one year is also presented. These data will contribute to future preservation programs of the PEQC, as well as to the knowledge of the RS biodiversity.

Material and methods

1. *Study Area*

The Jacuí River basin is one of the largest watersheds of the Rio Grande do Sul state, presenting 800 km of extension and 71.600 km^2 of drainage area (Zamanillo et al. 1989). The middle course, where this study was conducted, is located in altitudes ranging from 50 to 500 m (Marchiori et al. 1982), showing a rugged landscape. Rivers are of 1^{st} to 7^{th} order, according to Strahler (1952) classification, and their beds are constituted mainly by gravels, cobbles and boulders (Neri et al. 2005). Aquatic vegetation is scarce, but *Podostemum* can be common in certain stretches (Spies et al. 2006, Floss et al. 2012). Lentic environments are rare, represented by few backwaters located near the beginning of the lower Jacuí (Spies et al. 2006).

The climate of the region is subtropical humid, according to Köppen's classification, showing mean annual temperature varying from 13 °C in winter to 18-22 °C in summer, and mean annual precipitation of 1708 mm. Thus, clime can be consider temperate (Maluf 2000). The vegetation belongs to the Seasonal Deciduous Forest, integrating the Atlantic Forest biome (Quadros & Pillar 2002). Present day, it is represented by small fragments of secondary growth and by sparse riparian vegetation (Marchiori et al. 1982), protected near the rivers banks by the PEQC (SEMA, 2005).

2. *Sampling and data analysis*

For the spatial and temporal distribution analyses, samplings were conducted between June 2001 and May 2002 on a monthly basis in four sites (Table 1, Fig. 1). Larvae and adults were collected in areas with running water and stony substrate, with Surber sampler (area = 0.36 m^2, mesh = 1 mm). The margins and the center of the streams were sampled, except in Site 4, in which only the left bank was sampled. When the macrophyte *Podostemum* was found, it was scraped off and included in the samples. The specimens were preserved with 80% ethyl alcohol. For the identification to genus level the keys of Benetti et al. (2006), Manzo & Archangelsky (2008), Domínguez & Fernández (2009) and Segura et al. (2011) were used.

For the overall inventory, additional specimens were obtained from samplings conducted with the same methodology, but with irregular frequency, between April 2000 and May 2002, in other six sites (Fig. 1, Table 1). Voucher specimens are deposited in the Coleção de Macroinvertebrados of the Departmento de Biologia, Universidade Federal de Santa Maria (UFSM), RS (numbered from IA 3606 to IA 3779).

Table 1. Description of the sampling sites of the Elmidae larvae and adults assemblages sampled between April 2000 and May 2002 in the middle course of the Jacuí River, Rio Grande do Sul, Brazil.

Sites	Rivers	Altitude (m)	Order	Width (m)	Grain Size (%)	Site description
1	Rio Carijinho	92	4th	8	Boulder: 54.9 Cobble: 33.9 Gravel: 7.8	arboreous vegetation in one bank; little shading; *Podostemum* sp. present
2	Lajeado da Gringa	107	3rd	6	Boulder: 48 Cobble: 49 Gravel: 1.1	shrubby vegetation in one bank; no shading; *Podostemum* sp. present
3	Lajeado do Gringo	140	4th	5	Boulder: 35.8 Cobble: 49.5 Gravel: 6.8	arboreous vegetation in one bank; little shading
4	Rio Jacuí	57	7th	200	Boulder: 30.1 Cobble: 66.6 Gravel: 2.1	little arboreous vegetation; little shading; stony bottom; anthropogenic influence
5	Rio Carijinho	95	4th	8	Boulder: 15.8 Cobble: 57.1 Gravel: 22.2	arboreous vegetation in one bank
6	Lajeado do Tigre	140	1st	3	Boulder: 44.7 Cobble: 52.1 Gravel: 0.62	well preserved riparian; much shading
7	Lajeado do Tigre	107	2nd	6	Boulder: 0 Cobble: 68.1 Gravel: 20.7	arboreous vegetation in one bank; one bank shaded
8	Lajeado do Tigre	107	2nd	5	Boulder: 50 Cobble: 36.8 Gravel: 7.8	arboreous vegetation in one bank; onde bank shaded
9	Lajeado da Gringa	152	3rd	13,5	Boulder: 66.8 Cobble: 30.6 Gravel: 0.4	arboreous vegetation in one bank; no shading
10	Lajeado do Gringo	140	4th	9	Boulder: 26.3 Cobble: 56.1 Gravel: 10.5	arboreous vegetation in one bank; little shading

In each sampling site, the data of air and water temperature (AT and WT), dissolved oxygen (DO), pH, depth (WD), and water velocity (WV) were taken. Data on monthly accumulated rainfall (mm) and average monthly regional temperature (TMM, °C) were taken from the Departamento de Fitotecnia of the UFSM.

Differences in abiotic data among sites and months were analyzed by means of variance analysis (ANOVA one-way), followed by Tukey test. The significance level used was 5% (Zar 1999).

The diversity in the study area was assessed considering absolute (N) and relative (%) abundance, richness (S) and taxonomic composition. The cumulative richness of genera considered monthly (2001 and 2002) and additional samples was estimated using the collector curve, based on the generation of 500 curves through random addition of samples, using EstimateS 8.2 software (Colwell 2006).

The richness of the genera of the four sampling sites used for studying temporal and spatial distribution was compared using the rarefaction technique (1,000 permutations) (Simberloff 1972). The comparison of richness by means of the rarefaction technique must be done to the highest level of comparison between communities (Gotelli & Entsminger 2006). The curves were generated by EcoSim 700 software (Gotelli & Entsminger 2006). Site 4 was excluded from the analysis due to its very low number of individuals (five specimens).

Seasonal patterns in the temporal distribution of the abundance and richness of Elmidae assemblages were verified by means of Statistical Circular Analysis (Zar 1999). In this analysis, the sampling months were transformed into 30°- angle intervals (May/2002 = 0°; June/2001 = 30°). For each site, the following parameters were estimated: i) mean vector angle (μ), which represents the time of the year during which the greatest abundance and richness was registered; ii) circular standard deviation (SD); and iii) length of the vector (r), a measure of the concentration of the data along the cycle analyzed (year), of which the value varies from 0 (maximum dispersion of data) to 1 (maximum concentration of data). The significance of the mean angle was determined using Rayleigh's Test (Z) (Zar 1999). The circular analysis was performed using Oriana 4.01 software (Kovach 2012).

The influence of the environmental variables in the spatial and temporal distributions of assemblages was analyzed by means of Canonical Correspondence Analysis (CCA) (Legendre & Legendre 1998), using the software CANOCO

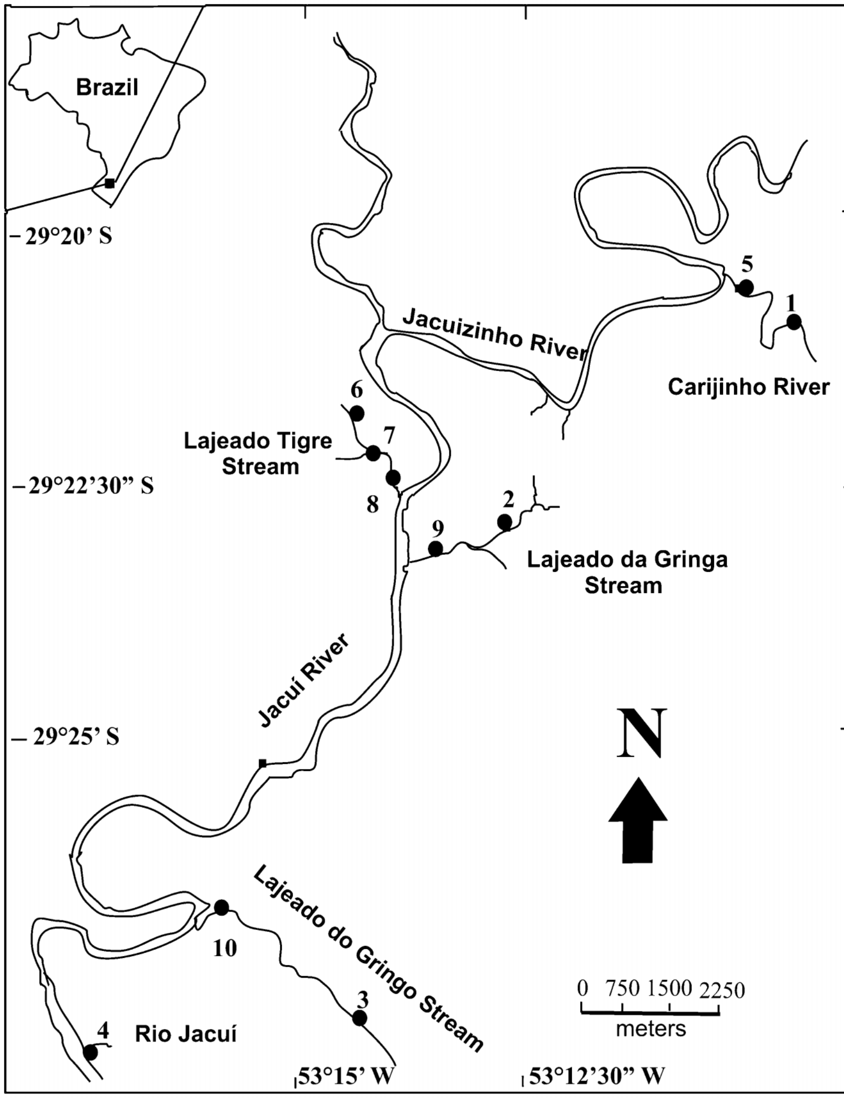

Figure 1. Map of the study area, indicating the ten sampling sites in the middle course of the Jacuí River Basin, Brazil. (Sites 1 – 4 = sampled between June 2001 and May 2002; Sites 1–10 = sampled between April 2000 and May 2002).

4.5 (Ter Braak & Šmilauer 2002). Due to the spatially structured character of the samplings (Legendre & Legendre 1998), a possible relationship between spatially correlated samples was checked out by a Principal Coordinates Matrix Neighboring (PCNM) analysis. In the CCA, the following environmental variables were tested in addition to the model through the *manual forward stepwise* selection procedure ($p < 0.05$ according to Monte Carlo's permutation test with 999 randomizations): pH, DO, WT, AT, WD, WV, altitude, and rainfall. Only three of these variables — WT, WD, WV — were

Table 2. Diversity ;larvae and adults of Elmidae found at the ten sampling sites, in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil (l = larvae; a = adults).

Sites	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Genera	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**
Austrolimnius				(x)																
Heterelmis	x		x		x		x		x								x		x	
Hexacyl-loepus	x	(x)	x	(x)			x		x			(x)		(x)		(x)	x	(x)	x	
Macrelmis			x		x	(x)											x		x	
Neoelmis	x	(x)	x	(x)	x	(x)	x		x								x	(x)	x	(x)
Phanocerus																	x		x	
Stegoelmis	x		x		x					(x)	x						x		x	

Table 3. Abundance (N) and richness (S) of Elmidae assemblages found in the middle course of the Jacuí River, Rio Grande do Sul, Brazil (l = larvae, a = adults; l+a = sum of larvae and adults).

Sites	1		2		3		4		TOTAL		
Genera	l	*a*	l	*a*	l	*a*	l	*a*	l	a	l+a
Heterelmis	25	*0*	92	*0*	24	*0*	1	*0*	**142**	**0**	**142**
Hexacylloepus	2	*0*	6	*13*	0	*13*	0	*1*	**8**	**27**	**35**
Macrelmis	0	*0*	31	*0*	13	*0*	0	*0*	**44**	**0**	**44**
Neoelmis	36	*1*	208	*43*	81	*4*	3	*0*	**328**	**48**	**376**
Phanocerus	0	*0*	3	*0*	1	*0*	0	*0*	**4**	**0**	**4**
Stegoelmis	26	*0*	35	*0*	15	*0*	0	*0*	**76**	**0**	**76**
N	**89**	***1***	**375**	***56***	**134**	***17***	**4**	***1***	**622**	**75**	**697**
S	**4**	***1***	**6**	***2***	**5**	***2***	**2**	***1***	**7**	**2**	**7**

included. This method was also efficient in removing the multicollinearity among the explaining variables, since none has showed a high variance inflation factor (VIF) (*sensu* Ter Braak & Šmilauer 2002). Monte Carlo's test (999 randomizations) was used to test the significance of the canonical axes (Ter Braak & Šmilauer 2002). The abundance matrix was log transformed (log X+1).

Results

Among the abiotic data, Site 3 had higher pH values than Sites 1 and 2 (F=7.03; p<0.05); Site 4 had lower DO than Site 2 (F = 2.88; p<0.05); Site 1 had higher WD than others (F=5.235; p<0.05); Site 3 had higher WV than Site 4 (F=3.774; p<0.05). Monthly differences between variables were recorded for TMM (F=18.25; p<0.05), WT (F=25.01; p<0.05) (winter-spring and winter-summer months), and DO (F=2.339; p<0.05) (winter-summer months). The higher monthly precipitations were recorded in September 2001 (237.1 mm) and March 2002 (252.1 mm).

Considering both samplings, i.e., those used for the spatial and temporal distribution analyses and the additional samplings, 1,433 specimens, represented by 119 adults and 1,314 larvae, were found in the middle course of the Jacuí River (Table 3). Larvae were identified in seven genera (Table 3). Only Elminae genera were recorded in adult stage. *Hexacylloepus* Hinton, 1940 was the best distributed genera, occurring in nine of the ten sampling sites (Table 3). The cumulative curve of genera, for the ten sampling sites, showed stabilization, indicating that the asymptote was reached (Fig. 2).

From June 2001 to May 2002, 697 specimens (662 larvae and 75 adults) were found in the four sites sampled for the community structures analysis. They were represented by the genera *Heterelmis* Sharp, 1882, *Hexacylloepus*, *Macrelmis* Mostchulsky, 1859, *Neoelmis* Musgrave, 1935, *Phanocerus* Sharp, 1882, and *Stegoelmis* Hinton, 1939 (Table 5). *Neoelmis* was the dominant genus (64%), and together with *Hexacylloepus* and *Heterelmis*, was recorded in all sampling sites. *Phanocerus* was the rarest genus (0.2%), occurring only in two sites (Table 5). The rarefaction graphic, based on 90 specimens, showed overlapping estimated richness for Sites 2 and 3, which had both higher values than Site 1 (Fig. 3).

No specimens of Elmidae were found in February, March and April 2002. Excluding these months, the lowest abundance was found in December 2001, with five specimens collected. The highest abundance was recorded in November 2001, when 148 specimens were collected. Temporal structure was detected by the Circular Analysis, indicating seasonality in elmid assemblages, with most of abundance concentrations in spring periods. Abundance data showed significant Rayleigh test statistics in all sites (Table 4), with mean vector concentrated between August and November (i.e., end of winter and through spring), except for Site 3, in which the mean vector concentrated in the end of fall (Fig. 4). However, richness data in Rayleigh test did not show statistical significance for all sites but Site 3, which concentrated in the end of fall, although the angle of mean vector had indicated spring periods in all sites (excluding Site 4, Fig. 5).

No spatial dependence was detected by the PCNM (p = 0.16) among the sampling sites. Thus, the influence of space was not considered in the following analyses. In the CCA, all axes were significantly different from chance (F = 2.782, p = 0.006). The two first axes together resumed 32.1% of the variability of the Elmidae abundance data, and 97.6% of these data were explained by the relationship with the environmental data (Table 5). The first axis of the CCA evidenced positive correlation with the WT and WV, and negative with WD (Table 6, Fig. 6). The second axis showed strong positive correlation with WT and weak with WD, and negative with WV. In general, Axis 1, resumed the temporal structure, segregating autumn and winter samples from spring and summer ones (Fig. 6). Some genera and their respective life stages were influenced by environmental factors (Fig. 6).

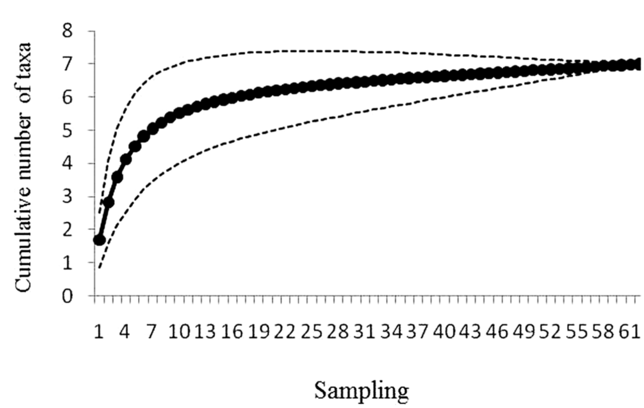

Figure 2. Cumulative curve of genera of the Elmidae adults and larvae assemblages recorded in four rivers, between June 2001 and May 2002, in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

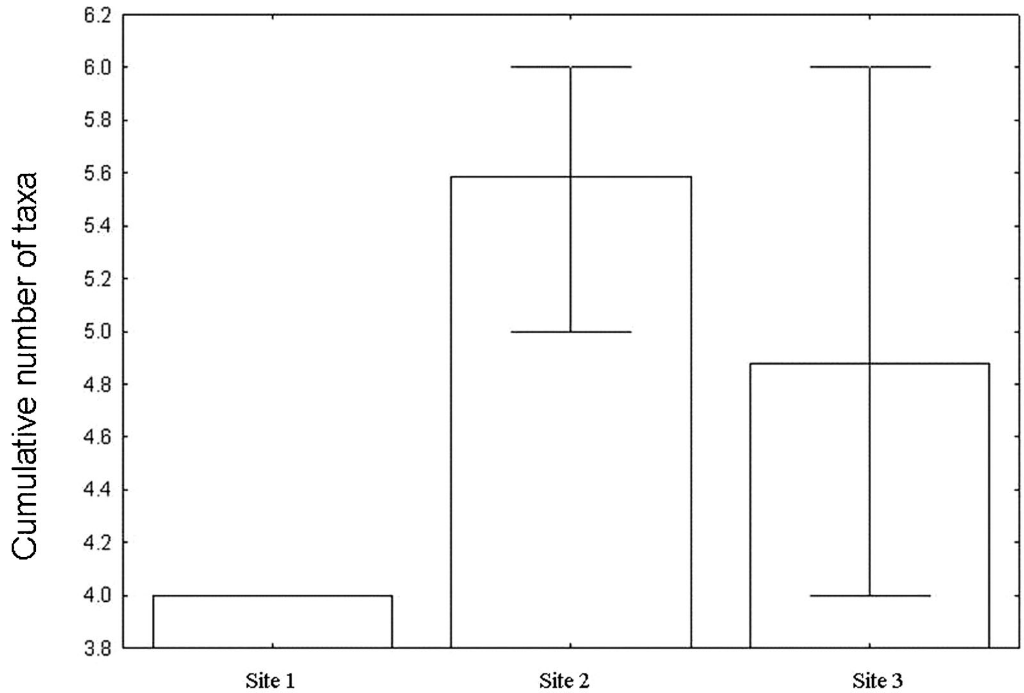

Figure 3. Comparison of the estimated richness of genera of the Elmidae assemblages among the sampled sites in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

Neoelmis and *Hexacylloepus* adults were negatively related to WD and positively to WV, while larvae, like those from *Heterelmis* and *Stegoelmis*, were more related to lower WV. *Macrelmis*, *Hexacylloepus* and *Phanocerus* larvae were slightly related to higher WT.

Discussion

The stabilization of the collector curve (Fig. 2) suggests that a small enhancement in richness should be expected for the riffle beetle genera of the middle Jacuí River, if sampling effort was increased. Richness of elmid genera usually varies from six to eight in southeastern Brazilian rivers (Passos et al. 2003a, Buss et al. 2004, Paula & Fonseca-Gessner 2010), and increases towards northern Brazilian region, according to Fernandes (2010) and Barbosa et al. (2013) information. Thus, southernmost Brazil should sustain a lower richness of riffle beetles than northern and tropical areas, but higher than recorded in this study here (seven genera), because other southern Brazilian regions (e.g., Santa Catarina state) have ca. 13 elmid genera (Segura et al. 2013).

The first record of *Austrolimnius* and *Macrelmis* in Rio Grande do Sul is not a surprise. These genera have been found in others southernmost countries of South America, such as Argentina (Fernández et al. 2008) and Chile (Jerez & Moroni 2006). Besides, all genera recorded in this study have been

Table 4. Circular Analysis of the abundance (N.) and richness (S.) of the larvae and adults Elmidae assemblages in the middle course of the Jacuí River Basin, Rio Grande do Sul, Brazil.

Sites	1		2	
Descriptor	N	S	N	S
Mean vector (μ)	134.05°	78.43°	90.62°	69.40°
Circular standard deviation	52.75°	86.51°	98.19°	101.83°
Average vector length (r)	0.65	0.32	0.23	0.21
Rayleigh Test (Z)	38.56	1.02	23.91	1.40
Rayleigh Test (p)	<0.01	0.37	<0.01	0.25
Sites	**3**		**4**	
Descriptor	**N**	**S**	**N**	**S**
Mean vector (μ)	109.20°	118.41°	116.56°	281.56°
Circular standard deviation	48.06°	63.31°	72.17°	72.17°
Average vector length (r)	0.70	0.54	0.45	0.45
Rayleigh Test (Z)	74.21	5.31	1.02	1.02
Rayleigh Test (p)	<0.01	<0.01	<0.01	0.38

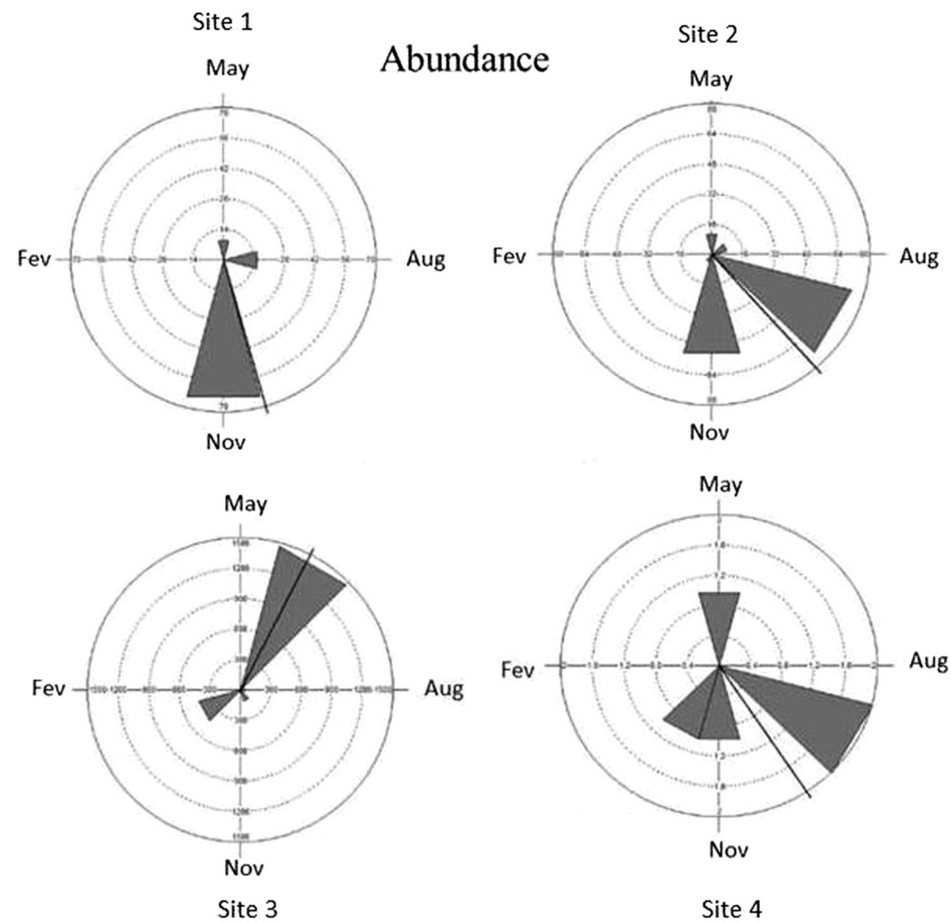

Figure 4. Temporal distribution of the abundance of the Elmidae larvae and adults assemblages in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

previously found in other Brazilian states (Spangler & Santiago-Fragoso 1992, Passos et al. 2007, Paula & Fonseca-Gessner 2010, Fernandes 2010, Segura et al. 2012, Segura et al. 2013). On the other hand, *Stegoelmis* had its distribution extended southwards in the Neotropical region, because until now it had only been recorded below northwards (02°S) (Fernandes 2010, Segura et al. 2013). Additionally, the elmid community composition found in the Jacuí River is similar to those recorded in tropical rivers also showing stony bottoms and strong water current (Passos et al. 2003a, Buss et al. 2004, Mugnai et al. 2008, Fernandes 2010).

The higher abundance and richness registered in Sites 2 and 3 (Figs. 3 and 4) should be associated to the lower WD of both sites, as well as to the expressive presence of the macrophyte *Podostemum*. Aquatic vegetation usually favors the occurrence of high diversity of macroinvertebrates, because it increases the habitat heterogeneity (Taniguchi & Tokeshi 2004). Besides, great macrophyte biomass also represents shelter for larvae and a local for retention of their food (Connel 1978).

Site 1 showed higher WD than Sites 2 and 3, conditions not suitable to Elmidae, especially to *Macrelmis* and *Neoelmis* (Spangler 1997, Passos et al. 2007, Fernandes, 2010). Site 4 is of 7th order, and had the lowest DO and WC mean values, accounting for the lowest richness and abundance. However, the strong water level fluctuation determined by the operation of the Hydroelectric Power Station Dona Francisca (only 2 km upstream), as well as the absence of riparian vegetation and of *Podostemum* (Spies et al. 2006, Floss et al. 2012), are possibly the most important factors avoiding the Elmidae assemblages establishment.

In the end of spring (November 2001), when the highest mean TMM was registered, the highest Elmidae abundance and richness were observed. Similar TMM value was also recorded in October 2001. Previous studies conducted in other temperate regions of the world showed that high WT values favor the occurrence of these coleopterans, because determine faster growth rates (Brown 1987). But riffle beetles are also usually associated to high DO concentrations (Brown 1987). Thus, in March 2002 (summer), when the lowest DO value was registered, no individuals were found. The absence of Elmidae in February and April 2002 can be related to the heavy rainfall that concentrated days before collections of February (100 mm) and along March 2002 (252.1 mm). Rain can exert high influence on the aquatic fauna, washing out the substrate, causing organisms to drift, and altering habitat characteristics (Nessimian and Sanseverino 1998).

The relationships of WT and DO with abundance and richness of the communities were not clear. During the sampling period, months with low DO (September 2001 and May 2002), had regular abundance and richness, and months with high temperature (e.g., December 2001), showed low abundance and richness. Thus, it is possible that these factors affect the genera differently. The Circular Analysis and the Rayleigh Test corroborated seasonality concerning Elmidae

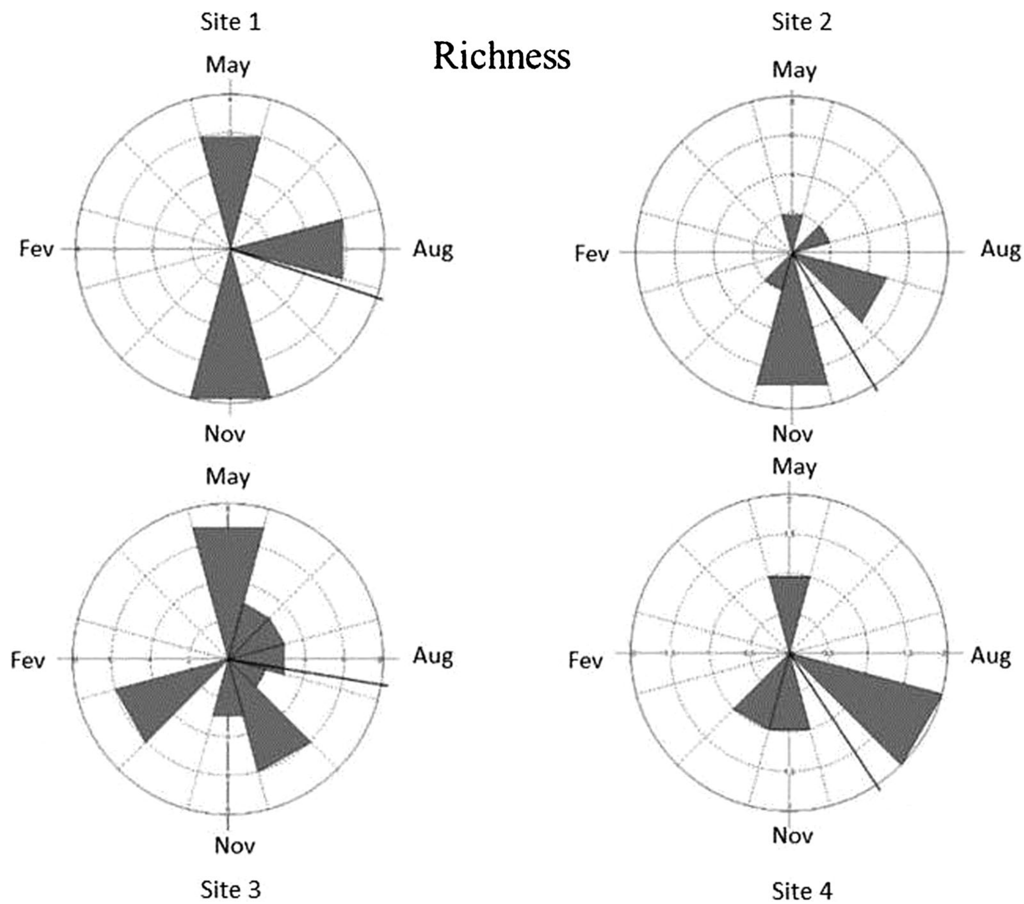

Figure 5. Temporal distribution of the richness of the Elmidae larvae and adults assemblages in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

Table 5. Eigenvalues, taxon-environment coefficients of correlation and explained cumulative percentage of the four first axes of the Canonical Correspondence Analysis of the Elmidae assemblages of the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

	Axis 1	Axis 2	Axis 3	Axis 4	Total variance
Eigenvalues	0.25	0.05	0.01	0.25	0.94
Taxon-environment relation	0.75	0.56	0.28	0	
Cumulative variance percentage of the data of taxa	26.5	32.1	32.9	59.8	
Taxon-environment relationship	80.5	97.6	100	0	
Total sum of the eigenvalues					0.94
Total sum of canonical eigenvalues					0.31

Table 6. Inter-set correlations between the first two axes of the Canonical Correspondence Analysis and the environmental variables (water temperature = WT, water depth = WD, water velocity = WV) of the Elmidae assemblages in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil, between June 2011 and May 2002.

Environmental factors	Axis 1	Axis 2
WT	0.3425	0.4841
WD	-0.4914	0.0933
WV	0.5292	-0.2545

abundance in spring, but only suggests similar relationship concerning richness (no statistical significance). These results are probably related to life cycle particularities of the most abundant genera in each sampling site, as will be discussed.

Temperature is one of the main factors that affect elmids development, because their life cycle usually synchronizes with warmer temperatures (Brown 1987). In North America, adults emerge mainly in summer, and females wait until the next summer to lay eggs (Elliot 2008). In Brazil, no studies concerning elmid life cycle have been conducted, but some larvae were observed pupating by spring (for one to two weeks), when adults emerge (M. O. Segura pers. comm.). Thus, the data obtained here suggest that warmer temperatures may also influence Neotropical elmids life cycle, favoring the finding of diversified assemblages.

In the middle course of the Jacuí River, DO, WT and WV were the most important factors related to the structure of the

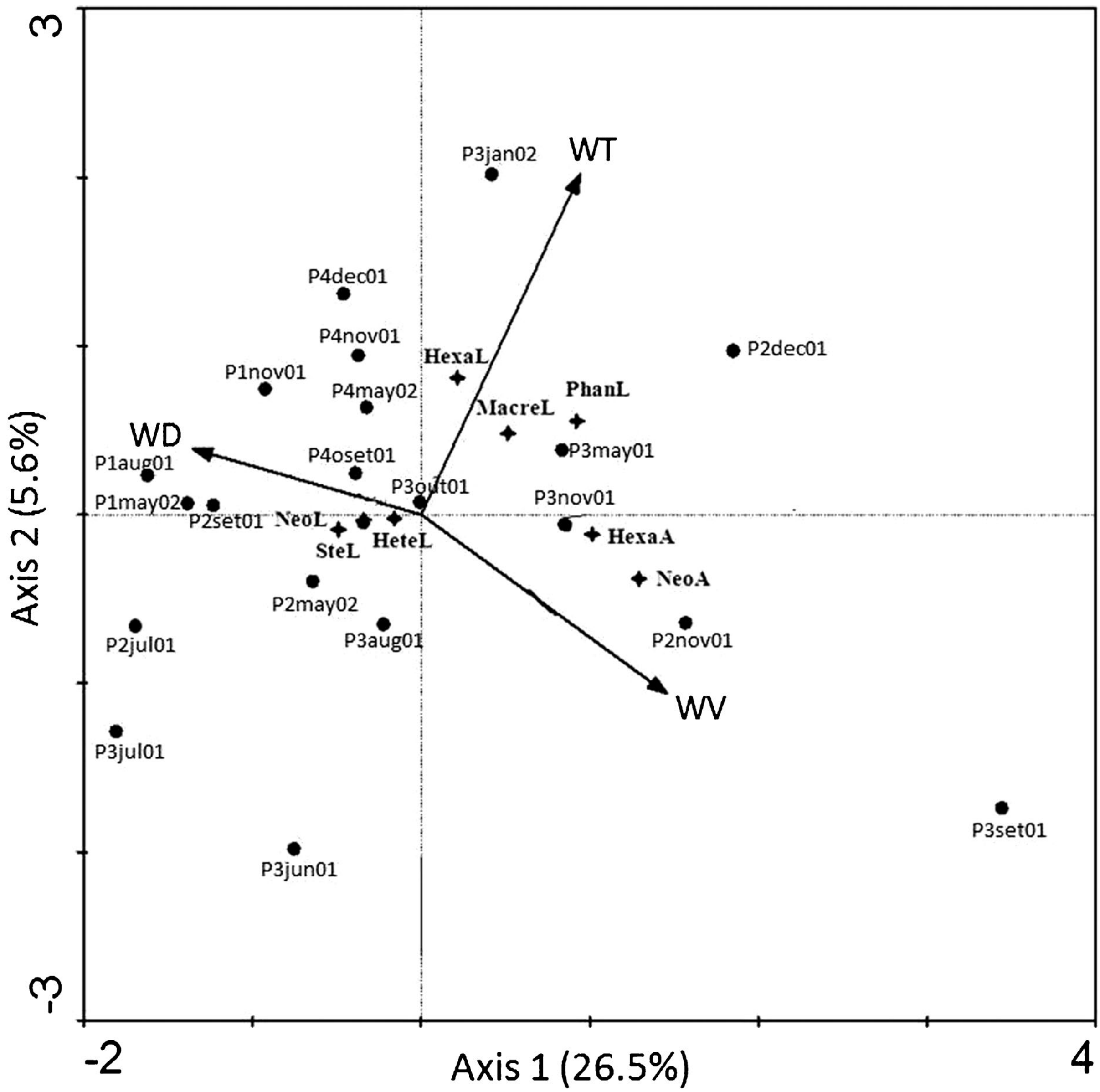

Figure 6. Diagram of ordination of the samples and taxa for the first two axes of the Canonical Correspondence Analysis of Elmidae larvae and adults assemblages in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil, and environmental variables, surveyed between June 2001 and May 2002. Abbreviations of the taxa: NeoA= *Neoelmis* adult, NeoL= *Neoelmis* larva, HexaA= *Hexacylloepus* adult, HexaL= *Hexacylloepus* larva, PhanL= *Phanocerus* larva, MacreL= *Macrelmis* larva, HeteL=*Heterelmis* larva, SteL= *Stegoelmis* larva, WD= water depth, WV= water velocity, WT= water temperature.

communities of the riffle beetles in a spatial and temporal perspective. In fact, Sites 1 and 4, which tended to segregate according high WD and low WV, exhibited the lowest richness. On the other hand, in months with warmer WT, and when the WV diminished, a relationship of these factors with certain genera were observed. *Neoelmis*, which was abundant in Sites 2 and 3, are typical dwellers of habitats with stony substrate with stems and leaves, and also occur in shallow areas with strong water current (Passos et al. 2003a, b, Passos et al. 2007, Fernández et al. 2008, Fernandes 2010). Thus, the predominance of this genus in the studied area reflects the general environmental conditions of the middle Jacuí River. Habitat preferences of *Hexacylloepus* are not mentioned in literature, but it is probably similar to those of *Neoelmis*, because their larvae have been found together with *Heterelmis* in leaf packs (Spangler & Santiago-Fragoso 1992). *Heterelmis* are found in shallow waters with in running waters, and in warmer temperatures sites (Fernandes 2010). In this study, their larvae were associated to lower WV, as well as those of *Stegoelmis*. *Macrelmis* and *Phanocerus* larvae, which were slightly related to higher WT in the studied area, have been found in riverine habitats containing submerse stems and roots (Spangler & Santiago-Fragoso 1992, Spangler 1997, Fernandes 2010). The genus *Phanocerus* was very rare in the middle Jacuí. Members of this genus were found above the water line (Spangler & Santiago-Fragoso 1992), living in streams with fast and clear waters (Hinton 1940).

Final remarks

River basins located in the escarpment of the Serra Geral Formation, in southernmost Brazil, can sustain Elmidae assemblages with similar richness of genera to that recorded in basins of tropical/warmer climate regions of Brazil. Shallow streams, stony substrate, presence of aquatic macrophytes and especially the occurrence of periods of low rainfall and warm water temperature are important drivers of the spatial and temporal distribution of elmids. Thus, the presence of these environmental conditions in the middle course of the Jacuí River basin is important for the diversity of this family in the escarpment region of RS. This study, as well others previously conducted in the Jacuí River, reinforces the role of the middle course as a hotspot of riverine macroinvertebrate diversity in RS.

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