Oligochaetes (Annelida, Clitellata) in a neotropical stream: a mesohabitat approach

Guilherme R. Gorni[1] & Roberto da G. Alves[2]

1. Departamento de Ciências Biológicas e da Sáude, Centro Universitário de Araraquara – UNIARA, Rua Carlos Gomes 1338, Centro, 14801-340, Araraquara, SP, Brazil. (grgorni@gmail.com)
2. Departamento de Zoologia, Instituto de Ciências Biológicas, Universidade Federal de Juiz de Fora – UFJF, Campus Universitário s/n°, Martelos, 36036-330, Juiz de Fora, MG, Brazil. (gama.alves@ufjf.edu.br)

ABSTRACT. This paper analyses the relationship among mesohabitat and aquatic oligochaete species in the Galharada Stream (Campos do Jordão State Park, state of São Paulo, Brazil). Between August 2005 and May 2006 a total of 192 samples were obtained in areas of four different mesohabitats: riffle leaf litter (RL), pool leaf litter (PL), pool sediment (PS) and interstitial sediment from rocky beds in riffle areas (IS). In the mesohabitats sampled, 2007 specimens were identified, belonging to two families (Naididae and Enchytraeidae). Among the oligochaetes identified Naididae was represented by six genera (*Allonais*, *Chaetogaster*, *Nais*, *Pristina*, *Aulodrilus* and *Limnodrilus*). Principal components analysis (PCA) revealed the first two axes explained 85.1% of the total variance of the data. *Limnodrilus hoffmeisteri* Claparede, 1862 and *Aulodrilus limnobius* Bretscher, 1899 were associated with the pool areas (PL and PS). Most species of genera *Pristina* and *Nais* demonstrated apparent affinity with the riffle mesohabitats. The Indicator Species Analysis (IndVal) revealed that *Nais communis* Piguet, 1906, *Pristina leidyi* Smith, 1896 and *Pristina (Pristinella) jenkinae* (Stephenson, 1931) are indicative of RL mesohabitat, while family Enchytraeidae was considered indicative of PL mesohabitat.

KEYWORDS. Aquatic oligochaetes, community structure, mountain stream, Campos do Jordão State Park.

RESUMO. Oligoquetos (Annelida, Clitellata) em um córrego neotropical: uma abordagem do mesohabitat. Este artigo analisou a relação entre mesohabitats e as espécies de oligoquetos aquáticos no Córrego Galharada (Parque Estadual de Campos do Jordão, Estado de São Paulo, Brasil). Entre agosto de 2005 e maio de 2006 um total de 192 amostras foram obtidas em quatro mesohabitats diferentes: folhiço em corredeiras (RL), folhiço em remanso (PL), sedimentos em remanso (PS) e sedimento intersticial de pedras em corredeiras (IS). Nos mesohabitats amostrados, foram identificados 2007 espécimes, pertencentes a duas famílias (Naididae e Enchytraeidae). Entre os oligoquetos identificados, Naididae foi representada por seis gêneros (*Allonais*, *Chaetogaster*, *Nais*, *Pristina*, *Aulodrilus* e *Limnodrilus*). A Análise de Componentes principais (ACP) revelou que os dois primeiros eixos explicaram 85,1% da variabilidade total dos dados. *Limnodrilus hoffmeisteri* Claparede, 1862 e *Aulodrilus limnobius* Bretscher, 1899 foram associadas às areas de remanso (PL e PS). A maioria das espécies dos gêneros *Pristina* e *Nais* demonstrou aparente afinidade com mesohábitats de corredeira. A análise de espécies indicadoras (IndVal) revelou que *Nais communis* Piguet, 1906, *Pristina leidyi* Smith, 1896 and *Pristina (Pristinella) jenkinae* (Stephenson, 1931) são indicadoras do mesohábitat RL, enquanto a família Enchytraeidae foi considerada indicadora do mesohábitat PL.

PALAVRAS-CHAVE. Oligoquetos aquáticos, estrutura da comunidade, córregos de montanha, Parque Estadual de Campos do Jordão.

Rivers and streams can be considered a network systems of areas with different size and environmental conditions (Clarke *et al.*, 2008), where complex communities live. These ecosystems have a wide range of environmental conditions and the biotic communities have a variety of spatial scales, from microhabitats to entire landscapes and ecoregions (Heino *et al*., 2004).

Among the spatial scales, the "mesohabitat" is considered a useful unit in studies of natural ecosystems, because the physical factors (consequence of the micro-topography and hydrodynamics), food supply, reproduction and age of organisms and the biological interactions determine the structure of stream assemblages (Pardo & Armitage, 1997). According to Johnson *et al.* (2004), the variations of these factors explain changes in the spatial distribution of benthic macroinvertebrates, once these organisms relate dynamically with the changing habitat conditions (Beisel *et al.*, 1998).

The community of benthic macroinvertebrates is an important indicator of great importance for understanding the structure and functioning of lotic ecosystems (Cummins, 1993), because this community is influenced by the processes that occur in these environments (Heino *et al*., 2003; Soldner *et al*., 2004). Studies of the spatial distribution of oligochaete species have shown that these invertebrates respond to the nature of the substrate and the water flow conditions (Stacey & Coates, 1996; Verdonschot, 1999, 2001; Alves *et al*., 2006; Schenková & Helešic, 2006, among others).

This contribution analyses the relationship among mesohabitat and aquatic oligochaetes species in the Galharada Stream, located in Campos do Jordão State Park in the state of São Paulo, Brazil. This paper has the null hypothesis that the nature of mesohabitat does not exert influence on aquatic oligochaetes species.

MATERIAL AND METHODS

Study area. The study was carried out in Campos do Jordão State Park (PECJ), located in the northern part of the municipality of Campos do Jordão, in the state of São Paulo (22°45'S, 45°39'W), covering an area of roughly 8,172 hectares, with altitude between 1,600 and 1,700 m, in the Mantiqueira mountain range (Seibert, 1975). The park's lotic environments are characterized as shallow, rich in riffles (or swifts) and pebbled substrate, with cool, clean and oxygenated water (Schroeder-Araujo *et al*., 1986). The samples were taken in Galharada Stream because its entire course is located within the park's limits.

Sampling and identification. Forty-eigth samples (12 for each mesohabitat) were taken for the quantitative

sampling in each season from August 2005 to May 2006. The analysed months were August and November 2005, and February and May 2006, totalizing 192 samples. The organisms were collected using a Surber sampling device (McCafferty, 1981; Bicudo & Bicudo, 2004) with an area of 0.0362 m^2 and mesh of 0.25 mm. Four mesohabitat types were considered: riffle leaf litter (RL), pool leaf litter (PL), pool sediment (PS) and interstitial sediment in rocky riffle beds (IS) (Huamantinco & Nessimian, 2000). The material sampled was fixed in 10% formaldehyde and brought to the laboratory for examination under a stereoscopic microscope. The oligochaete species were identified and classified according to taxonomic criteria adopted by Brinkhurst & Jamieson (1971), Righi (1984), Brinkhurst & Marchese (1989), Collado & Schmelz (2000) and Erséus *et al.* (2008). The specimens identified were preserved in 70% alcohol and vouchers deposited in the Anelídeos collection of the Departmento de Zoologia of Universidade Federal de Juiz de Fora (UFJF) in Minas Gerais, Brazil.

Data analysis. The structure of the oligochaete assemblages was characterized by the abundance, richness of taxa and Shannon-Wiener diversity index (H'). The mesohabitats' richness was evaluated by rarefaction curves (Monte Carlo permutation method), using the lowest observed richness (320 organisms: IS mesohabitat). The procedures were performed using the program Ecosim 7 (Gotelli & Entsminger, 2004). To assess the effect of mesohabitats on the Shannon-Wiener diversity index was applied the One-Way ANOVA ($\alpha = 0.05$).

The relation between the oligochaete species and the mesohabitats sampled was verified by Principal Components Analysis (PCA) after converting the data to logarithmic form [$(\log_{10} (x+1)$]. In this analysis, the juvenile Tubificidae specimens without hair chaetae were included in the species *Limnodrilus hoffmeisteri* Claparede, 1862. The Multivariate Statistical Package (MVSP - version 3.1) program was used to analyze the data.

The Indicator Species Analysis (IndVal) was performed to evaluate possible species typically associated with mesohabitats studied. This analysis was performed using the PC-ORD 5.15 (McCune & Mefford, 2006).

RESULTS

Taxonomic composition. After the identification, 2007, specimens were collected, representing two families: Naididae (15 species) and Enchytraeidae. The Naididae family was composed of six genera (*Allonais*, *Chaetogaster*, *Nais*, *Pristina*, *Aulodrilus* and *Limnodrilus*). The Enchytraeidae specimens were only identified to the family level. The oligochaetes identified and the respective occurrences in the mesohabitats sampled are listed in Tab. I.

Tab. I. List of aquatic oligochaete species collected between August 2005 and May 2006 in the riffle leaf litte (RL), interstitial sediment from rocky beds in riffle areas (IS), pool leaf litter (PL) and pool sediment (PS) mesohabitats in Galharada Stream, in Campos do Jordão State Park (state of São Paulo, Brazil) (+, presence; –, Absence).

Species	Mesohabitats			
	RL	IS	PL	PS
Enchytraeidae				
Enchytraeid	+	+	+	+
Naididae				
Naidinae				
Allonais paraguayensis (Michaelsen, 1905)	–	–	+	–
Chaetogaster diastrophus (Gruithuisen, 1828)	+	+	+	+
Nais communis Piguet, 1906	+	+	+	
Nais variabilis Piguet, 1906	+	–	–	–
Pristininae				
Pristina biserrata Chen, 1940	+	–	–	–
Pristina leidyi Smith, 1896	+	+	+	+
Pristina osborni (Walton, 1906)	+	+	+	+
Pristina proboscidea Beddard, 1895	+	–	+	+
Pristina (Pristinella) jenkinae (Stephenson, 1931)	+	+	+	+
Pristina (Pristinella) longidentata (Harman, 1965)	–	–	+	–
Pristina (Pristinella) minuta (Stephenson, 1914)	+	+	–	–
Pristina (Pristinella) notopora Cernosvitov, 1937	+	+	+	–
Pristina (Pristinella) sima (Marcus, 1944)	+	+	+	–
Tubificinae				
Aulodrilus limnobius Bretscher, 1899	+	+	+	+
Limnodrilus hoffmeisteri Claparede, 1862	–	+	+	+
Tubificinae (without hair chaetae)	–	+	+	+

The estimated richness did not differ between mesohabitats RL, IS and PL (12.7, 12.0, and 12.3 respectively), however was significantly lower in mesohabitat PS (7.8). According to One-Way ANOVA, the Shannon diversity index differ significantly between the sampled mesohabitats in the Galharada Stream ($p = 0.000$). The highest diversity index observed in RL mesohabitat ($H' = 1.351$), while the lowest diversity was observed in the PS mesohabitat ($H' = 1.029$) (Tab. II).

Principal component analysis (PCA). The first two PCA axes explained 85.14% of the faunistic data variation. *Limnodrilus hoffmeisteri* and *Aulodrilus limnobius* Bretscher, 1899 were associated with the pool areas (PL and PS) ordered on axis I (Fig. 1). The higher abundance of these species in relation to the others contributed to the low diversity in these mesohabitats. *Pristina (Pristinella) notopora*, *Pristina (Pristinella) minuta* (Stephenson, 1914), *Pristina (Pristinella) sima* (Marcus, 1944), *Nais communis* Piguet, 1906 and *Nais variabilis* Piguet, 1906 were negatively projected on the same axis, demonstrating greater affinity with the riffle mesohabitats. The first principal component synthesizes the effect of the water flow conditions, with the right side of the graph corresponding to the erosion zone (riffles) and the left side to the deposition zone (pools).

Axis II was composed positively of PS and IS mesohabitats, and negatively of the species *Pristina proboscidea* Beddard, 1895, *Pristina leidyi* Smith, 1896, *Pristina (Pristinella) jenkinae* (Stephenson, 1931), *Pristina (Pristinella) longidentata* (Harman, 1965) and *Chaetogaster diastrophus* (Gruithuisen, 1828), which were abundant in the PL and RL mesohabitats. The second principal component synthesizes the effect of the type of substrate in the mesohabitats, with the upper part corresponding to the mesohabitats with mineral substrate (IS and PS) and the lower part to those with organic substrate (PL and RL).

Tab. II. Abundance (number of individuals), estimated richness (ES), Shannon-Wiener diversity index of the riffle leaf litte (RL), interstitial sediment from rocky beds in riffle areas (IS), pool leaf litter (PL) and pool sediment (PS) mesohabitats of Galharada Stream, Campos do Jordão State Park, state of São Paulo, Brazil.

	RL	IS	PL	PS
ES	12.7	12	12.3	7.8
N° Individuals	420	320	878	389
Diversity index (H')	1.351	1.132	1.218	1.029

Tab. III. Indicator Species Analysis (IndVal) of Oligochaeta collected between August 2005 and May 2006 in the riffle leaf litte (RL), interstitial sediment from rocky beds in riffle areas, pool leaf litter (PL) and pool sediment mesohabitats in Galharada Stream, Campos do Jordão State Park, state of São Paulo, Brazil.

	Mesohabitat	IndVal	$p < 0.01$
Enchytraeidae	PL	33.0	0.0398
Nais communis	RL	12.1	0.0084
Pristina leidyi	RL	14.6	0.0046
Pristina (Pristinella) jenkinae	RL	24.6	0.0014

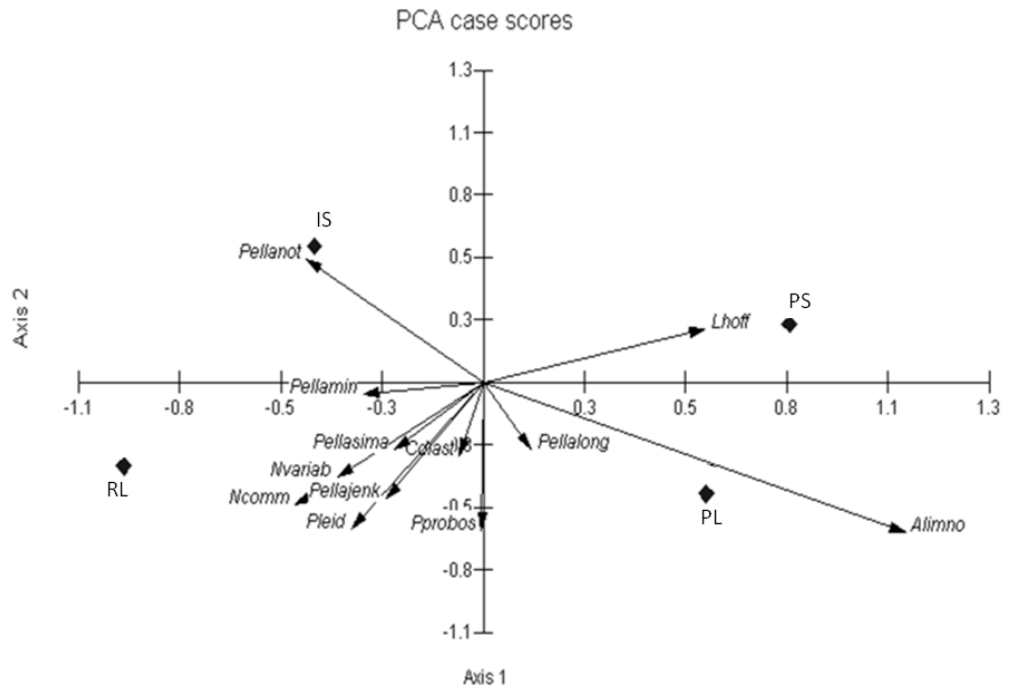

Fig. 1. Chart produced by Principal Component Analysis (PCA) of the species of Oligochaeta and the mesohabitats sampled from August 2005 to May 2006 along Galharada Stream, Campos do Jordão State Park, state of São Paulo, Brazil (*Cdiast*, *Chaetogaster diastrophus*; *Ncomm*, *Nais communis*; *Nvariab*, *Nais variabilis*; *Pleid*, *Pristina leidyi*; *Pprobos*, *Pristina proboscidea*; *Pellajenk*, *Pristina (Pristinella) jenkinae*; *Pellalong*, *Pristina (Pristinella) longidentata*; *Pellamin*, *Pristina (Pristinella) minuta*; *Pellanot*, *Pristina (Pristinella) notopora*; *Pellasima*, *Pristina (Pristinella) sima*; *Alimno*, *Aulodrilus limnobius*; *Lhoff*, *Limnodrilus hoffmeisteri*; PS, sediment accumulations in still-water areas; PL, leaf matter accumulations in pool areas; IS, interstitial sediment from rocky beds of riffles; RL, leaf matter accumulations in riffles).

Indicator Species Analysis (IndVal). The IndVal revealed four taxa indicators of mesohabitats RL and PL, and no taxa indicator of mesohabitats IS and PS (details on Tab. III).

DISCUSSION

The variation diversity index may reflect the hydraulic conditions and type of substrate in the composition of oligochaete assemblages in the mesohabitats sampled. According to Pardo & Armitage (1997), the types of substrate and flow pattern result in a mosaic distribution of species in mesohabitats, each inhabited by particular assemblages of indicator species. In general, majority of the oligochaetes considered as indicators prefer specific habitats and the occurrence of these habitats depends on a complex interaction between different substrate types and water flow patterns (Verdonschot, 2001).

According to Beisel *et al.* (1998), the species richness increases with the heterogeneity of the habitat and the total abundance rises with the food availability, while the diversity of species tend to increase with the stability of the substrate. Our results demonstrate most varied communities mainly in habitats with greater apparent structural complexity (accumulation of leaves, corresponding availability of food in the form of organic litter).

Disregarding the effect of abundance, Mathooko & Otieno (2002) reported that increased richness of invertebrate species can be explained by the micro and macrostructures that define the textural complexity of the plant detritus, such as the presence of furrows, holes and undulations. Taniguchi & Tokeshi (2004) stated that the habitat complexity is important because of its influence on the food supply and places of refuge against fast water flow and agile predators.

According to Dangles *et al.* (2001), leaf accumulations play another important role, namely the retention of organic particles suspended in the water column, influencing the richness and abundance of the invertebrates that colonize these habitats. The organic matter content, even in low concentrations, is very important since it permits colonization by fungi and bacteria, on which oligochaetes feed (Alves & Strixino, 2000). In contrast, the rocky substrates, because they are more stable, influence the composition of the communities differently, by providing more hiding places for invertebrates in search of refuge and food (Effenberger *et al.*, 2006).

The Principal Components Analysis (PCA) showed that the aspects that most influenced the structure and composition of the oligochaete fauna were differences in water flow (pools versus riffles), making the substrate secondary, though still important. Martínez-Ansemil & Collado (1996) and Pardo & Armitage (1997) both considered that current speed and substrate stability are the main factors to explain the spatial distribution of oligochaete species.

The result of the PCA analysis suggest that *L. hoffmeisteri* was associated with still habitats with fine sediment (PS), corroborating the information reported by Verdonschot (1989), Dumnicka & Kukula (1990), Marchese & Drago (1999), Timm *et al.* (2001) and Alves *et al.* (2006). Similarly, the tubificid *Aulodrilus limnobius* was present mainly in still-water habitats with large amounts of allochtonous organic material (leaves and twigs). On the other hand, Montanholi-Martins & Takeda (2001) reported *A. limnobius* in the erosion zone of the Ivinhema River (state of Paraná, Brazil), inhabiting coarse sediment, while Nijboer *et al.* (2004) stated that this species is typical of running water. These reports along with our findings show that this species can occur in habitats with or without current and in substrates with different physical characteristics. According to Dumnicka & Kukula (1990), the tubificids are most numerous in places with weak or no current, where organic matter accumulates. *Pristina (Pristinella) notopora* was associated with running-water habitats in pebbled or sandy beds. However, Stacey & Coates (1996) reported this species as being associated with muddy substrates slightly enriched with organic matter.

The Indicator Species Analysis showed that *Nais communis*, *Pristina leidyi* and *Pristina (Pristinella) jenkinae* are indicator of environments with running water and accumulation of allochtonous organic material. Dumnicka (1976, 1982) also reported the species of *Nais* in environments with similar physical conditions to the stream we studied. Nevertheless, Dumnicka & Kukula (1990) and Lencioni *et al*. (2004) reported that these species prefer standing water. *Pristina leidyi* was reported by Learner *et al*. (1978) on pebbles, and *P. (P.) jenkinae* was reported to be associated with muddy and sandy substrates and submersed vegetation (Stacey & Coates, 1996). The family Enchytraeidae was pointed as an indicator of habitat with standing water and accumulation of sandy sediment. The enchytraeids are essentially terrestrial oligochaetes but many species have marked aquatic tendencies. Healey & Bolger (1984) recorded the tendency of some species inhabit soils which were submerged or frequently flooded. According Johnson & Ladle (1989) most Enchytraeidae adopt a "generalist" ecological strategy, being able to inhabit a wide range of environments (can cope with variations in hydrological conditions, temperature and salinity).

In general, the results reveal a complex relationship between the oligochaete fauna and nature of the mesohabitats, supporting the information of Schenková & Helešic (2006) that the majority of oligochaete species have wide ecological amplitude and habitat preferences. Martínez-Ansemil & Collado (1996) have also concluded that aquatic oligochaetes of different geographic regions show different preferences for type of substrate and current speed, a quality that considerably expands the variation of their distribution.

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