

UNIVERSIDADE COMUNITÁRIA DA REGIÃO DE CHAPECÓ

Programa de Pós-Graduação em Ciências Ambientais

Patricia Isabel Teixeira Jardim

**UNIDADE DE CONSERVAÇÃO: INFLUÊNCIA NA
INTEGRIDADE LIMNOLÓGICA DE RIACHOS**

Chapecó-SC, 2016

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Patricia Isabel Teixeira Jardim

Dissertação apresentada ao Programa de Pós-Graduação da Universidade Comunitária da Região de Chapecó, como parte dos pré-requisitos para a obtenção do título de Mestre em Ciências Ambientais.

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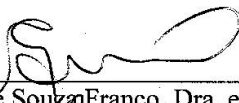
UNIVERSIDADE COMUNITÁRIA DA REGIÃO DE CHAPECÓ
Programa de Pós-Graduação *stricto sensu* em Ciências Ambientais

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LIMNOLÓGICA DE RIACHOS**


Patricia Isabel Teixeira Jardim

Esta dissertação foi julgada adequada para a obtenção do grau de

Mestre em Ciências Ambientais
sendo aprovado em sua forma final.



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Chapecó, 27 de março de 2015.

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RESUMO

JARDINI, Patricia Isabel Teixeira **UNIDADE DE CONSERVAÇÃO: INFLUÊNCIA NA INTEGRIDADE LIMNOLÓGICA DE RIACHOS**. Dissertação (Mestrado). Universidade Comunitária da Região de Chapecó, 2016.

Este estudo avaliou a importância da unidade de conservação (UC), Parque Estadual das Araucárias (PEA) na integridade de riachos, através da composição da comunidade de macroinvertebrados bentônicos e a influência da integridade do habitat sobre essas comunidades. As coletas ocorreram trimestralmente entre fevereiro a dezembro de 2013. A metodologia envolveu amostragem qualitativa e quantitativa (busca ativa e arrasto). Foram analisadas as variáveis físicas e químicas da água, textura do sedimento, protocolo de integridade de habitat, abundância e riqueza dos macroinvertebrados. Para avaliar diferenças na composição das famílias com relação à localização dentro e fora da UC, foi realizado teste de ANOSIM. Através de uma CCA verificou-se a influência das variáveis ambientais sobre a estrutura dos macroinvertebrados bentônicos. O teste de INDVAL buscou relacionar táxons bioindicadores com relação de fidelidade ao habitat. Foram coletados 1882 organismos, compondo 42 famílias, sendo a classe insecta mais abundante. A similaridade encontrada tanto nas variáveis ambientais como na comunidade de macroinvertebrados, sem bioindicadores fortemente relacionados a ambientes mais íntegros, indica que a UC-PEA, e em especial a comunidade de macroinvertebrados, está sofrendo alterações no equilíbrio do ecossistema. Esta pesquisa indica aos órgãos gestores a necessidade de ampliar os propósitos das áreas protegidas já existentes, incluindo sistemas de proteção de bacias hidrográficas ou corredores ecológicos visando a continuidade das áreas florestais, principalmente na extensão dos rios.

PALAVRAS-CHAVE: espécies, indicadores, sedimento, vegetação ciliar.

ABSTRACT

This study evaluated the importance of a conservation unit (CU), the Parque Estadual das Araucárias (PEA), in maintaining the integrity of streams using the community composition of benthic macroinvertebrates and the influence of habitat integrity on these communities. Sampling occurred quarterly from February to December 2013. Benthic macroinvertebrates were qualitatively and quantitatively sampled (active searches and drag-sampling) and physicochemical variables of the water, sediment texture, habitat integrity index, and the abundance and richness of macroinvertebrates were analyzed. Differences in composition of macroinvertebrate families between inside and outside of the CU were evaluated using ANOSIM. Canonical correlation analysis (CCA) determined that the environmental variables had an influence on the structure of benthic macroinvertebrate communities. The INDVAL test was used to search for bioindicators with habitat fidelity. A total of 1882 organisms were collected representing 42 families, with the most abundant class being Insecta. The similarity of environmental variables, including biological variables, added to the fact that there were no bioindicators related to environments with greater integrity, indicating that CA-PEA, and especially the community of macroinvertebrates, is suffering from alterations to ecosystem equilibrium. This study also indicated the necessity to broaden the purposes of existing protected areas, including systems for the protection of hydrogeographic basins and ecological corridors that produce a continuity of forest areas, especially along the length of rivers.

KEYWORDS: species, indicators, sediment, riparian vegetation

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LISTA DE ABREVIATURAS E SIGLAS

APREMAVI: Associação de prevenção do meio ambiente e a vida

UC: Unidade de conservação

PEA: Parque Estadual das Araucárias

FATMA: Fundação do Meio Ambiente

IIH: Índice de Integridade de Habitat

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1. INTRODUÇÃO

Os ecossistemas aquáticos são ambientes complexos integrados com as características do habitat. Segundo Vannote et al. (1980) são ambientes abertos apresentando fluxo contínuo e unidirecional da nascente para a foz. Respondem às variações climáticas e às interferências sofridas ao seu entorno (Silveira et al., 2006). Sendo assim constituem-se receptores finais dos resíduos produzidos (Moreno & Callisto, 2006) e como componentes que ao todo formam as bacias hidrográficas.

A integridade dos rios e riachos constitui uma preocupação para a humanidade atual principalmente em virtude das modificações antrópicas que se concentram no entorno das bacias de drenagem (Hepp & Santos, 2009). Agricultura, pastagem, remoção da vegetação ciliar são ações que contribuem para a desestruturação destes ambientes (Bonai et al., 2009) diminuindo a disponibilidade de alimentos, alterando as condições do habitat (Biasi et al., 2008). É de amplo conhecimento que essas alterações podem provocar perturbações nos ambientes aquáticos alterando sua estrutura, refletindo na comunidade de macroinvertebrados bentônicos.

A utilização dos macrobentos para avaliar a integridade dos ecossistemas aquáticos é uma ferramenta muito usada, pois estes organismos apresentam características próprias que facilitam o estudo, respondendo bem as condições do ambiente (Bonada et al., 2006; Copatti et al., 2013).

Os estudos em Unidades de Conservação como parâmetros de referência, deve levar em consideração não somente seu tamanho ou seu papel na preservação da qualidade biológica dos riachos (Mancini et al., 2005), mas os acontecimentos que ocorrem em toda a bacia de drenagem, pois impactos mesmo que fora do limite do parque podem trazer consequências negativas para os habitats de água doce dentro do parque (Sobczak et al., 2013).

Diante desses aspectos, o objetivo deste estudo foi avaliar a composição da comunidade de macroinvertebrados bentônicos entre riachos situados dentro e fora da Unidade de Conservação (UC), Parque Estadual das Araucárias (PEA). Investigando o papel do PEA na integridade dos ambientes aquáticos, a hipótese é a de que os riachos dentro da UC-PEA terão maior diversidade de macroinvertebrados bentônicos.

2. OBJETIVOS

2.1. OBJETIVO GERAL

Avaliar a composição da comunidade de macroinvertebrados bentônicos entre riachos situados dentro e fora da Unidade de Conservação (UC), Parque Estadual das Araucárias (PEA). Investigando o papel do PEA na integridade dos ambientes aquáticos.

2.2. OBJETIVOS ESPECÍFICOS

- Avaliar os parâmetros físicos e químicos da água em riachos situados dentro e fora da UC-PEA.
- Conhecer a composição de macroinvertebrados bentônicos em riachos localizados dentro e fora da Unidade de Conservação (PEA).
- Avaliar o papel da UC-PEA na integridade ambiental dos riachos.
- Determinar se a UC-PEA contribui na integridade biológica dos riachos

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3. ARTIGO CIENTÍFICO:

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CONSERVATION UNITS: THEIR INFLUENCE ON THE LIMNOLOGICAL INTEGRITY OF STREAMS

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ABSTRACT

This study evaluated the importance of a conservation unit (CU), the Parque Estadual das Araucárias (PEA), in maintaining the integrity of streams using the community composition of benthic macroinvertebrates and the influence of habitat integrity on these communities. Sampling occurred quarterly from February to December 2013. Benthic macroinvertebrates were qualitatively and quantitatively sampled (active searches and drag-sampling) and physicochemical variables of the water, sediment texture, habitat integrity index, and the abundance and richness of macroinvertebrates were analyzed. Differences in composition of macroinvertebrate families between inside and outside of the CU were evaluated using ANOSIM. Canonical correlation analysis (CCA) determined that the environmental variables had an influence on the structure of benthic macroinvertebrate communities. The INDVAL test was used to search for bioindicators with habitat fidelity. A total of 1882 organisms were collected representing 42 families, with the most abundant class being Insecta. The similarity of environmental variables, including biological variables, added to the fact that there were

no bioindicators related to environments with greater integrity, indicating that CA-PEA, and especially the community of macroinvertebrates, is suffering from alterations to ecosystem equilibrium. This study also indicated the necessity to broaden the purposes of existing protected areas, including systems for the protection of hydrogeographic basins and ecological corridors that produce a continuity of forest areas, especially along the length of rivers.

KEYWORDS: SPECIES, INDICATORS, SEDIMENT, RIPARIAN VEGETATION.

INTRODUCTION

The ecological condition of rivers and streams is directly related to the structure of the surrounding landscape (Hepp & Santos, 2009). Physical elements of the habitat and the influence of the landscape, such as catchment area, geomorphology and habitat structure (depth, substrate, water velocity), have received special attention (Johnson & George, 2010) because they act as agents in structuring benthic macroinvertebrate communities (Ferreira et al., 2014, Saly et al., 2011, Ligeiro et al., 2013,). Aquatic ecosystems are complex environments that are deeply integrated with the characteristics of the habitat. They are also highly responsive to climatic variation and disruption to their surroundings (Silveira et al., 2006). In this sense, rivers and streams constitute the ultimate recipients of alterations to the drainage basin (Moreno & Callisto, 2006). Furthermore, according to Vannote et al. (1980), aquatic ecosystems are open environments and feature a continuous, one-way flow from their source to their mouth.

Presently the integrity of aquatic ecosystems is a serious concern for humanity mainly because of anthropic modifications concentrated in the vicinity of drainage basins (Hepp & Santos, 2009). Agriculture, grazing and removal of riparian vegetation contribute to the deconstruction of these environments (Bonai et al., 2009) thereby decreasing food availability and altering the habitat (Biasi et al., 2008).

Estimates of the loss of biodiversity of aquatic ecosystems are alarming (Allan & Castillo, 2007), yet knowledge of their biodiversity is an important step for their preservation and restoration (Ligeiro et al., 2010). Research on the use of bioindicators for assessing limnological quality provide an important tool for the acquisition of information because these organisms respond efficiently to the ecological characteristics

of the environment and provide a wide variety of measurements of the possible impacts that can reach the water (Callisto & Moreno 2005; Moreno et al., 2009).

Aquatic macroinvertebrates are commonly used as bioindicators (Bonada et al., 2006) because their characteristics facilitate their implementation, such as their strong association with sediment where pollutants accumulate (Buss et al., 2006). Furthermore, they perform an integrated function in the trophic structure of aquatic ecosystems by feeding on decaying organic matter and serving as food for other invertebrates (e.g. Moulton et al., 2010) and fish (Copatti et al., 2012, Copate et al., 2013). Efforts to biomonitor aquatic ecosystems have focused primarily on understanding the processes involved, such as environmental ecology and the biology of macroinvertebrates (Bonada et al., 2006).

In Brazil, studies involving macroinvertebrate communities have emerged as an important component of evaluating the biological integrity of freshwater ecosystems, especially rivers and streams (e.g. Mazzoni et al., 2014; Copatti et al., 2010; Hepp et al., 2008;). The search for a reference habitat for monitoring with macroinvertebrates as indicator organisms is still not completely understood (Baptista, 2008). Nonetheless, the search for a reference habitat should proceed in the direction of an area where anthropogenic pressures have not significantly altered the structural and functional processes that are important for community organization (Baptista, 2008).

Using conservation units to acquire reference parameters must first take into consideration not only their size or their role in preserving biological quality of streams (Mancini et al., 2005), but also the events that occur throughout the drainage basin because even impacts outside of the boundaries of the protected area may have negative consequences for the freshwater habitat within (Sobczak et al., 2013).

Considering all these issues, we intended to assess the role of conservation units (CUs) in maintaining the integrity of aquatic habitats. Therefore, the objective of this study was to compare the composition of the benthic macroinvertebrate communities of streams within and outside of a CU, namely the Parque Estadual das Araucárias (PEA). We hypothesized that streams within the CU-PEA will have a greater diversity of benthic macroinvertebrates than streams outside of it.

MATERIAL AND METHODS

Study Area

The study area is situated within Parque Estadual das Araucárias (PEA), which is located in the Rio Chapecó basin in the municipalities of São Domingos and Galvão, Santa Catarina (26°27'08"S, 52°33'56"W). The climate of the region is classified as humid Mesothermic Subtropical with precipitation being distributed throughout the year totaling 1,250 mm to 2,000 mm annually (Araujo et al., 2006) and with harsh summers with average temperatures between 17°C and 19°C, according to the Köppen-Geiger classification (Pell et al., 2007).

Stream substrate, depth and width were measured for each study site, whereas the current was observed and described as weak, moderate or strong (Table 1). The location of the streams in relation to the CU is reported as inside or outside, and stream classification followed drainage hierarchy according to the Strahler method (Christofolletti, 1980).

Table 1: General characteristics of study points/streams in the Rio Jacutinga and Rio Bonito basins, São Domingos, SC. The table shows the code used to denote the sampling points, the stream name, the predominant river-bottom substrate, the width from shore to shore, the average depth, the description of the current and the location relative to CA.

Code	Stream	Substrate	Width (m)	Depth (m)	Current	Location
RJ1	R. Jacutinga (RJ1)	Sandy/OM/mud	4	1	Moderate	Inside CU.
RS2	R. da Soja (RS2)	Sandy/OM/mud	0.5	0.15	Weak	Outside CU.
AJ3	Afluente do Jacutinga (AJ3)	Rock slab/boulders/sand	3	0.5	Strong	Outside CU.
RJ4	R. Jacutinga after PEA (RJ4)	Sandy/rock slab	6.8	0.8	Strong	Outside CU.
RA5	R. Araçá (RA5)	Sandy/OM/mud	4.9	0.2	Moderate	Outside CU.
RB6	R. Bonito (RB6)	Rock slab/boulders/sand	4.6	0.8	Moderate	Outside CU.
RJ7	R. Jacutinga before PEA (RJ7)	Sandy/mud	6	0.15	Strong	Outside CU.
AB8	R. Água Branca (AB8)	OM/mud	1	0.5	Weak	Inside CU.
RA9	R. Araçá (RA9)	Rock slab/then sand	3.8	0.2	Strong	Inside CU.
RT10	R. das Taquaras (RT10)	Sandy/OM	2	0.2	Moderate	Inside CU.
RB11	R. da Bica (RB11)	Sandy/OM/ mud	1.5	0.2	Moderate	Inside CU.
RL12	R. da Lagoa (RL12)	Sandy/OM/ mud	5.5	0.15	Moderate	Inside CU.

Six of the study streams were located inside the CU and possessed landscape structures that guarantee a good state of conservation of the riparian vegetation. Six other study streams were located outside of the CU, predominantly in areas of agriculture and livestock land use (Figure 1). Data collection took place from February to December of 2013 on a quarterly basis for a total of four sampling visits.

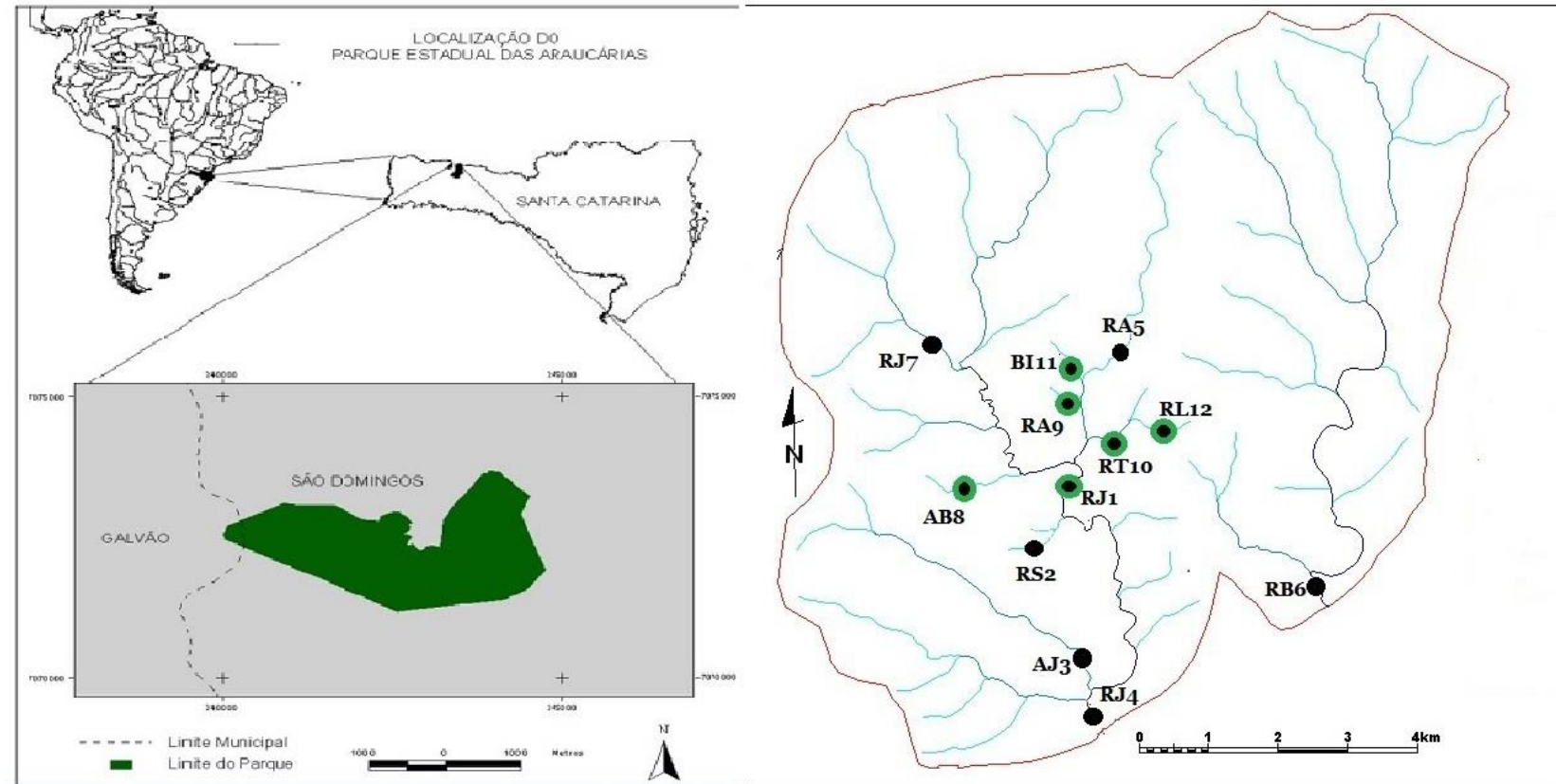


Figure 1 – Geographic location of sampling points of the Rio Jacutinga and Bonito, São Domingos hydrographic basins, Santa Catarina. Legend for codes: Riacho Jacutinga (RJ1, RJ4, RJ7), Riacho da Soja (RS2), Riacho Afluente do Jacutinga (AJ3), Riacho Araçá (RA5, RA9), Riacho Bonito (RB6), Riacho Água Branca (AB8), Riacho das Taquaras (RT10), Riacho da Bica (RB11) and Riacho da Lagoa (RL12). The green shaded points are located inside the CU, whereas the un-shaded points are located outside the CU. Source: adapted from Apremavi (2002)

Habitat Integrity Index

In order to determine and evaluate the condition of the environments of the study streams, the habitat integrity index (HII) was adapted from Nessimian et al. (2006, 2008) was used. The HII was determined using the following characteristics of the sampling sites: the pattern of use of the riparian vegetation; the size, composition and conservation status of the riparian vegetation; restraint systems; sediments; structure and/or excavation of the bank; characteristics of the riverbed; debris; and aquatic vegetation. The HII classifies environments from 0 to 100%, with 100% being environments the highest integrity and 0% the lowest.

Data collection

Physiochemical analysis of the water was performed *in loco* for temperature (°C), dissolved oxygen (mg/L) and pH. Water samples were taken in vials for subsequent laboratory analysis for the following variables: conductivity ($\mu\text{S}/\text{cm}$) and turbidity (NTU). All assays were performed as directed by Standard Methods (Apha, 1995).

Sediment samples were collected for assessment of granulometric texture and percentage of organic matter. Determination of the granulometric texture of the sediment followed the scale of Wentworth (1922). The level of organic matter (OM) was determined by calcining the samples at 550 °C, weighing them, and calculating the difference between the initial sample weight and the weight after calcination.

Organisms were collected with a drag-type sampler with a 300 μm mesh net for five minutes at each sampling point. Active searches using a sieve were also performed

for 40 minutes/person. The sediment collected with the sampler was placed in plastic barrels with 70 % alcohol and taken to the laboratory where it was screened with a set of mesh sieves of 2, 1 and 0.5 mm. The organisms retained in the first two sieves were packaged and preserved in 70 % alcohol, whereas the sediment in the last sieve was screened under a stereomicroscope. The collected invertebrates were identified to the taxonomic level of family with the aid of the taxonomic keys of Mugnai et al., (2010), Pes et al., (2005) and Dominguez et al. (1997), with the exception of Oligochaeta and Hirudinea, which were grouped into classes.

Data analysis

Streams with a HII of less than 30% were classified as of low integrity (LI), those with a HII between 50 to 65% were classified as of average integrity (AI) and those with a HII greater than 70% were classified as of high integrity (HI).

In order to assess the influence of the environmental variables on the structure of the benthic macroinvertebrate community, a canonical correlation analysis (CCA) was performed using R Core Team Software program (2014) with the variables selected by the *stepwise* test (Melo & Hepp, 2008).

For analysis of the biological community, abundance (N) and taxonomic richness (S) were calculated. To compare the macroinvertebrate composition of streams inside and outside of the CU, the biological data on the family composition was submitted to an analysis of similarity (ANOSIM) using a matrix of distances between streams based on their species composition. The Bray-Curtis distance metric and the UPGMA grouping method were used. The sum of the abundances from the four samples of each stream was used in this analysis.

In order to determine which organisms were dominant in the communities of each stream, the dominance index of Kownacki (1971), was calculated using the formula:

$$d = \frac{\bar{Q} \times 100 \times f}{\sum \bar{q}}$$

Where d = dominance;

Q = average number of individuals of the examined family in the series of samples.

F= the ratio n/N, where (n) is the number of samples in which the examined family was represented and (N) is the total number of samples.

$\sum Q$ = sum of the average number of individuals for each family.

In order to determine which taxa are potential bioindicators, an analysis of indicator values was performed using INDVAL (Dufrêne and Legendre, 1997). This test was chosen because it seeks to identify relationships of fidelity between the identified families and groups of the study streams by combining measures of specificity and fidelity by measuring frequency and abundance (Mcgeoch et al., 2002) of the families in each group of streams. Species with high specificity and fidelity in a habitat will have a high indicator value. The significance of INDVAL was evaluated using the Monte Carlo randomization test. The program PCORD 6 was used to perform this analysis.

An analysis of variance (ANOVA) was performed on data from Rio Jacutinga in order to determine if there were significant differences in richness and abundance of the families of macroinvertebrates with respect to being located upstream, within and downstream of CU-PEA.

RESULTS

The assessment of the integrity of the streams using HII showed that all the streams located within the CU had HII values greater than 70%, classifying them as of high integrity (HI). Among the streams outside of the CU, five had values within 50 to 65%, classifying them as average integrity (AI). Only one stream, also located outside the CU, had a score of only 30% classifying it as of low integrity (LI).

The values for abiotic variables were homogeneous among streams (Table 2 Appendix). The physiochemical analysis of the water showed no oscillations indicative of disorder. However, three variables, conductivity, organic matter and pebbles, were selected by the CCA with the first axes explaining 17% of the observed pattern.

Forty-two families of the benthic macroinvertebrates were recorded in this study. Of the 1,882 specimens collected, the class Insecta was most abundant with 1,397 individuals, followed by Bivalvia with 147, Gastropoda with 112 and Annelida with 105 individuals (Table 3 Appendix). The taxonomic richness was greater outside of the CU than it was inside, with 40 and 34 benthic macroinvertebrates, respectively.

Chironomidae was dominant both inside and outside of the CU, with 10.7 and 30% of the abundance, respectively (Table 3 Appendix). The subdominant families represented 40.5%, whereas the non-dominant families totaled 57%.

The INDVAL analysis of indicator value (Table 4 Appendix) found only the family Chironomidae to have good fidelity with streams located outside the CU. The value of the INDVAL analysis was 59.7% ($p = 0.02$). The indicator values for all the other families were not indicative of good fidelity with the habitat in which they were found (Table 4 Appendix).

The results of the similarity analysis shown in the dendrogram (Figure 2) demonstrate that the streams form a cohesive group and that the taxonomic composition of groups of streams are not significantly different (ANOSIM) ($R = -0.107$; $p = 0.824$).

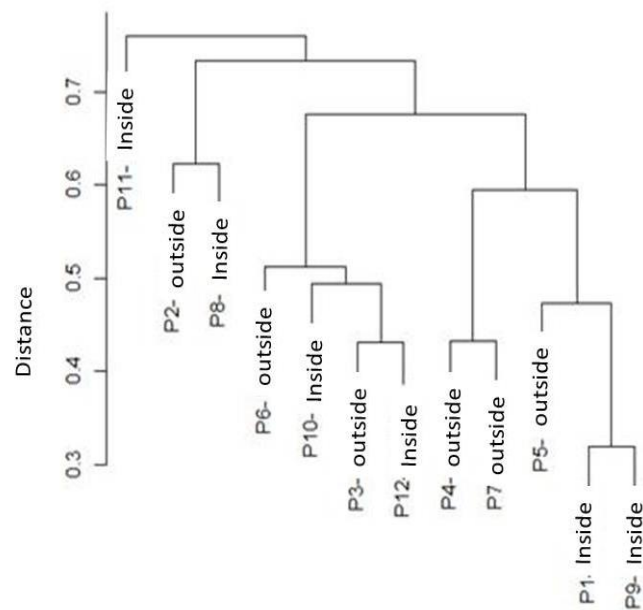


Figure 2- Dendrogram of similarity in species composition of benthic macroinvertebrates of the sampled rivers in the Rio Jacutinga and Rio Bonito hydrogeographic basins, São Domingos, Santa Catarina: Inside = within the CU; Outside = outside of the CU.

Analysis of variance (ANOVA) was used to test for differences in richness and abundance of benthic macroinvertebrates among locations relative to the CU in the Rio Jacutinga basin because it included collection points both upstream, within and downstream of the CU. The analysis found $p=0.19$ for richness and $p=0.30$ for abundance. From these results it can be inferred that the richness and abundance of macroinvertebrates did not differ significantly between locations within or downstream of the CU.

DISCUSSION

The homogeneity of the physicochemical variables of the water and of the sediment texture in streams both within and outside of the CU-PEA reinforces the fact that these measurements are specific and that they represent a transitory situation (Queiroz et al. 2008). This fact is also addressed by Roque and Trivinho-Strixino (2000), who commented on the importance of including biological measures in assessing the integrity of ecosystems and the long-term effects of pollution.

The presence of insects of the most common taxa is not surprising given the fact that they are one of the most abundant and diverse groups of the benthic fauna (Higuti et al. 1993). Among these, Chironomidae was the most abundant family of macroinvertebrates, likely due to their great ecological plasticity, adaptation potential and opportunistic tendencies (Kleine and Trivinho-Strixino, 2005; Moretti & Callisto, 2005; Molozzi et al., 2007; Corbi and Trivinho-Strixino, 2008) making them capable of living in varied environmental conditions (Silva et al., 2008).

The associations observed in the INDVAL analysis of indicator species indicate that the family Chironomidae was associated with streams outside of the CU-PEA. These organisms are known to be tolerant of large changes in temperature and to variation in the level of pollution (Dominguez et al., 2006).

The similarity found in both species composition and richness of macroinvertebrates inside and outside of the CU-PEA may be related to land use in the drainage basin. Allan (2004) argues that streams suffer effects of agricultural land use when it exceeds 30-50% of the catchment area. This finding reinforces the important role of riparian vegetation in attenuating the effects of runoff from rainwater that carry nutrients and contaminants into the waterways since it is located on the soil (not impacted) surface and acts to absorb and drain water (Santos & Spavorek, 2011).

Riparian vegetation also contributes to the equilibrium of aquatic environments by being a source of primary production, thereby providing nutrients and organic matter that make up the base of the heterotrophic food chain (Silveira, 2004). Thus, aquatic ecosystems, even within the CU, can experience numerous changes in their physical, chemical and biological characteristics in response to human activities that occur in the environment, especially agricultural activities and the draining of springs (Kasangaki et al., 2008).

The greatest richness and abundance of macroinvertebrates was at a point downstream from the CU, but the analysis of variance (ANOVA) found no significant differences. Thus, the hypothesis that CU-PEA influences the integrity of contributing streams by maintaining greater diversity and richness of benthic macroinvertebrates was not supported by this study. On the other hand, the similarity in environmental variables among streams, such as having communities of macroinvertebrates without bioindicators that are strongly related to environments of more integrity, indicates that CU-PEA, and especially the overall community of macroinvertebrates, are suffering alterations to ecosystem equilibrium.

These results corroborate other studies (e.g. Medeiros & Young, 2011; Agostinho et al., 2004; Takeda et al., 2004) in arguing that although water resources and conservation of biodiversity are not their the primary purposes of protected areas, their creation can be an important and effective tool for the preservation of these ecosystems and their communities. In this study, the streams located within the CU had greater HII values than those located outside. Such higher integrity, as well as other biological results presented herein, should indicate to governing bodies the need to expand the purposes of existing protected areas, including systems for protection of

hydrogeographic basins and ecological corridors that produce a continuity of forest areas, especially along the length of rivers (Pera et al., 2013; Paz et al., 2008).

CONCLUSIONS

Regarding the maintenance of the biological integrity of streams, we conclude that CU-PEA is suffering from a strong influence by the surrounding area, particularly from the actions of agriculture. The lack of riparian vegetation that ensures continuity from spring to mouth is compromising the equilibrium of these aquatic ecosystems and, especially, the community of benthic macroinvertebrates. The aim of the CU-PEA has been to protect terrestrial species within its limits, especially araucaria vegetation. However, freshwater ecosystems are susceptible to anthropic pressures. Therefore, effective recovery of permanent preservation and areas of riparian vegetation along the entire length of the waterways is recommended in order to ensure the preservation of the hydrogeographic basin and restore the integrity of the biological communities.

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APPENDICES

Table 2. Characteristics, physicochemical variables of the water and granulometry of the sampling points in the Rio Jacutinga and Bonito hydrogeographic basins, São Domingos, SC. DO = dissolved oxygen; pH = hydrogen potential; C = conductivity; om = organic matter; PE = pebbles; CS = course sand, MS = med; VFS = very fine sand.

Classif	Points	DO (mg/L ⁻¹)	pH	Temp	C (µS/cm)	Turbidit y	OM%	PE	CS	MS	FS	VFS	Mud
LI	RA5	5.77 (± 0.68)	6.51 (± 0.78)	19.03 (± 3.90)	44.5(±3.67)	6.15	12(±0.96)	20.12(±35.74)	8.07(±3.7)	18.01(±11.2)	15.75(±9.25)	22.81(±13.6)	15.2(±8.1)
		5.38 - 6.79	5.69 - 7.23	14.2 - 22.80	39.3-47.1	1.68-9.04	12.7-10.96	0.5-73	3.3-12.5	5.6-29.2	3.6-33.4	4-36.4	6.5-25.7
AI	RS2	5.75 (± 1.75)	6.12 (± 0.67)	16.55 (± 3.96)	27.7(±5.79)	6.28	18.25(±4.78)	15.85(±9.22)	20.03(±12.3)	24.51(±4.7)	12.2(±3.8)	16.33(±8.5)	11.01(±5.8)
		4.07 - 7.94	5.5 - 6.85	11.4 - 20.80	19.5-31.8	4.89-8.11	22.9-13.1	6.2-26.7	8.6-37.4	20.4-29.9	7.6-16	5.6-26.3	2.4-15.3
	AJ3	6.71 (± 1.58)	6.68 (± 1.02)	17.4 (± 4.89)	41.43(±4.90)	6.55	15.05(±7.37)	36.95(±25.6)	21.97(±4.9)	19.38(±11.1)	10.13(±9.5)	6.96(±6.1)	4.57(±4.1)
		5.23 - 8.84	5.4 - 7.90	12.4 - 23.7	34.5-44.9	1.87-12.52	25.8-9.6	13.9-61	17.3-27.3	0-31.3	1.2-20	0.31-12.3	0.2-9.1
	RJ4	7.14 (± 1.37)	6.78 (± 1.02)	16.03 (± 3.52)	38.76(±3.29)	8.02	12.72(±3.80)	27.6(±26.9)	13.86(±9)	13.63(±8.3)	11.17(±5.7)	20.77(±23.9)	12.94(±12.8)
		6.16 - 9.14	5.4 - 7.63	13 - 19.60	34.1-41.1	3.67-	18-8.9	0.05-59.5	0.4-19.2	3.1-23.4	3.6-17.7	2.2-55.3	1.4-28.8

					16.57								
RB6	6.44 (± 1.17)	6.17 (± 0.81)	18.68 (± 2.72)	31.7(±3.39)	9.8	12.57(±4.3 4)	4.7(±3.62)	9.48(±7.3)	21.12(±5.2)	30.03(±9.9)	26.04(±10. 7)	8.59(±3.5)	
	5.24 - 7.94	5.32 - 6.92	15.7 - 22.10	26.9-34.1	4.9-16	18.5-8.5	1.3-8.1	4.1-15.7	15.4-28	20-42.9	16-41.2	4.1-12.5	
RJ7	6.62 (± 1.30)	6.79 (± 0.76)	22.25 (± 6.99)	54.1(±6.08)	6.49	11.07(±5.1 0)	15.84(±10. 9)	8.94(±7.1)	16.14(±4)	16.01(±4 3.4)	21.36(±10. 6	21.68(±14. 3)	
	5.53 - 8.40	5.92 - 7.45	15.4 - 29.80	45.5-58.4	2.32-	18.3-6.3	4.5-25.9	2.3-15.5	11.5-19.9	12.2-19.4	12.5-36.5	8.5-40	
					14.13								
HI	RJ1	5.89 (± 2.04)	7.41 (± 1.32)	19.62 (± 7.28)	44.46(±1.4 6)	6.27	15.92(±4.8 2)	4.87(±6.8)	20.72(±16. 9)	16.88(±13. 8)	17.6(±12.3)	14.22(±10. 2)	25.69(±23. 6)
		3.76 - 8.48	5.7 - 8.91	11.9 - 28.9	42.4-45.5	3.8-11.04	22-13.1	0.35-14.7	3-43.7	3.7-32.7	3.6-18.2	2.9-25.5	5.3-23.6
AB8	6.46 (± 1.72)	6.05 (± 0.24)	18.98 (± 4.93)	26.3(±2.40)	20.73	38.17(±10. 86)	38.3(±6.84)	18.35(±6.1)	14.35(±5.1)	7.41(±2.4)	15.04(±14. 8)	6.54(±2.2)	
	4.65 - 8.56	5.85 - 6.35	14.8 - 26.00	22.9-28	6.63-	49-24.8	33.6-48.4	10.7-25.4	8.8-19.3	3.9-9.4	7-37.2	4-9.5	
					43.26								

Continuatin of Table 2

Points		DO	pH	Temp	C ($\mu\text{S/cm}$)	Turbidity	OM%	PE	CS	MS	FS	VFS	Mud
Classif	HII	(mg/L^{-1})				y							
AI	RA9	6.51 (\pm 1.06)	6.73 (\pm 0.60)	20.8 (\pm 5.23)	46.46(\pm 0.1 8)	5.99	15.5(\pm 10.9 0)	12.52(\pm 11. 9)	9.62(\pm 7.8)	15.18(\pm 7.4)	14.33(\pm 7.1)	21.4(\pm 8.5)	26.92(\pm 20. 5)
		5.77 - 8.07	5.85 - 7.24	16.2 - 26.00	46.2-46.6	1.55-9.85	31.5-7.1	3.2-28.9	6.5-20.6	4.1-20.3	5.5-22.7	12-29.9	4.5-53.5
	RT10	6.28 (\pm 1.60)	6.81 (\pm 0.82)	19.68 (\pm 3.48)	43.3(\pm 3.95)	18.21	13.4(\pm 4.68)	7.9(\pm 10.5)	13.75(\pm 10. 5)	16.45(\pm 5)	37.79(\pm 11. 8)	15.26(\pm 16. 2)	8.8(\pm 7.6)
		5.23 - 8.65	5.61 - 7.45	16 - 23.30	37.7-46.1	2.7-44.68	19.9-9.3	0.05-24.3	2.1-15.2	6-16.4	12.4-37.7	13-44	8.8-23.4
	RB11	5.99 (\pm 1.71)	6.47 (\pm 0.87)	22.35 (\pm 6.65)	35.53(\pm 0.8 0)	7.81	12.53(\pm 7.1 4)	18.72(\pm 12)	17.32(\pm 7)	19.78(\pm 6.4)	15.36(\pm 9.9)	13.89(\pm 7.3)	14.77(\pm 12. 2)
		4.5 - 8.45	5.49 - 7.30	15.50 - 29.40	34.4-36.1	4.76- 10.24	18.5-2.20	8.06-35.9	12.4-29	19.7-25.8	7.4-29	4.8-21.2	2.3-31
	RL12	6.48 (\pm 0.68)	6.47 (\pm 0.61)	18.45 (\pm 2.57)	47.5(\pm 4.24)	2.59	20(\pm 9.28)	20.01(\pm 27. 4)	10.37(\pm 6.6)	14.5(\pm 7.3)	28.57(\pm 10. 3)	9.57(\pm 21)	15.37(\pm 9.9)
		5.81 - 7.12	5.64 - 7.11	16.5 - 22.10	41.5-50.5	1.48-3.82	22.4-12.2	0.13-60	0.64-14.7	5.2-22.6	5.5-28.5	4.7-51.3	4.3-26.8

Table 3 – Aquatic invertebrates sampled from streams in the Rio Jacutinga and Bonito hydrogeographic basins, São Domingos, Santa Catarina, from February to December 2013. N = Taxa abundance. Dominance index according to Kownacki (1971): ND = Not dominant; SD = Subdominant; and D = Dominant. Location of streams with respect to the CU: outside and inside.

Taxa	Outside	Inside	N	D
Mollusca				
Gastropoda				
Ancylidae		17	49	66
Planorbidae		2	5	7
Lymnaeidae		8	2	10
Physidae		28	1	29
Bivalvia				
Sphareiididae		68	79	147
Annelida				
Oligochaeta				
		26	8	34
Tubificidae		1		1
Hirudinea				
		26	13	39
Glossiphonidae		9	22	31
Arthropoda				
Crustacea				
Hyalloelidae		1	20	21
Copepoda		1		1
Aeglidae		38	61	99
Insecta				

Ephemeroptera

Baetidae	43	3	46
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Continuation of Table 3

Caenidae	85	66	151
Leptohyphidae	6		6
Leptophlebiae	72	92	164
Odonata			
Aeshnidae	6	23	41
Corduliidae	1		1
Libellulidae	18	32	50
Gomphidae	40	42	82
Calopterygidae	32	20	52
Coenagrionidae		1	1
Megapodagrionidae	5	2	7
Dicteriadidae	3	1	4
Plecoptera			
Perlidae	2	6	8
Gripopterygidae	14	6	20
Heteroptera			
Belostomatidae	12	3	15
Coleoptera			
Dytiscidae (adulto)	5	12	17
Elmidae (larva)	78	90	168
Hydrophilidae (larva)	2	3	5
Girynidae (adulto)	13	6	19
Noteridae (adulto)		1	1
Dryopidae (adulto)	3		3
Trichoptera			
Calamoceratidae	24	27	51
Hydropsychidae	35	2	37

Hydroptilidae	3		3
Odontoceridae	2	2	4

Continuation of Table 3

Philopotamidae	8	2	10
Polycentropodidae	11	1	12
Leptoceridae	1		1
Diptera			
Ceratopogonidae	2		2
Chironomidae	331	85	416
Abundance	1082	788	1870

Table 4- Percentage values of the indicator families in streams inside of PEA (1) and outside of PEA (2).

Column	Maxgrp	Value(IV)	Mean	S. Deav	p
Ancy	1	12.4	15	5.18	0,6 277
Plano	1	3.0	5.6	2.68	1.0 000
Lymn	2	6.7	7.2	3.09	0.4 827
Physi	2	12.1	8.8	3.76	0.2 286
Spha	2	5.8	8.8	3.97	0.7 451
Oligo	2	12.7	11.8	4.45	0.3 847
Hiru	1	2.8	7.2	3.48	1.0 000
Tubi	2	4.2	4.2	0.06	1.0 000
Glossi	1	8.9	11.6	4.31	0.6 063
Hyallo	1	11.9	8.7	3.75	0.2 394
Cope	1	4.2	4.2	0,06	1.0 000
Aegli	1	30.8	28.6	6.19	0.3 057
Bae	2	22.8	15	5.19	0.1 084
Cae	2	32.8	32.1	6.59	0.3 823
LeptoHy	2	8.3	5.1	3.13	0.4 897
Leptoph	1	35.1	38.9	6.18	0.6 637
Aesh	1	18.7	22.7	5.86	0.7 081
Cordu	2	4.2	4.2	0.06	1.0 000
Libe	1	34.7	30.8	5.57	0.2 346
Gomph	1	25.6	30.7	6.27	0.7 810
Calo	2	30.8	33.2	5.79	0.5 821
Coena	1	4.2	4.2	0.06	1.0 000
Mega	2	11.9	11.2	4.15	0.5 107
Dicte	2	9.4	8.2	3.87	0.6 123
Perli	1	12.5	10.0	3.91	0.2 993
Gripo	2	11.7	14.6	5.04	0.6 955

Continuation of Table 4

Belos	2	10	11.8	4.44	0,6 155
Dytis	1	17.6	15	4.63	0.2 825
Elmi	1	32.3	36.6	6.63	0.6 929
Hydrop	2	3.3	7.2	3.25	1.0 000
Giry	2	5.7	8.8	3.59	0.8 716
Note	1	4.2	4.2	0.06	1.0 000
Dryop	2	8.3	5.5	2.78	0.4 873
Cala	2	21.6	28	5.86	0.9 228
Hydrods	2	23.6	14	4.75	0.0 416
Hydropti	2	8.3	5.6	2.78	0.4 999
Odon	2	4.2	7.3	3.09	1.0 00
Philo	2	10	8.6	3.53	0.4 699
Polyc	2	15.3	10	4.01	0.1 736
Lepto	2	15.3	10	4.01	0.1 736
Cerat	2	4.2	4.2	0.06	1.0 000
Chiro	2	59.7	41.5	7.11	0.0 206

