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THAIS DE FATIMA CORREA

USO DE COLEÓPTEROS AQUÁTICOS PARA CARACTERIZAÇÃO DE RIACHOS CONSERVADOS DO CERRADO BRASILEIRO

Anápolis
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Dissertação apresentada ao Programa de Pós-Graduação *Stricto Sensu* em Recursos Naturais do Cerrado, da Universidade Estadual de Goiás para obtenção do título de Mestre em Recursos Naturais do Cerrado. Orientador: Prof. Dr. Beat Oertli. Co-orientador: Prof. Dr. Fabrício Barreto Teresa.

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DEDICATÓRIA

Ao Bioma Cerrado.

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Muitíssimo obrigada.

SUMÁRIO

RESUMO

Em paisagens que estão sob alta pressão antrópica, como o Cerrado brasileiro, é importante definir condições de referência presentes em áreas ainda conservadas. A utilização de indicadores biológicos permite a caracterização destes habitats e, além disso, podem evidenciar estágios iniciais de degradação. Neste estudo, pretende-se investigar se riachos conservados do Cerrado brasileiro poderiam ser caracterizados usando besouros aquáticos (Coleoptera), e se as respostas da comunidade poderiam evidenciar impactação moderada. As coletas foram realizadas durante a estação seca de 2010, no estado de Goiás, Brasil. As amostras, utilizando Surber, foram tiradas de 48 córregos situados em duas bacias hidrográficas do rio Paraná e rio Tocantins. Um total de 4.194 indivíduos de besouros aquáticos foram coletados representando 42 táxons. Os riachos foram classificados em cinco grupos com base na estrutura e composição taxonômica da comunidade. Condutividade e turbidez foram as variáveis que apresentaram maior influência sobre as comunidades. O impacto nos riachos relacionado com a degradação da paisagem influenciou as comunidades dos besouros aquáticos, afetando os traços morfológicos relacionados a respiração. Este estudo evidenciou que coleópteros aquáticos podem ser usados para a caracterização de riachos conservados, porém não são apropriados para a detecção de estágios iniciais de degradação, para isso, uma abordagem que utilize um conjunto de indivíduos que representem diferentes Ordens de insetos aquáticos seria mais eficiente.

Palavras-chave: riachos de cabeceira, uso do solo, biomonitoramento, traços bio-ecológicos, integridade do habitat.

ABSTRACT

In landscapes that are under high anthropogenic pressure, like the Brazilian Cerrado, it is important to define the reference conditions that are present in the still existing pristine areas. The use of biological indicators allow to characterize these habitats, and furthermore can highlight early stages of degradation. In this study, we aim to investigate whether pristine streams from the Brazilian Cerrado could be characterized using aquatic beetles (Coleoptera), and whether early community's responses could be evidenced for a low impairment. Field work was performed during the dry season of 2010 in the state of Goias, Brazil. Surber samples were taken from 48 streams located in two Watersheds: river Paraná and river Tocantins. A total of 4.194 individuals of aquatic Coleoptera were collected representing 42 taxa. The streams could be classified in five groups on the bases of the taxonomic structure and composition of the community. Conductivity and turbidity were the main driving variables. Stream impairment related to landscape degradation impacted the aquatic beetles communities, namely driving the morphological traits linked to respiration. This study evidenced that coleopteran can be used for characterization of pristine streams. Nevertheless, they are not appropriated for detecting early states of degradation, and for this an approach using a set of individuals from different Orders of aquatic macroinvertebrates is likely to be more efficient.

Keywords: headwaters, land-use, biomonitoring, bio-ecological traits, habitat integrity.

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Figure 1. State of Goias, Brazil, with the location of the 48 sampled streams within the Paraná River (1) and Tocantins River (2) watersheds.

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Figure 3. PCA graphics for the distribution of the streams based on environment data, axis 1 = 29% of explanation and axis = 16% of explanation about how data vary (WRF = width of riparian forest, VRF = vegetation of riparian forest in 10 m, CRF = completeness of riparian forest and RCE = Riparian, Channel and Environmental Inventory). Colors represent the stream classification resulting from the cluster analysis of the faunal data (i.e. stream groups).

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Figure 6. Boxplots for conductivity and turbidity characterizing the five stream groups (grouped according to Coleopteran communities, i.e. Table 6). The outlier streams (Nr 14 in the group 4 (value = 120) and Nr 42 in the group 5 (value = 110.56)) were removed for a better visualization but were kept in the Kruskal Wallis analysis). Between groups significant differences were tested using Mann-Whitney U tests.

Table 1. Functional traits based on morphology and ecology of the organisms, according to Poff, 1997; Tomanova et al., 2008; Colzani et al., 2013.

Table 2. Percentage of streams where the taxa is present, in each of the five groups. The color and percentages indicate the frequency of occurrence of the taxa in the stream group, the lightest represent the smallest percentage the darker the largest. The groups 1, 2 are the streams with taxa observed in less than two samples; the groups 3, 4 and 5, the streams with taxa observed in more than three samples. A= adults and L= larvae.

Table 3. Correlation (Spearman Rank correlation test) between the taxonomic metrics (abundance, and richness Chao 1) and functional diversity metrics (Mean Pairwise Distance (MPD) and Trait diversity (TD)) (**= significant at $p<0.01$ and * =significance at $p<0.05$).

Table 4. Correlations (Spearman rank correlation test) between the environmental variables and the taxonomic metrics: abundance and taxonomic richness. (# = near significant correlation at $p<0.10$ and * = significant correlation at $p<0.05$).

Table 5. Correlations (Spearman rank correlation test) between the environmental variables, RCE and functional diversity metrics.

Table 6. Spearman rank correlation test between frequencies of occurrence of the 21 traits categories and the environmental variables. The analyses exclude the streams where no coleopteran was found # = significant correlation at $p<0.10$ and * = significant correlation at $p<0.05$).

INTRODUÇÃO GERAL

O processo de exploração de recursos naturais implica na conversão de habitats para a produção de pastagens e áreas cultiváveis ocasionando a fragmentação, perda de habitat e biodiversidade interferindo assim no funcionamento de serviços ecossistêmicos nos Biomas (Silva et al., 2011). No Cerrado brasileiro, considerado um mosaico florestal, formado por diferentes fitofisionomias como savanas, campos, matas seca e de galeria e o segundo maior bioma em extensão territorial da América do Sul, tem se observado uma redução de sua extensão nas últimas décadas devido à expansão agrícola em suas áreas. Atualmente, restam em torno de 20% de sua área natural e desse percentual, cerca de 3% localiza-se em áreas de preservação (Jepson, 2005; Klink and Machado, 2005; Marris, 2005).

O Cerrado apresenta uma elevada biodiversidade abrigando uma variedade de plantas, animais e microrganismos. Devido a esse fato e somado a velocidade com que a degradação ambiental afeta o Bioma seja por plantações, formações de pastagem, desmatamento, queimadas ou por ocupação humana, hoje é considerado, assim como a Mata Atlântica, um *hotspot* brasileiro para conservação (Myers et al., 2000; Marris, 2005; Mittermeier et al., 2005; Meyer et al., 2007).

Além de sua biodiversidade, o Cerrado possui também, elevada importância em relação aos recursos hídricos devido à quantidade de nascentes em seu território que contribuem para a formação e manutenção de seis das oito bacias hidrográficas do país (Wantzen, 2003; Wantzen et al., 2006). Parte dessas nascentes está inserida em ambientes que apresentam uma variação nos níveis de degradação ambiental, relacionada com os diferentes padrões de uso do solo, dos quais a agricultura e a pecuária estão entre os que promovem alterações da paisagem de suas bacias de drenagem gerando impactos sobre a integridade aquática (Niyogi et al., 2007; Carvalho et al., 2009; Heino et al., 2013). Dentre esses impactos podemos citar, a sedimentação, o enriquecimento de nutrientes, a contaminação por metais pesados dentre outros (Allan, 2004).

Entretanto, sabemos que a mata ripária representa uma importante barreira, amenizando os efeitos da degradação, pois está intimamente ligada nos processos de estruturação e manutenção dos ambientes aquáticos de acordo com seus serviços ecológicos como aqueles relacionados a qualidade da água, estabilização de barrancos, fonte de material alóctone e retenção de sedimentos (Patten, 1998; Meixler and Bain, 2010; Casatti et al., 2012; Moraes et al., 2014). Assim, neste trabalho, definimos como efeitos de “degradação moderada”, as variações ambientais das bacias de drenagem, causada por diferentes padrões de uso do solo, que atuam sobre riachos com uma elevada integridade local.

A degradação na paisagem modifica o ambiente de forma que provoca diminuição da mata ripária, reduz a absorção de água, aumenta a erosão e a compactação do solo, gera assoreamento, eleva a temperatura, a incidência de luz e quantidade de matéria orgânica levando a variações da condutividade e turbidez, diminuição da quantidade de oxigênio dissolvido, contaminação da água por poluentes, lixiviação, e reduz a disponibilidade de recursos variados. Tais modificações proporcionam a homogeneização do ambiente, reduzindo a diversidade de micro-habitat e, consequentemente, a diversidade de áreas possíveis de colonização (Townsend et al., 1997; Nogueira et al., 2011; Ricklefs 2011).

As comunidades aquáticas respondem a diversos fatores ambientais (Vannote et al., 1980; Townsend et al., 2006; Casatti et al., 2012) e os insetos aquáticos bentônicos, por serem altamente responsivos às alterações ambientais, são considerados bioindicadores de qualidade de água (Rosenberg and Resh, 1993; Pond, 2012). Neste grupo estão os besouros aquáticos da ordem Coleoptera, maior ordem dentro da classe Insecta, com aproximadamente 400 mil espécies já descritas ao redor do mundo, entretanto apenas uma parte (4%) é aquática (Jäch and Balke, 2008; Segura et al., 2011). Além disso, apresentam uma ampla distribuição devido as suas características biológicas que permitem dispersão e colonização de diferentes habitats (Picazo et al., 2012).

Os efeitos das alterações ambientais sobre os padrões de diversidade de insetos aquáticos são conhecidos, principalmente no que se refere aos descritores tradicionais de diversidade (Callisto et al., 2001). Entretanto, se as alterações na composição de espécies em resposta aos impactos ambientais repercutem em outros componentes da diversidade biológica, como a diversidade funcional, que baseia-se em atributos funcionais observados nos organismos e que podem interferir no funcionamento dos ecossistemas, é uma questão que ainda precisa ser melhor explorada (Usseglio-Polatera et al., 2000; Tilman, 2001; Colzani et at., 2013).

Desta forma, considerando a velocidade com que áreas naturais de Cerrado são perdidas, é de suma importância caracterizar e conhecer as áreas de referência (não degradadas), assim como avaliar a influência das modificações antrópicas nas bacias de drenagem sobre o corpo d’água e as suas comunidades. O que permitirá propor e identificar medidas de recuperação e preservação desses ambientes (Sponseller et al., 2001; Weigel et al., 2003; Allan, 2004; Boyero et al., 2009).

OBJETIVOS

O objetivo do trabalho foi investigar se riachos conservados do Cerrado brasileiro poderiam ser caracterizados utilizando besouros aquáticos da ordem Coleoptera e se as respostas primárias da comunidade, para um nível moderado de degradação, poderiam ser evidenciadas.

Os objetivos específicos foram determinar:

(i) como a estrutura e a composição, taxonômica e funcional, da comunidade variam entre riachos conservados;

(ii) como um moderado grau de degradação poderia influenciar a comunidade.

Como hipótese temos que riachos conservados e semiconservados são heterogêneos, e possuem uma variedade de nichos disponíveis o que permite uma maior diversidade taxonômica e funcional. Outra hipótese relaciona-se com o fato de que mesmo uma degradação moderada já produz um impacto perceptível sobre a comunidade de besouros aquáticos, evidenciando assim, o seu potencial como organismos sentinelas.

O artigo será submetido na Revista *Annales de Limnologie – Internacional Journal of Limnology* e as citações e referências foram formatadas de acordo com as normas da Revista.

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ARTIGO

USE OF AQUATIC BEETLES (COLEOPTERA) AS SENTINELS FOR CHARACTERIZATION OF PRISTINE STREAMS IN THE BRAZILIAN CERRADO

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ABSTRACT

In landscapes that are under high anthropogenic pressure, like the Brazilian Cerrado, it is important to define the reference conditions that are present in the still existing pristine areas. The use of biological indicators allow to characterize these habitats, and furthermore can highlight early stages of degradation. In this study, we aim to investigate whether pristine streams from the Brazilian Cerrado could be characterized using aquatic beetles (Coleoptera), and whether early community's responses could be evidenced for a low impairment. Field work was performed during the dry season of 2010 in the state of Goias, Brazil. Surber samples were taken from 48 streams located in two Watersheds: river Paraná and river Tocantins. A total of 4.194 individuals of aquatic Coleoptera were collected representing 42 taxa. The streams could be classified in five groups on the bases of the taxonomic structure and composition of the community. Conductivity and turbidity were the main driving variables. Stream impairment related to landscape degradation impacted the aquatic beetles communities, namely driving the morphological traits linked to respiration. This study evidenced that coleopteran can be used for characterization of pristine streams. Nevertheless, they are not appropriated for detecting early states of degradation, and for this an approach using a set of individuals from different Orders of aquatic macroinvertebrates is likely to be more efficient.

Keywords: headwaters, land-use, taxonomic metrics, bio-ecological traits, habitat integrity.

1. INTRODUCTION

The Brazilian Cerrado is the largest savanna in South America, the second largest biome in the country and currently one of the two Brazilian hotspots of diversity with the Atlantic Forest (Myers et al., 2000). Destruction of natural areas is more intense in the Cerrado than in the Amazon forest and only about 20% of the vegetation cover is still in a pristine state. Further, only 3% of these pristine areas, that present original, native vegetation, are protected. The Cerrado is presently under threat due to the development of cereal crops and cattle ranching which alters its natural landscape (Jepson, 2005; Klink and Machado, 2005; Marris, 2005).

The Cerrado plays also an important part on Brazil’s hydrology. Important rivers such as the Amazon, Paraná-Paraguay, and San Francisco have their source in the Cerrado. This biome is covered by a network of streams and rivers, many of them being still in pristine or near pristine state. However, it is likely that in a near future, pristine streams will disappear from the Cerrado, due to change in land use. For conserving and managing the natural Cerrado landscape, it is presently critical to describe the existing pristine systems and their ongoing impairment (Klink and Machado, 2005; Marris, 2005).

Landscape structures influence the structure and processes of biotic communities in stream ecosystems (Whittaker et al., 2001; Cushman and McGarigal, 2002; Allan, 2004; Larsen and Ormerod, 2010). Environmental stream degradation related to different patterns of land use, such as crop production and livestock ranching are numerous: water contamination, modification of physic-chemical parameters, silting, and riparian vegetation alteration. These degradations can also lead to stream habitat homogenization and consequently to the reduction of the diversity of micro-habitats, affecting so the taxonomic and functional biodiversity (Vannote et al., 1980; Townsend et al., 1997; Ricklefs, 2011; Heino et al., 2013).

However, riparian zone can act as an important barrier, mitigating the effects of degradation, because it is closely linked with the structuring processes and maintenance of aquatic environments according to their ecological services such water quality, wadi stabilization, source of allochthonous material and sediment retention (Patten, 1998; Meixler and Bain, 2010; Casatti et al, 2012;. Moraes et al, 2014.). In this work, we define "moderate degradation" as the environmental variations of drainage basins, caused by different patterns of land use, acting on streams with a high local integrity.

In landscapes that are today under an increasing anthropogenic pressure, like the Brazilian Cerrado, it is crucial to define the reference (i.e. non-degraded) conditions by surveying the remaining pristine areas (Boyero et al., 2009). Biological indicators sensitive to an early stage of degradation have also to be identified, such organisms can act as sentinels (Barbour et al., 1996; Stoddard et al., 2006) in the management of the aquatic resources. Macroinvertebrates are widely used as biological indicators of environmental quality, basically because they respond to different levels of environmental stress, either natural or anthropogenic (Rosenberg and Resh, 1993; Bonada et al., 2006). Among them, aquatic beetles (Coleoptera) are widespread and diversified in all type of freshwater habitats, and their community composition respond potentially to environmental changes (Vannote et al., 1980; Townsend et al., 2006; Jach and Balke, 2008; Picazo et al., 2012).

Nevertheless, it is often difficult to define whether the variation of a community is a result of a random natural event or a result of an anthropogenic pressure. Thus some authors suggest that the use of the functional approach, based on species traits, combined with the more traditional taxonomic approach, offers some additional bases to understand ecological processes (Cianciaruso et al., 2009; Dolédec et al., 2011; Audino et al., 2014).

In this study, we aimed to investigate whether pristine streams from the Brazilian Cerrado could be characterized using aquatic Coleoptera beetles, and whether early community's responses to a low impairment could be evidenced. Therefore our specific objectives were to determine: (i) how the taxonomy-based and trait-based composition and structure of the community vary among pristine and near-pristine streams and (ii) how a moderate degree of degradation influences the community. Our hypothesis is that pristine and near-pristine streams are heterogeneous (e.g. morphometric, habitats) and have a large amount of available niches, allowing a great taxonomic and functional diversity of the beetles' communities. We also hypothesize that a moderate impairment has already a perceivable impact on these metrics, evidencing therefore the potential of the beetles as sentinel organisms.

2. METHODS

2.1. Study area

Field work was performed during the dry season between the months of July and August of 2010 in the state of Goias, Brazil. Data were collected from 48 streams distributed within two watersheds: river Paraná and river Tocantins (Figure 1). All streams are surrounded by riparian forest. The river bed is covered by stones or gravel on a sheets substrate and has a maximum width of 5 meters.

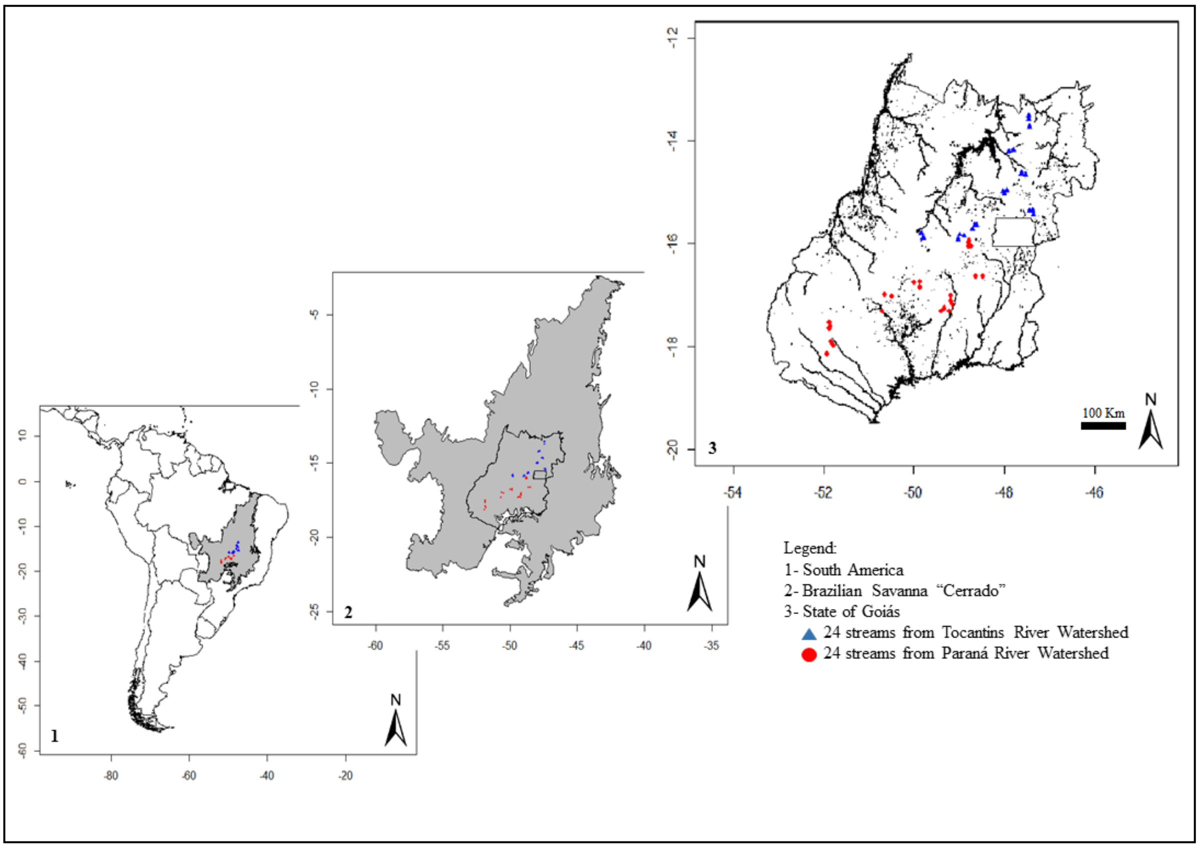

Figure 1. State of Goias, Brazil, with the location of the 48 sampled streams within the Paraná River (1) and Tocantins River (2) watersheds.

2.2. Stream integrity assessment

To assess and characterize the relative physical integrity of the reaches sampled in each stream, we used twelve questions from the Riparian, Channel and Environmental Inventory (RCE) developed by Petersen (1992) with some adaptations. The RCE was proposed for small streams inserted in agricultural landscape, and allows a rapid stream evaluation based on characteristics of the main channel and of the riparian zone.

Each question has four gradual possible answers, the first one with highest scores (30, 25 or 15) is related to a high stream quality and the one with lowest score (1) is associated with a low stream quality. Therefore, the total score of the twelve questions can vary from 12 to 280 and based on it, the environmental integrity allows classifying the stream reaches in five categories (excellent, very good, good, fair and poor).

According the RCE scores calculated in this study (details of scores of each reach in Appendix 1), most (96%) of the 48 stream reaches are unimpaired or suffer only a low impairment. Indeed their statute was excellent (29%), very good (42%), good (25%) or fair (4%). None was classified as poor this highlighted the good conditions of the streams, confirming their statutes of pristine or near-pristine streams.

2.3. Environmental variables

For each stream reach we collected information related to the water physic-chemistry, reach morphometry and the near environment (buffer area): oxygen concentration, pH, temperature, conductivity, turbidity, depth, speed, discharge, rive width, width of riparian forest (WRF), completeness of riparian forest (CRF) and vegetation of riparian forest (VRF).

The 12 questions from the RCE (see previous section) required the measurements of different variables: land use pattern, riparian zone, bank, channel, stream bottom, riffles and pools, or meanders, aquatic vegetation, detritus. Additionally, we also measured the coverage through the different land uses at 3 scales (at a distance of 100, 200 and 400 m from the stream). The percentage was calculated from Landsat TM satellite images (2010), with a resolution of 30 x 30 m composed by seven spectral bands. The composition of the images was performed with three bands (TM5, TM4, TM3), georeferenced and recorded.

The mosaic of images obtained was analyzed to classify land use in natural areas (savanna and forest form) and degraded areas (deforested areas, cereal crops and pastures) (Figure 2). The patterns highlighted here shows a high proportion of degraded landscapes in the vicinity of the streams. This evidence that the good and very good RCE scores, can often hide an impairment of a given variable (like here the riparian landscape). The main impairment factor in this study is the degradation of the riparian landscape, often turned from natural savanna into deforested areas.

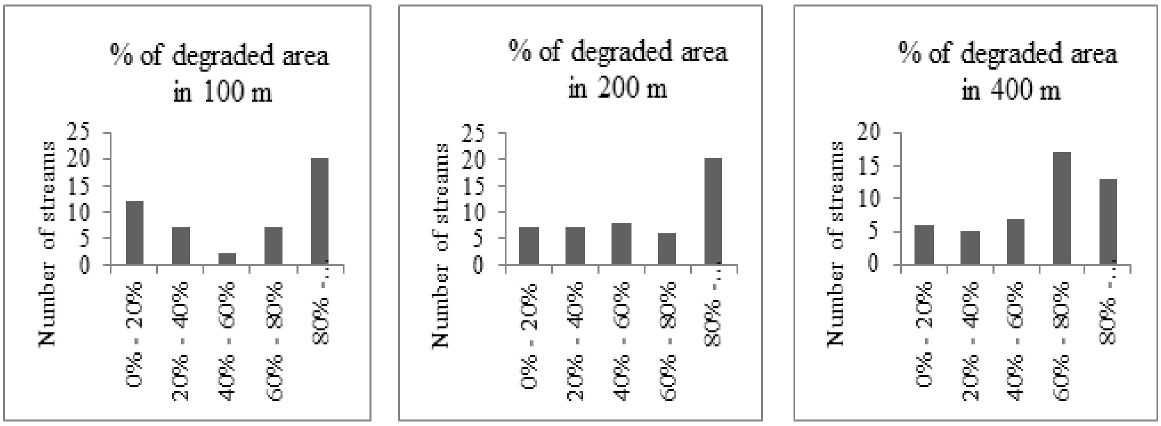

Figure 2. Distribution of the 48 stream reaches into 5 classes of landscape degradation at distances of 100, 200 and 400 meters from the stream. The five classes represent increasing landscape degradation, from 0-20% of the surface to 80-100%. The measures were based on Landsat TM satellite images

2.4. Macroinvertebrates data

Samples were taken at five equidistant points along a stretch of 100 m in each one of the 48 selected streams. Capture of insects were performed in substrates of rocks and leaves, on a 1 m^2 area per point, passing twice with a Surber sampler (Size: 0.092 m^2 and 250 µm mesh). The collected material was sorted in the field and fixed in 5% formalin. In the laboratory, the material was transferred to alcohol 80%. Taxonomic identification until Genus level and the description of the functional traits were performed using several taxonomic keys (Merritt & Cummins, 1996; Domínguez & Fernández, 2001; Segura et al., 2011) and other literature (Poff, 1997; Tomanova et al., 2007; Colzani et al., 2013). The 5 samples were pooled for calculation of the faunal and functional metrics and community structures analyses.

The taxonomic structure of aquatic beetle communities was assessed using three metrics: abundance (number of individuals), taxonomic richness calculated by mean of the Chao1 richness estimator (Cowell and Coddington, 1994; Cowell, 2013) and stream reach community composition. For the functional approach, seven species traits having each, two to five categories, were selected (Table 1). The trait profiles were transformed into frequency distributions and multiplied by the taxa-abundance matrix to calculate the percentage of individuals within each trait category for each stream reach.

The functional diversity was measured by quadratic entropy Rao (Rao, 1982) and Mean Pairwise Distance (MPD) proposed by Webb (2000) and Trait diversity (TD) Larsen &

Ormerod (2010). No functional diversity metric was calculated for stream reaches where no or just 1 individual were found.

Table 1. Functional traits based on morphology and ecology of the organisms, according to Poff, 1997; Tomanova et al., 2008; Colzani et al., 2013.

Biological trait	Code	Trait Category
Morphology		
Exoskeleton	T1C1	Soft body
	T1C2	Lightly sclerotized
	T1C3	Well protected
Respiration	T2C1	Integumentary
	T2C2	Branchial
	T2C3	Air
Body size	T3C1	Small > 9mm
	T3C2	Medium 9 - 16 mm
	T3C3	Large > 16 mm
Body shape	T4C1	Hydrodynamic
	T4C2	Not Hydrodynamic
Ecology		
Rheophily	T5C1	Depositional
	T5C2	Depositional and erosional
	T5C3	Erosional
Habit	T6C1	Burrowers
	T6C2	Climbers
	T6C3	Clingers
	T6C4	Swimmers
Trophic group	T7C1	Collectors
	T7C2	Collector-filters
	T7C3	Herbivores
	T7C4	Predators
	T7C5	Shredders

2.5. Statistical analyses

Sampling efficiency was tested prior data analyses. Species accumulation curves (preformed with EstimateS 9, Cowell, 2013) evidenced that sampling effort was unsufficient to collect all present taxa. Therefore the observed richness was converted to the real species richness through the use of the species richness estimator "Chao1" (Cowell and Coddington, 1994; Cowell, 2013). Principal component analysis (PCA) was used to reduce the dimensionality and collinearity among environmental variables and characterize the streams according to environmental variables. A Cluster analysis was used to evidence the grouping of the streams according to taxonomic composition, using Jaccard distances (presence/ absence data). A Mantel test was used to test the concordance between environmental patterns and taxonomic community structure, using a Bray-Curtis distance matrix based on standardized environmental data and a Bray-Curtis distance matrix on log(x+1) transformed abundance data for faunal data. Relations between environmental data and taxonomic and functional metrics were assessed using Spearman rank correlation tests. Kruskal Wallis nonparametric tests and U tests (Wilcoxon, Mann-Whitney) were used to investigate differences in environmental variables among the stream groups defined according to their taxonomic composition.

All statistical analyses were carried out using the statistical computing software R (R Development Core Team, 2013), using the "ade4" package (Oskanen et al. 2013) for the multivariate analyses.

3. RESULTS

3.1. Abiotic characterization of investigated streams and relation with impairment

The correlation between the environmental variables (Annex 2) shows that several land use variables were strongly correlated (Spearman values, r - values > 0.75) Therefore, degraded area for 200 meters (correlated with 100 and 400 meters with r = 0.92 and r = 0.80 respectively) and natural area for 100, 200 and 400 meters (high levels of correlation with degraded areas (r > 0.75)) were removed from further analyses. Oxygen concentration, pH and temperature were also removed, because these variables are known to be highly variable throughout the day and the seasons.

A Principal Component Analysis (Figure 3) was used to: i) identify stream ordination patterns in relation to environmental parameters and ii) assess if the landscape impairment can be related with the abiotic variables. No clear segregation pattern of the stream reaches could be observed, their distribution presenting more a continuum. The first axis (explaining 29% of total variation) was positively correlated with turbidity and negatively correlated with CRF, VRF, WRF, altitude, depth, river width and RCE. The second axis (explaining 16% of total variation) was positively correlated with conductivity and discharge and negatively correlated with speed, degraded area in 100 and 400 meters. The landscape degradation was reflected through conductivity, turbidity and speed: in a degraded landscape, the water conductivity tend to be low and turbidity and water velocity being high.

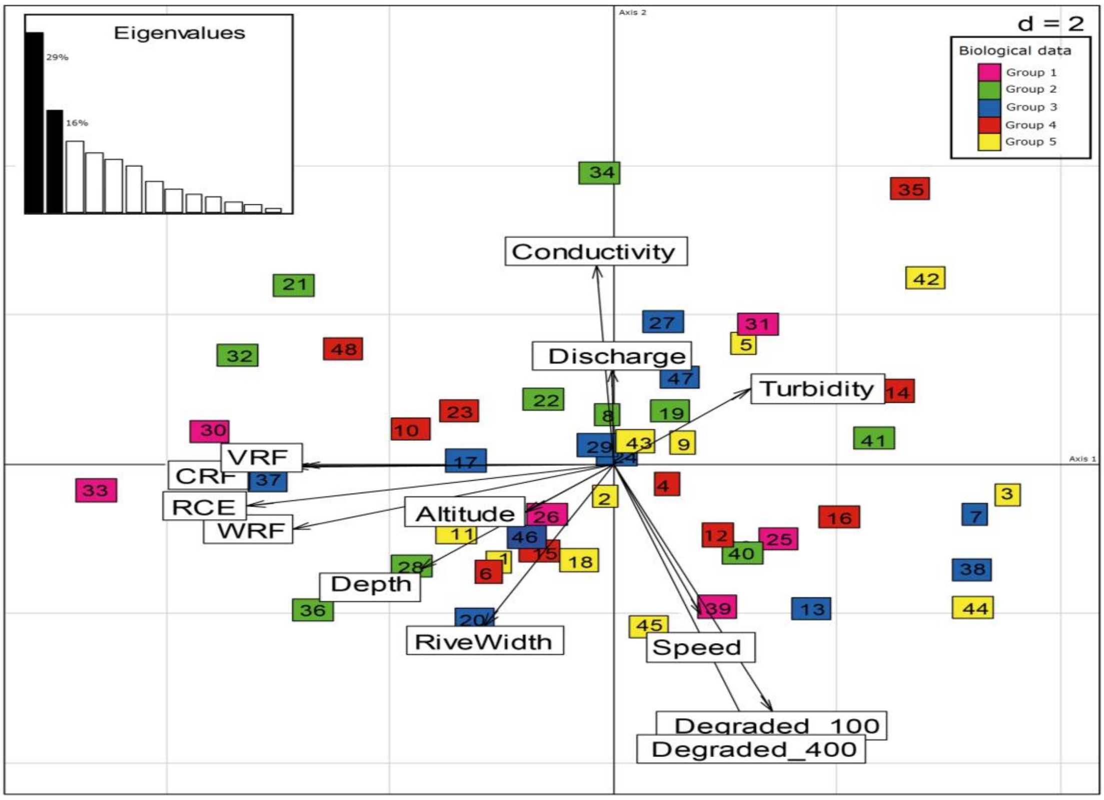

Figure 3. PCA graphics for the distribution of the streams based on environment data, axis 1 = 29% of explanation and axis = 16% of explanation about how data vary (WRF = width of riparian forest, VRF = vegetation of riparian forest in 10 m, CRF = completeness of riparian forest and RCE = Riparian, Channel and Environmental Inventory). Colors represent the stream classification resulting from the cluster analysis of the faunal data (i.e. stream groups).

3.2. Faunal (taxonomic and functional) characterization of investigated streams

3.2.1. Taxonomic structure and composition of Coleoptera community

Among the 48 streams a total of 4194 individuals (3137 larvae and 1057 adults) were sampled representing 42 taxa. The most abundant Family was Elmidae represented by 21 Genus. The most representative Genus was *Heterelmis* (represented in 83.3% of the streams), *Microcylloepus* (77.1%), *Macrelmis* (71%), *Cylloepus* (33.3%), *Gyretes* (33.3%) and *Ptilodactilidae* (23%).

Based on taxonomic composition five distinct groups of streams was identified (Table 2). The first group include the 6 streams in which no Coleoptera were observed. The second group is composed by 10 streams where the Coleoptera were rare, i.e. where the observed taxa were present only in one or two of the five samples. For the 32 other streams, where the

Coleopteran were more abundant, a cluster analyses allowed to define 3 groups according to community composition (group 3, 4 and 5, figure 4).

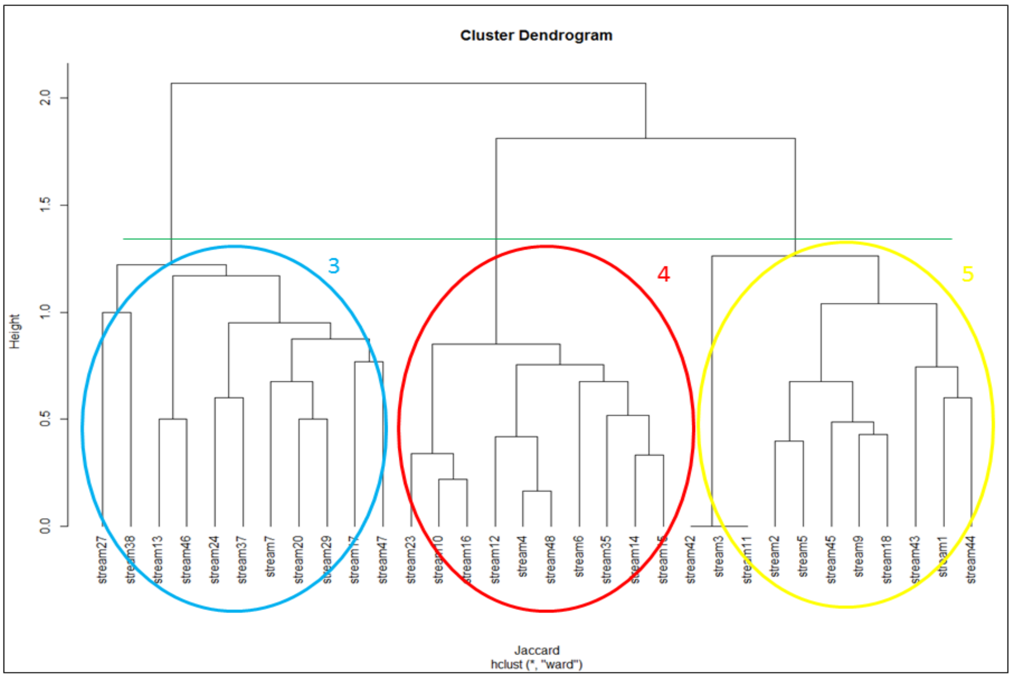

Figure 4. Cluster dendrogram - streams similarity based on the 32 streams where taxa were present at more than two samples (Jaccard Clustering), evidencing a separation in 3 groups. Two further groups (not presented here) were evidenced with the 16 other streams (see Table 3).

Table 2. Percentage of streams where the taxa is present, in each of the five groups. The color and percentages indicate the frequency of occurrence of the taxa in the stream group, the lightest represent the smallest percentage the darker the largest. The groups 1, 2 are the streams with taxa observed in less than two samples; the groups 3, 4 and 5, the streams with taxa observed in more than three samples. A= adults and L= larvae.

Taxa	Group 1 n= 6	Group 2 n= 10	Group 3 n = 11	Group 4 n = 10	Group 5 n = 11
Austrolimnius(A)	0%	10%	0%	0%	0%
Berosos(A)	0%	0%	0%	10%	0%
Curculionidae(A)	0%	10%	0%	0%	0%
Cylloepus(A)	0%	20%	18%	10%	9%
Dryopidae(A)	0%	40%	27%	20%	0%
Dryopidae(L)	0%	10%	9%	10%	0%

DytiscidaeNI(L)	0%	0%	9%	0%	0%
ElmidaeNI(L)	0%	0%	0%	10%	0%
GenusA(L)	0%	10%	0%	0%	0%
GenusM(L)	0%	10%	0%	0%	0%
Gyrelmis(A)	0%	0%	0%	10%	0%
Gyretes(L)	0%	20%	9%	10%	18%
Heterelmis(A)	0%	40%	9%	100%	9%
Heterelmis(L)	0%	80%	73%	100%	91%
Hexacylloepus(A)	0%	20%	18%	30%	18%
Hexacylloepus(L)	0%	60%	0%	90%	100%
Hexanchorus(L)	0%	20%	0%	10%	0%
Huleechius(L)	0%	0%	9%	0%	0%
HydrophilidaeNI(L)	0%	10%	9%	0%	0%
Laccophilus(L)	0%	20%	0%	0%	0%
Lutrochidae(A)	0%	0%	9%	0%	0%
Macrelmis(A)	0%	10%	0%	10%	0%
Macrelmis(L)	0%	50%	55%	90%	55%
Matus(L)	0%	10%	0%	0%	0%
Microcylloepus(A)	0%	60%	36%	90%	18%
Microcylloepus(L)	0%	40%	9%	60%	45%
Neoporus(A)	0%	10%	0%	0%	0%
Oolimnius(A)	0%	0%	0%	10%	0%
Phanocerus(A)	0%	10%	0%	0%	0%
Phanocerus(L)	0%	30%	36%	0%	27%
Ptilodactylidae(L)	0%	10%	18%	30%	18%
Quadriops(A)	0%	10%	0%	0%	0%
Ranthus(A)	0%	10%	0%	0%	0%
Staphylinidae(A)	0%	0%	9%	0%	0%
Stegoelmis(L)	0%	10%	0%	10%	0%
Xenelmis(L)	0%	20%	18%	20%	0%

Group 3 was characterized by the low quantity of adults from the dominant genus *Heterelmis* and the absence of larvae from the genus *Hexacylloepus* present in the groups two, four and five. This genus was on the contrary present in 90% and 100% for the fourth and fifth group respectively. For group 4, we observe a dominance by genus *Heterelmis*, present in 100% of the streams that make up the group and weren't dominant any other group. The group 5 can be characterized by the absence of some genus that can be viewed in groups 3 and 4 (adults from the genus *Heterelmis* and *Microcylloepus*).

Both the total number of taxa and abundance per stream varied significantly between the 5 groups (Kruskall Wallis test, species richness p= 0.00015; abundance p = 6.70E-06; Figure 5), and group 4 presented highest richness and abundance.

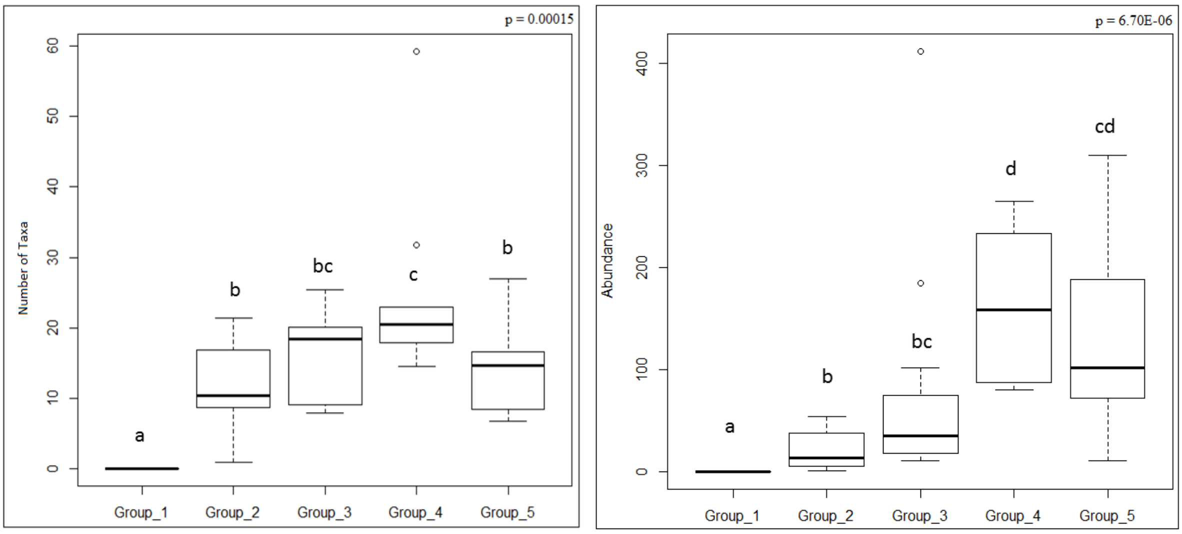

Figure 5. Boxplots for taxonomic richness and abundance (number of individuals) between group significant differences were tested using Mann-Whitney U tests ($p<0.05$).

3.2.2. Functional diversity of Coleoptera community

Most coleopteran taxa found in the Cerrado streams were characterized by a well-protected exoskeleton (99% of the individuals), branchial respiration (75% of the individuals), a body size smaller than 9 mm (97% of the individuals) and a hydrodynamic body shape (70% of the individuals). Almost all individuals also showed similar ecological preferences, with 93% of the individuals in erosional stream areas. 98% of the individuals collected are clingers, and can be classified as collectors (93% of individuals). A correlation between the taxonomic metrics (abundance, and taxonomic richness) and functional diversity metrics (Trait diversity (TD), Mean Pairwise Distance (MPD) and Rao) shows that taxonomic richness is here not correlated with trait diversity and Rao. These metrics are therefore to be handled separately as giving different (and complementary) information (Table 3).

Table 3. Correlation (Spearman Rank correlation test) between the taxonomic metrics (abundance, and richness Chao 1) and functional diversity metrics (Mean Pairwise Distance (MPD) and Trait diversity (TD)) (**= significant at p<0.01 and * =significance at p<0.05).

R-values					
	Abundance	Taxonomic richness	TD	MPD.obs	Rao
Abundance	1				
Taxonomic richness	**0.444	1			
TD	*-0.364	0.175	1		
MPD.obs	0.005	*0.318	**0.518	1	
Rao	*-0.369	0.179	**0.996	**0.493	1

3.3. Relationships between faunal (taxonomic and functional) and environmental data

The five stream groups (grouped according to Coleopteran communities, i.e. Table 2) were characterized by the environmental variables. We conducted boxplots for conductivity, turbidity, depth, speed, discharge, river width, (WRF), (CRF), (VRF), degraded area in 100 m and 400 m, altitude and RCE. Only conductivity and turbidity varied significantly among the five stream groups (Kruskal Wallis test p = 0.014, p= 0.032 respectively) (Figure 6), and no significant between-group differences could be detected for the other tested environmental variables. The faunistic grouping of the streams was not related to the degradation of the landscape. Conductivity values of the streams in group 1 were characterized by low values. Conductivity of streams belonging to the groups 2 and 4 were quite similar and showed the highest values. For the turbidity, the group 3 has a wide range of turbidity values, whereas the other stream groups showed more uniform values.

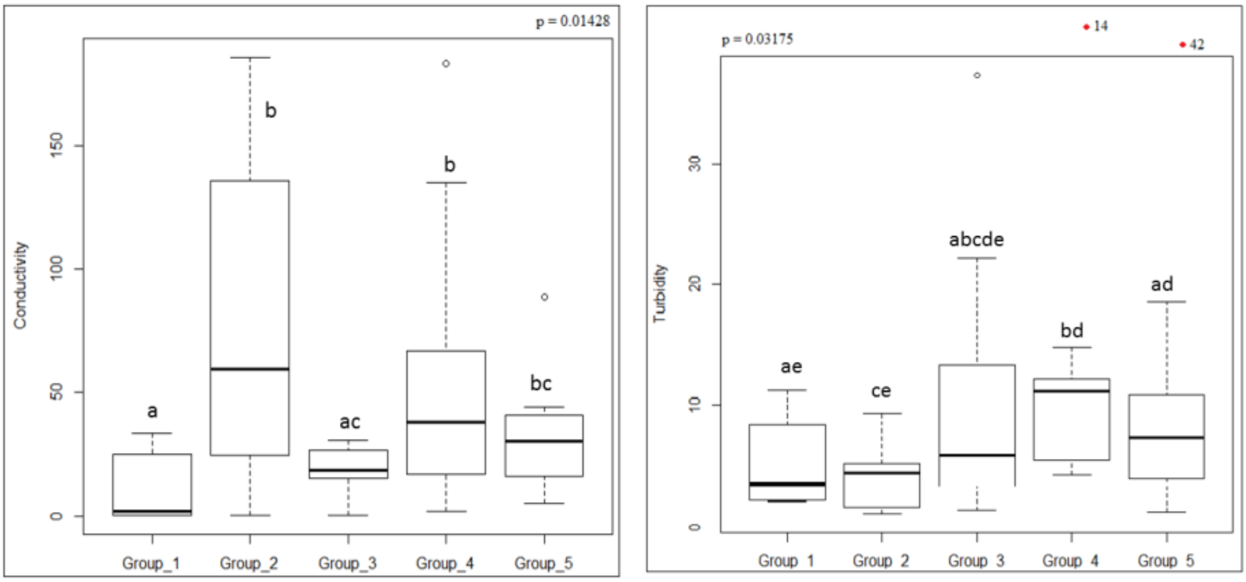

Figure 6. Boxplots for conductivity and turbidity characterizing the five stream groups (grouped according to Coleopteran communities, i.e. Table 6). The outlier streams (Nr 14 in the group 4 (value = 120) and Nr 42 in the group 5 (value = 110.56)) were removed for a better visualization but were kept in the Kruskal Wallis analysis). Between groups significant differences were tested using Mann-Whitney U tests.

The taxonomic metrics (abundance and taxonomic richness) were also put in relation with the environmental variables. Conductivity was here also evidenced as a key variable, and was significantly correlated to the abundance (Table 4). The degradation of the landscape appears here to be not related to the taxonomic metrics.

Table 4. Correlations (Spearman rank correlation test) between the environmental variables and the taxonomic metrics: abundance and taxonomic richness. (* = significant correlation at $p<0.05$).

R - values	Conductivity	Turbidity	Depth	Speed	Discharge	RiveWidth	WRF	CRF	VRF	Degraded_100	Degraded_400	Altitude	RCE
Taxonomic richness	0.158	0.050	-0.010	0.076	-0.069	0.111	-0.034	0.063	0.032	-0.026	-0.073	0.220	0.062
Abundance	*0.331	0.239	0.019	0.040	-0.219	-0.022	-0.108	-0.040	-0.108	0.144	0.100	-0.014	-0.088

No significant correlation between the environmental variables and the functional diversity metrics were observed (Table 5). Here also, the degradation of the landscape was unrelated to the taxonomic richness and to the traits diversity.

Table 5. Correlations (Spearman rank correlation test) between the environmental variables, RCE and functional diversity metrics (Mean Pairwise Distance (MPD) and Trait diversity (TD)) (**= significant at p<0.01 and * =significance at p<0.05).

R-values	Conductivity	Turbidity	Depth	Speed	Discharge	RiveWidth	WRF	CRF	VRF	Degraded_100	Degraded_400	Altitude	RCE
TD	-0.117	-0.171	-0.186	-0.220	0.074	-0.015	0.213	0.128	0.068	-0.180	-0.259	0.162	0.089
MPD.obs	0.156	-0.067	-0.287	-0.232	0.024	-0.188	-0.072	-0.027	-0.008	-0.109	-0.190	0.010	-0.063
Rao	-0.121	-0.162	-0.190	-0.220	0.084	-0.019	0.240	0.145	0.088	-0.166	-0.246	0.181	0.107

When taking into consideration each of the 22 traits, anyone individual present the trait T1C1 (Exoskeleton (soft body)) and this trait category was removed from the following analyses. Relation with environmental variables could them be evidenced (Table 6), both for morphology and ecology related traits. The water depth and speed and the proportion of degraded landscape at a distance of 400 meters (as well at a distance of 100 m, but in a lesser extent) were the most important variables. The depth and speed act on traits describing rheophily, habit and trophic group. Landscape degradation is acting on respiration form, decreasing the frequency of integumentary respiration form and increasing the frequency of branchial respiration form.

Table 6. Spearman rank correlation test between frequencies of occurrence of the 21 traits categories (Morphology: Exoskeleton (T1C1= Soft body; T1C2= Lightly sclerotized; T1C3= Well protected); Respiration (T2C1= Integumentary; T2C2= Branchial; T2C3=Air); Body size (T3C1= Small > 9mm; T3C2= Medium 9 - 16 mm; T3C3= Large > 16 mm); Body shape (T4C1= Hydrodynamic; T4C2 = Not Hydrodynamic). Ecology: Rheophily (T5C1= Depositional; T5C2= Depositional and erosional; T5C3= Erosional); Habit (T6C1= Burrowers; T6C2= Climbers; T6C3= Clingers; T6C4= Swimmers); Trophic group (T7C1= Collectors; T7C2= Collector-filters; T7C3= Herbivores; T7C4= Predators; T7C5= Shredders)

and the environmental variables. The analyses exclude the streams where no coleopteran was found (# = significant correlation at p<0.10 and * = significant correlation at p<0.05).

R-values	Conductivity	Turbidity	Depth	Speed	Discharge	RiveWidth	WRF	CRF	VRF	Degraded_100	Degraded_400	Altitude	RCE
T1C2	-0.161	-0.131	-0.077	-0.126	-0.092	0.086	-0.045	-0.070	-0.071	-0.067	-0.186	0.184	-0.031
T1C3	0.161	0.131	0.077	0.126	0.092	-0.086	0.045	0.070	0.071	0.067	0.186	-0.184	0.031
T2C1	-0.111	-0.235	-0.189	-0.209	0.194	-0.131	0.164	0.170	0.177	-0.252	* -0.311	0.235	0.013
T2C2	0.111	0.235	0.189	0.209	-0.194	0.131	-0.164	-0.170	-0.177	0.252	* 0.311	-0.235	-0.013
T2C3	-0.097	0.083	0.086	0.010	-0.111	0.112	-0.133	-0.025	-0.115	0.136	0.088	0.043	-0.155
T3C1	0.091	-0.112	-0.140	0.054	-0.003	-0.212	-0.194	-0.168	0.111	-0.179	-0.018	-0.157	-0.086
T3C2	-0.091	0.112	0.140	-0.054	0.003	0.212	0.194	0.168	-0.111	0.179	0.018	0.157	0.086
T4C1	0.103	0.127	0.070	0.128	-0.164	0.178	-0.174	-0.208	-0.207	0.221	0.244	-0.127	-0.026
T4C2	-0.103	-0.127	-0.070	-0.128	0.164	-0.178	0.174	0.208	0.207	-0.221	-0.244	0.127	0.026
T5C1	-0.097	0.083	0.086	0.010	-0.111	0.112	-0.133	-0.025	-0.115	0.136	0.088	0.043	-0.155
T5C2	-0.052	-0.151	* -0.304	-0.232	0.033	-0.061	-0.005	0.005	-0.084	-0.074	-0.174	0.074	-0.063
T5C3	0.056	0.154	* 0.306	0.239	-0.026	0.053	0.003	-0.011	0.083	0.068	0.171	-0.082	0.065
T6C1	-0.012	-0.099	-0.192	-0.159	-0.023	-0.015	0.115	-0.001	0.046	-0.107	-0.117	0.168	-0.002
T6C2	-0.051	-0.195	* -0.320	-0.250	0.027	-0.022	-0.021	0.050	-0.043	-0.096	-0.198	0.083	-0.027
T6C3	0.036	0.157	0.141	0.123	-0.103	0.047	0.131	0.055	0.072	0.091	0.196	-0.027	0.052
T6C4	0.044	-0.171	-0.137	# -0.265	-0.006	-0.107	-0.104	0.042	-0.096	-0.146	-0.249	-0.032	-0.063
T7C1	0.081	0.136	0.256	* 0.344	-0.076	0.139	-0.111	-0.166	-0.022	0.072	0.238	-0.194	-0.070
T7C2	-0.097	0.083	0.086	0.010	-0.111	0.112	-0.133	-0.025	-0.115	0.136	0.088	0.043	-0.155
T7C3	0.029	-0.016	-0.157	# -0.283	0.049	-0.094	0.126	0.130	0.066	-0.118	-0.217	0.138	0.020
T7C4	-0.111	-0.114	-0.197	-0.180	-0.006	-0.113	-0.027	-0.051	-0.068	-0.168	-0.192	0.079	-0.002
T7C5	0.092	0.045	-0.255	# -0.278	-0.220	-0.244	0.057	0.032	-0.117	-0.256	-0.203	-0.039	-0.094

4. DISCUSSION

The present pristine streams from Brazilian Cerrado can be characterized by aquatic Coleoptera, as their communities show different taxonomic and functional patterns in relation to environmental heterogeneity. Five groups of distinct streams could be defined based on the taxonomic composition. Environmental conditions influence community structures, as they act as filters for the biological traits of organisms, selecting the traits providing adaptive solutions to particular habitats conditions (Poff 1997, Statzner et al., 2004 and Mouillot et al. 2012).

The variations that contribute to form this filters can be either natural or anthropogenic. Here for example the water conductivity is evidenced as an important driver of the beetles communities. The range of conductivity values observed here (0.1 – 185.9 µS cm-1) were typical of natural conditions. Conductivity is nevertheless also sensitive to anthropic activities, and can easily highly increase in impaired systems. The conductivity, and also turbidity, are variables that can reflect stream degradation, generated by the increase of organic matter in streams, decrease of riparian zone that cause higher light input (Allan, 2004). In the Cerrado streams, these two parameters also varied significantly among stream groups characterized by different beetle communities.

Aquatic beetles, are known for their wide distribution and diversity of ecological strategies and life history (Picazo et al., 2012), and perform an important role in biodiversity and ecosystem functioning, so they can be found in a huge variety of habitats and their responses to environmental conditions vary in a different ways (e.g. traits related with life history, feeding strategies, respiration and body shape can offer information related to impairment levels) Tomanova et al. (2008).

Here we tested the impact of a moderate degradation of pristine streams on the beetles communities, through the influence of landscape degradation in the proximal environment (100 to 400 m) of streams. Contrarily to our research hypothesis, the communities appeared here unaffected through the landscape degradation. Similar result can be observed in Lammert and Allan (1999) where land use pattern was less important than habitat local variables to explain the structure and composition of fish and macroinvertebrates. However, it answer to variables as conductivity and speed that can reflect changes from degradation patterns in landscape.

A low impairment, as measured with global impairment index (e.g. Petersen, 1992), has already predictable effects on beetles communities. Here the effects of land degradation are better observed on functional metrics. Both species richness and trait diversity (TD, MPD and Rao) are not answering to the environmental variables, and therefore not to impairment. Individual trait category frequencies were more clearly related to environmental conditions, but only two from 21 traits were sensitive to the tested impairment (degraded area in 100 and 400 m), both being related to respiration. Rheophily, habit and trophic groups were also correlated with depth and speed.

Respiration traits were also related to land use degradation by Boechat et al. (2011), who observed changes of the composition of microbial communities and alteration of streams food webs in relation to land use. Individual trait frequency seems to be a good approach for stream monitoring using aquatic beetle, but remain with a low sensitivity for detecting slightly degradation in pristine systems in the Brazilian Cerrado. In other studies Vandewalle et al. (2010), Doledéc et al. (2011), Marzin et al. (2012), Schmera et al. (2013) found differential responses of trait and taxonomic measures, with trait responses being much more efficient in answering to different patterns of degradation.

Considering only one taxonomic group like Coleopteran here, is therefore certainly a limited approach. We recommend therefore enlarging our approach presented here to the other groups of macroinvertebrates. An enlarged approach should be more successful for detecting impairment of pristine streams.

5. CONCLUSION

Brazilian savanna (Cerrado) still has pristine systems, but undoubtedly under pressure and disappearing, and we need to improve our efforts to characterize, protect and preserve these ecosystems. This characterization can be based on the analysis of the interactions between abiotic and biotic variables. The studied streams could be classified as pristine systems, but inserted in a degraded landscape matrix. Our study evidenced that aquatic Coleoptera are a good group to be used for characterizing the diversity of these pristine streams. Nevertheless aquatic beetles are here much less efficient as sentinels for detecting a low degree of impairment. A single-group approach shows here its limits, and certainly enlarging to other macroinvertebrates groups would be more promesful, but this remains to be tested by future studies.

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7. ANNEX

Annex 1. Classification of streams according Riparian, Channel and Environmental Inventory (RCE) developed by Petersen (1992).

STREAMS	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	CLASS	SCORE	CLASSIFICATION
1	10	30	20	25	10	10	15	15	5	20	15	25	II	200	VERY GOOD
2	10	5	30	25	15	15	25	15	15	25	15	25	II	220	VERY GOOD
3	10	1	1	5	15	5	15	1	25	20	15	25	III	138	GOOD
4	10	20	20	25	15	15	15	5	5	20	15	25	II	190	VERY GOOD
5	10	20	5	15	10	15	15	15	5	10	10	25	III	155	GOOD
6	20	30	30	15	10	15	25	20	15	25	15	25	I	245	EXCELLENT
7	10	5	1	5	5	10	15	5	15	20	10	25	III	126	GOOD
8	1	20	20	25	1	10	15	15	25	25	15	10	II	182	VERY GOOD
9	10	5	20	15	15	15	25	20	25	20	15	25	II	210	VERY GOOD
10	20	30	30	25	15	15	25	20	15	20	15	25	I	255	EXCELLENT
11	10	30	20	25	15	15	25	20	25	25	15	25	I	250	EXCELLENT
12	10	20	20	15	1	5	5	15	5	20	10	25	III	151	GOOD
13	10	20	1	15	5	15	25	15	5	20	15	25	III	171	GOOD
14	1	5	20	5	15	15	15	20	15	20	15	25	III	171	GOOD
15	10	20	20	25	15	15	25	20	15	25	15	25	I	230	EXCELLENT
16	10	5	5	15	5	15	25	5	15	20	10	25	III	155	GOOD
17	10	20	20	25	15	15	25	15	25	10	15	25	II	220	VERY GOOD
18	10	5	20	25	15	15	25	15	15	20	15	25	II	205	VERY GOOD
19	10	5	20	25	15	10	15	5	15	20	15	25	II	180	VERY GOOD
20	30	30	30	25	5	10	25	15	5	10	15	25	II	225	VERY GOOD
21	10	30	30	25	15	15	25	20	25	25	15	25	I	260	EXCELLENT
22	10	5	30	25	15	10	25	15	25	20	15	25	II	220	VERY GOOD
23	10	20	30	25	10	10	5	20	25	25	15	25	II	220	VERY GOOD
24	10	20	20	15	10	10	15	15	15	20	15	25	II	190	VERY GOOD
25	20	5	5	5	15	10	15	15	15	20	1	25	III	151	GOOD
26	30	20	20	25	10	10	25	15	15	20	15	25	I	230	EXCELLENT
27	10	1	5	25	15	15	15	5	25	20	5	25	III	166	GOOD
28	30	30	30	15	15	15	25	20	25	20	15	25	I	265	EXCELLENT
29	30	5	20	15	15	15	25	15	25	10	5	25	II	205	VERY GOOD
30	30	30	30	25	15	15	25	15	25	25	15	25	I	275	EXCELLENT
31	30	5	20	5	15	15	15	20	15	10	1	25	II	176	VERY GOOD
32	30	30	30	25	15	15	15	20	25	25	15	25	I	270	EXCELLENT
33	30	30	30	25	15	15	25	20	25	25	15	25	I	280	EXCELLENT
34	10	5	20	25	10	15	15	15	15	20	15	25	II	190	VERY GOOD
35	10	1	1	5	1	10	5	5	25	1	5	25	IV	94	FAIR
36	30	30	30	25	15	15	25	20	25	25	15	25	I	280	EXCELLENT
37	30	30	30	25	15	15	25	20	25	25	15	25	I	280	EXCELLENT
38	10	1	5	5	10	15	15	5	5	10	15	10	IV	106	FAIR
39	10	30	20	15	15	15	15	15	25	10	10	10	II	190	VERY GOOD
40	10	5	20	15	10	10	25	5	25	20	10	25	II	180	VERY GOOD
41	10	5	20	5	5	10	5	5	15	20	15	10	III	125	GOOD
42	10	5	5	5	10	15	15	15	5	20	15	25	III	145	GOOD
43	10	30	20	15	10	15	15	15	5	10	15	25	II	185	VERY GOOD
44	10	5	1	5	10	15	5	5	5	25	10	25	III	121	GOOD
45	10	20	20	15	10	15	25	15	15	20	10	25	II	200	VERY GOOD
46	30	30	20	25	15	15	25	15	25	20	10	25	I	255	EXCELLENT
47	10	20	20	15	10	15	15	5	15	20	15	25	II	185	VERY GOOD
48	30	30	30	25	10	15	25	15	15	20	15	25	I	255	EXCELLENT

Annex 2. Correlation values (Spearman Rank correlation test) for the environment data. WRF = Width of Riparian Forest, CRF = Completeness of Riparian Forest, VRF = Vegetation of Riparian Forest, RCE = Riparian, Channel and Environmental Inventory; for p-values (# = significant at p<0.10; * = significant at p<0.05 and ** = significant at p<0.01).

R-values	Conductivity	Turbidity	Depth	Speed	Discharge	RiveWidth	WRF	CRF	VRF	Natural_100	Natural_200	Natural_400	Degraded_100	Degraded_200	Degraded_400	Altitude	RCE
Conductivity	1																
Turbidity	0.192	1															
Depth	-0.121	*-0.320	1														
Speed	-0.070	0.059	0.146	1													
Discharge	-0.151	-0.128	0.014	0.147	1												
RiveWidth	0.017	-0.179	**0.427	0.229	# -0.260	1											
WRF	-0.119	-0.088	# 0.261	-0.122	-0.240	# 0.280	1										
CRF	0.079	*-0.292	# 0.258	# -0.283	-0.155	0.123	0.684	1									
VRF	0.141	*-0.330	# 0.253	-0.125	0.088	0.059	**0.521	0.627	1								
Natural_100	-0.003	-0.145	0.043	# -0.242	0.168	-0.193	0.206	0.199	* 0.296	1							
Natural_200	-0.004	-0.119	0.065	# -0.274	0.113	-0.217	0.179	0.169	0.227	**0.920	1						
Natural_400	0.123	*-0.289	0.025	*-0.344	0.096	-0.227	0.078	# 0.255	0.226	0.741	0.831	1					
Degraded_100	-0.016	0.174	-0.055	# 0.248	-0.182	0.225	-0.192	-0.231	* -0.307	**-0.986	**-0.906	-0.748	1				
Degraded_200	-0.010	0.153	-0.055	*0.289	-0.119	# 0.261	-0.179	-0.206	-0.225	**-0.909	**-0.976	-0.800	**0.923	1			
Degraded_400	-0.141	*0.300	-0.024	*0.331	-0.103	# 0.240	-0.071	# -0.272	-0.229	-0.726	-0.814	**-0.991	0.753	0.803	1		
Altitude	**-0.506	**-0.509	0.145	-0.094	0.144	-0.002	0.158	0.207	0.227	0.076	0.131	0.197	-0.100	-0.131	-0.203	1	
RCE	-0.033	*-0.324	**0.387	-0.168	-0.113	0.233	0.784	0.854	0.745	# 0.277	# 0.270	0.227	* -0.286	# -0.276	-0.230	* 0.300	1

CONSIDERAÇÕES FINAIS

O Cerrado brasileiro ainda possui remanescentes e áreas inseridas em locais de preservação. Entretanto está sobre pressão e desaparecendo e precisamos ampliar nossos esforços para caracterizar, proteger e preservar esse ecossistema. Os riachos aqui estudados foram classificados como em condição de referência, mas ainda assim, estão inseridos em uma paisagem degradada, bacias de drenagem com diferentes níveis de impactação.

Uma das formas possíveis para a caracterização dos mesmos, pode ser baseada em análises de interação de variáveis biológicas e ambientais. Dessa forma, este estudo evidencia que coleópteros aquáticos é um bom grupo para ser utilizado para caracterizar a diversidade desses riachos. Porém, aqui este grupo se mostrou pouco eficiente como sentinelas para detectar degradação para além da zona ribeirinha.

Utilizar um único grupo evidenciou suas limitações, o que indica que uma abordagem acrescentando outros grupos de macroinvertebrados pode ser mais promissor o que pode ser testado em estudos futuros.