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Aquatic and Semiaquatic Heteroptera (Hemiptera: Insecta) Distribution in Streams on the Cerrado–Amazon Ecotone in Headwaters of Xingu River

Iluany Silva-Costa [1], Nubia França Silva Giehl [2], Ully Mattilde Pozzobom [3], Anderson André Carvalho-Soares [1], José Max Barbosa Oliveira-Junior [4], Helena Soares Ramos Cabette [5] and Karina Dias-Silva [1,6,*]

[1] Faculdade de Ciências Biológicas (FCB), Universidade Federal do Pará (UFPA), Rua Coronel José Porfírio, N. 2515, Bairro São Sebastião, Altamira 68372-040, PA, Brazil
[2] Laboratório de Ecologia de Bentos, Instituto de Ciências Biológicas (ICB), Universidade Federal de Minas Gerais (UFMG), Belo Horizonte 31270-901, MG, Brazil
[3] Laboratório de Ecologia e Investigação Aquática, Pós-graduação em Ecologia e Conservação da Biodiversidade (PPGBIO), Universidade Federal de Mato Grosso (UFMT), Cuiabá 78060-900, MT, Brazil
[4] Programa de Pós-Graduação em Sociedade, Natureza e Desenvolvimento (PPGSND), Programa de Pós-Graduação em Sociedade, Ambiente e Qualidade de Vida (PPGSAQ), Programa de Pós-Graduação em Biodiversidade (PPGBEES), Instituto de Ciências e Tecnologia das Águas (ICTA), Universidade Federal do Oeste do Pará (UFOPA), Santarém 68040-255, PA, Brazil
[5] Programa de Pós-Graduação em Ecologia e Conservação (PPGEC), Universidade do Estado de Mato Grosso (UNEMAT), Nova Xavantina 78690-000, MT, Brazil
[6] Programa de Pós-Graduação em Biodiversidade e Conservação (PPGBC), Faculdade de Ciências Biológicas (FCB), Universidade Federal do Pará (UFPA), Rua Coronel José Porfírio, N. 2515, Bairro São Sebastião, Altamira 68372-040, PA, Brazil
* Correspondence: diassilvakarina@gmail.com

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Abstract: The modification of landscapes surrounding water bodies leads to changes in limnological characteristics and decreased aquatic biodiversity, such as fish and macroinvertebrates. Aquatic insects are sensitive to changes in aquatic ecosystems and quickly respond to those changes. The aim of this paper was to evaluate the relationship between the compositions of aquatic and semi-aquatic Heteroptera with environmental variables along an environmental gradient in streams at the headwaters of the Xingu River, Brazil. We collected samples from 12 streams belonging to the Suiá-Miçú river basin and tributaries of the Xingu River, in September (dry season), 2008. The Suiá-Miçú river is one of the tributaries on the right bank of the Xingu River, and it is located in the ecotone between the Cerrado and the Amazon rainforest in the area characterized as the "arc of deforestation". Insects were sampled in fixed 100 m transections and divided into 20 segments of 5 meters each. To assess the habitat integrity in each stream, the habitat integrity index (HII) was applied. The following environmental variables were measured: electrical conductivity, turbidity, depth, and the normalized difference vegetation index (NDVI). The ordering of species composition was performed with the principal coordinate analysis (PCoA), and the relationship between environmental variables and composition was performed using a Mantel test. Of the 263 individuals collected, distributed in 8 families, there were 20 genera, of these, 12 were from Nepomorpha and 8 from Gerromorpha. The most abundant genera were *Limnocoris* (n = 121) and *Rhagovelia* (n = 32). Naucoridae was the most diverse family. Together, the environmental variables explained ~50% of the species distribution (r = 0.49; p = 0.001). These results reinforce the efficacy of aquatic Heteroptera to monitor environmental conditions. Here, in particular, the responses of this group to variations in landscape metrics, environmental integrity, and water variables together demonstrate that it can be useful to indicate the quality of habitat in streams.

Keywords: arc of deforestation; aquatic insects; land-use change; streams; environmental variables

1. Introduction

The biological diversity in streams and rivers can be strongly affected by the use of the surrounding soil, through the modification of natural areas in agricultural areas [1,2]. The main changes in streams are related to limnological variables, water flow and stream width, depth, and the available habitat for aquatic communities [3]. Previous studies have shown that the presence of riparian vegetation in streams contributes to energy maintenance [4–6]. For streams of the first and third orders, the flow of energy is preserved by riparian vegetation, providing shading and allochthonous material, resulting in habitat diversity and food for organisms [4,7]. In addition, the natural vegetation operates as a buffer zone during the rainy season, preventing the carrying of sediment and pollutants from the surrounding areas to the streams [1,8].

Factors such as increased luminosity, increase in water nutrients (eutrophication), increased flow during the rainy season, and decreased resource availability are responsible for affecting the aquatic insect communities [9,10]. However, these factors vary in accordance with the geographic region and changing landscape. For the group of insects analyzed for this, it is necessary to analyze how aquatic insects respond to variation in the environment in order to evaluate the physical integrity and quality of these aquatic ecosystems [11,12].

The Cerrado–Amazonia transition region, located in the region of the "arc of deforestation", has been the target of intense conversion from natural areas to areas for agriculture and livestock [13,14]. Earlier studies have determined that landscape change directly affects fish and macroinvertebrate communities [15–17], leading to a homogenization of the aquatic environment and a decrease in biodiversity [18]. In general, aquatic organisms depend on physical and chemical water conditions and the environment in streams [9]. Because of this, they are more sensitive and quickly respond to changes in aquatic ecosystems [19].

Among the studies on aquatic insects, there are few analyzing the relationship between the Heteroptera and environmental impacts [20–22]. Aquatic Heteroptera are divided into Gerromorpha, Nepomorpha, and Leptopodomorpha infra-orders that are cosmopolitans, not occurring just in Antarctica where major landmasses are absent [23]. Most of these insects are predators, except for some members of the Corixidae family. The Heteroptera are known for their ecological and environmental importance, such as the biological control of populations through predation, and thus, can be used as indicators of aquatic habitat quality [22,24,25]. Few studies have evaluated the effect of the anthropogenic impacts on the composition and structure of Heteroptera communities in the Cerrado–Amazon transition region [26], and little is known about the effects of changes on these organisms. There is an intense history of conversion about the land use for agriculture and livestock in the region of the deforestation arc, also characterized in the Cerrado–Amazon ecotone. In this context, we evaluated the relationship of Nepomorpha and Gerromorpha compositions with environmental variables and verified whether streams in forested and agricultural areas show differences in Heteroptera composition. Our hypothesis was that in forested streams, there would be a different composition of aquatic and semiaquatic Heteroptera compared with streams with agricultural influence, determined by the difference in environmental characteristics in each stream.

2. Materials and Methods

2.1. Study Area

The samples were taken from 12 streams of the 1st through 6th orders in accordance with Strahler's [27] classification, located in the Suiá-Miçú River basin and the Darro River, one of its main tributaries, in September of 2008 (Figure 1). The Suiá-Miçú River is located between the coordinates of 11°15′ S and 13°40′ S, and 53°15′ W and 51°15′ W in the ecotone between the Cerrado and the Amazon rainforest. This river is one of the main tributaries of the right margin of the Xingu River, crossing lowland areas in the Água Boa, Canarana, Ribeirão Cascalheira, and Querência municipalities in the Mato Grosso state, Brazil [28]. The region has a seasonal tropical climate, with a dry season extending from May to October and a rainy season that comprises the months from November to April. The predominant climate of the region is the tropical savanna (Aw) type, according to Köppen's [29] climate classification, with a predominance of the Cerrado sensu stricto phytophysiognomy; however, there are microregions of tropical monsoon (Am) and tropical rain (A) subtypes further north [30].

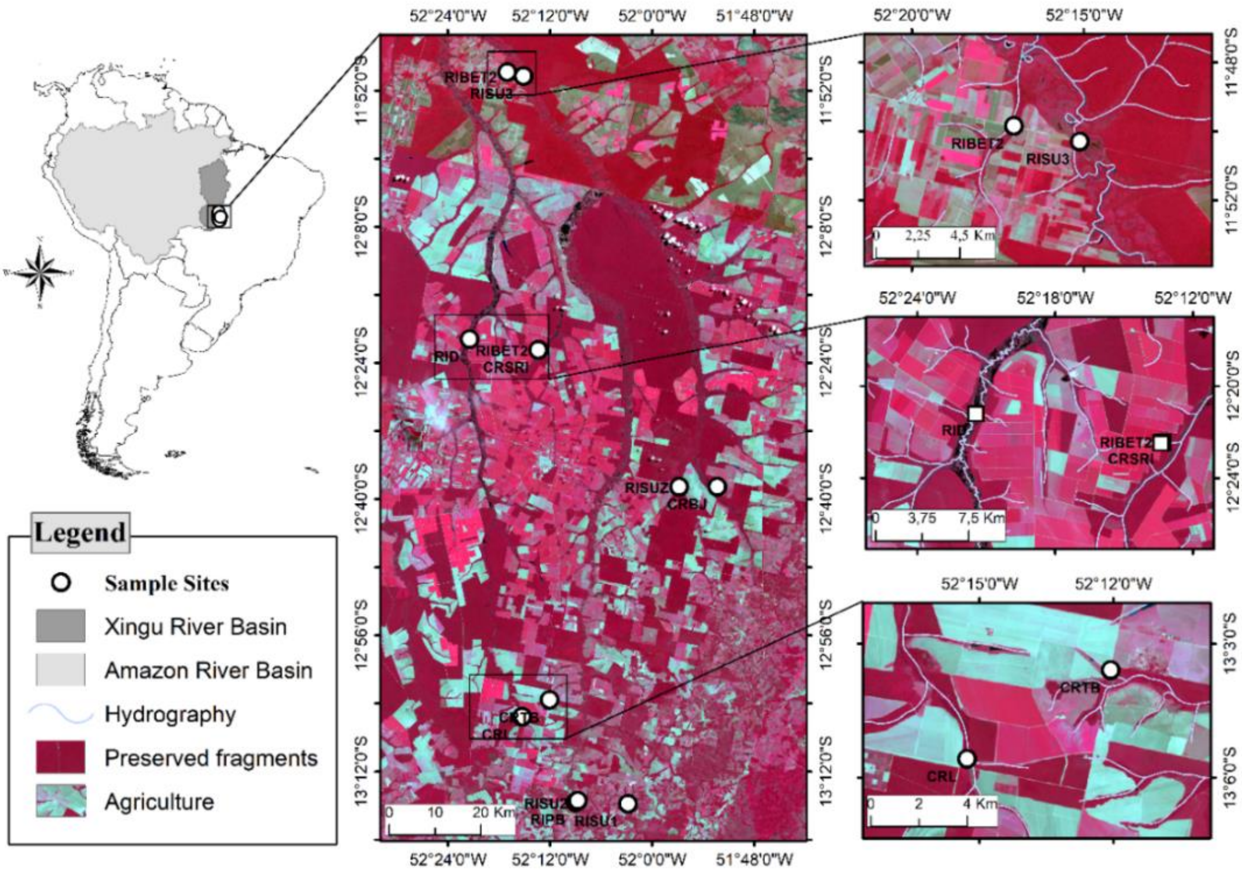

Figure 1. Study area and sampling sites from the upper Xingu River basin, Brazil, satellite image based on normalized difference vegetation index (NDVI). Composition false color bands 5/4/3—spatial resolution of 30 m (LANDSAT 8, 2017).

The average annual precipitation is 1370 mm, and the maximum and minimum temperatures range from 32.7 °C to 17.0 °C [30]. This region is experiencing an accelerated expansion of agriculture and is located in the area known as the "arc of deforestation" [31]. For many years, it was the target of logging and is now predominantly occupied by soy agriculture and extensive livestock [13].

2.2. Data Collection

2.2.1. Biological Sampling

Samples were obtained in fixed transections of 100 m, then divided into 20 segments of 5 m each per stream. The samples were collected using an 18-cm-diameter strainer and 0.05-mm mesh, passed three times through channel bed substrates and at the margins of each segment (modified by Ferreira-Peruquetti & De Marco [32], Dias-Silva et al. [33]). After a trial in the field, the material was preserved in 85% ethyl alcohol. The identification of genera/morphospecies was carried out with the help of dichotomous keys [34]. Specimens were deposited into the Zoobotanical collection "James Alexander Ratter" (CZNX), in Universidade do Estado do Mato Grosso (UNEMAT), Nova Xavantina city, MT, Brazil.

2.2.2. Environmental Variables

In each stream the variables were measured: pH, water temperature (°C), turbidity (NTU), dissolved oxygen (DO; mg/L), and conductivity (µm/s), with a multiparameter probe (Horiba®, HORIBA UK Limited, Northampton, UK). The width of the streams was measured with laser measuring (DISTOM®, Leica, Curitiba, Brazil, and the depth was measured with the help of an ecobathometer (Echotest® mod II, PlastimoSAS, Lorient, France). The water nutrients, total hardness, nitrate, and orthophosphate concentrations were measured following the protocol established by the APHA [35].

2.2.3. Habitat Integrity Sample

To assess the habitat integrity in each stream, we used the habitat integrity index (HII) proposed by Nessimian et al. [36]. This index consists of 12 items that assess the width of the riparian vegetation and its state of conservation within a range of 50 m, structure of the ravines, heterogeneity along the stream as to the type of substrate, retention devices in the stream bed, presence of rapids and wells, and type of crops adjacent to the riparian vegetation. The index ranges from zero to one, indicating an increasing gradient of integrity. The HII ranged from 0.39 to 0.74 in the sampled streams.

2.2.4. Sample of Vegetation Index

To obtain the vegetation indexes in the study area, ArcGis 10.1 geoprocessing software was used [37]. Initially, we obtained two scenes from a Landsat 8 satellite (22468 and 22469) free of charge for research purposes on the Earth Explorer website (https://earthexplorer.usgs.gov/) (accessed on 2 April 2020) for the same month and year of samples. This satellite had 170 × 183 km of imaging, a temporal resolution of 16 days, and 11 bands, but only three were used in this study (near infrared—band 5, red—band 4, and blue—band 2). The classification of land use was made with supervised classification. These three bands of each scene were subjected to a conversion of pixel values from digital numbers to reflectance in ArcGis 10.1 (Arctoolbox—Spatial Analyst Tools—Map Algebra—Raster Calculator) (Esri, Redlands, CA, USA), using the formula provided by the American Geological Agency—USGS (https://www.usgs.gov/land-resources) (accessed on 2 April 2020):

$$p_\lambda = \left(Mo\ Q_{cal} + A_p\right) \times Sin(\theta_E)$$

where:

p_λ = Reflection of the top of the atmosphere;
Mo = Band-specific multiplicative scaling factor;
Q_{cal} = Band-specific additive scaling factor;
A_p = Calibrated standard product pixel;
θ_E = Local elevation angle of the sun.

After the transformation of the digital number for reflectance, we used a calculator raster in ArcGis 10.1 to calculate the normalized difference vegetation index (NDVI) and the enhanced vegetation index (EVI) in a linear buffer with 30 m of width. The NDVI calculation assisted the mapping and prediction of land cover degradation [38], indicating the amount of green vegetation in one pixel [39]. This is because of the green leaves' high absorption of visible light, together with the high reflectance in the near infrared, resulting in positive values of NDVI. Exposed soil, cloud, and impermeable surfaces had NDVI values close to zero, while water had negative NDVI values [40]. The EVI was useful in assessing the vegetation vigor, as it was directly related to variations in vegetation cover [41]. The first index was calculated using the following formula:

$$\text{NDVI} = (\text{NIR} - \text{Red})/(\text{NIR} + \text{Red})$$

where:

NIR = Spectral band of near infrared;

Red = Red spectral band.

We based the second index on Justice et al. [41], and we used the following formula:

$$\text{EVI} = \text{G}\times\left(\frac{\text{NIR} - \text{Red}}{(\text{NIR} + \text{C1}\times\text{Red}) - (\text{C2}\times\text{Blue} + 1)}\right)$$

where:

G = 2.5;
C1 e C2 = Adjustment coefficients for the effect of aerosols in the atmosphere, being C1 = 6, C2 = 7.5;
NIR = Spectral band of near infrared;
Red = Red spectral band;
Blue = Blue spectral band.

2.3. Data Analysis

First, environmental variables were standardized with the "decostand" function from the "vegan" package (version 1.17-4) [42]. Second, environmental variables most important for aquatic and semi-aquatic Heteroptera were selected through the best subset of environmental variables with maximum (rank) correlation with community dissimilarities (BIOENV) analysis, which consists of a method of selecting variables [43], with the "bioenv" function from the "vegan" package [42].

To visualize the composition of species at the sites, the principal coordinate analysis (PCoA) was executed, using the distance matrix of Bray–Curtis [44]. For PCoA, the abundances were log-transformed with the log function (x + 1) and "rda" function from the "vegan" package [42]. To evaluate the relationship of the environmental variables selected by BIOENV with the composition of aquatic and semi-aquatic Heteroptera genera, we used a Mantel test, with a Bray–Curtis distance matrix for species and the Euclidian distance matrix for environmental variables with the "vegdist" function [44] with the "mantel" function from the "vegan" package [42]. All analyses were performed using R language (version 3.6.2, R Foundation for Statistical Computing, Vienna, Austria) [45].

3. Results

We sampled 263 individuals from 8 families and 20 genera. Representatives of the two infra-orders were collected, 12 genera belonging to Nepomorpha (aquatic) and 8 to Gerromorpha (semi-aquatic). The most abundant genera were *Limnocoris* (n = 121) (Nepomorpha) and *Rhagovelia* (n = 32) (Gerromorpha) belonging to the families Naucoridae and Veliidae, respectively. Naucoridae was the most diverse family with five genera collected (Table 1).

As for the environmental variables, the HII showed mean values of 0.69 and a ±0.09 standard deviation, EVI (0.30 ± 0.11), NDVI (0.50 ± 0.14), pH (4.88 ± 0.44), turbidity (62.20 ± 25.94), air temperature (30 ± 2.77), water temperature (24.13 ± 0.93), dissolved oxygen (8.21 ± 1.24), depth (1.28 ± 1.06), width (34.57 ± 42.17), nitrate (0.35 ± 0.11), phosphorus (0.08 ± 0.07), total hardness (4.71 ± 4.39), Ca (2.33 ± 3.91), and Mg (2.38 ± 0.64) in the analyzed environments (see Table S1). When the variation coefficient was calculated, the variables that showed the greatest variation when compared with the others were Ca = 1.67, width (1.21), and depth (0.82).

When we evaluated which environmental variables were most important for Heteroptera aquatic and semi-aquatic genus compositions, of the 16 environmental variables analyzed, the best explanation was related to a group of 5 variables, with HII, NDVI, conductivity, turbidity, and depth together explaining (52%) of the composition (Table 2). The relationship between environmental variables and aquatic and semi-aquatic Heteroptera was significant (r = 0.49; p = 0.001).

Table 1. Composition and abundance of aquatic and semi-aquatic Heteroptera in 12 streams located in the transition zone between the Amazon and Cerrado biomes in headwaters of Xingu River, Brazil.

Infraorder/Family/Genus	Total	Forest	Agriculture
Gerromorpha			
Gerridae			
Brachymetra Mayr, 1865	10		×
Cylindrostethus Mayr, 1865	13	×	×
Limnogonus Stål, 1868	1		×
Neogerris Matsumura, 1913	16	×	×
Hydrometridae			
Hydrometra Latreille, 1796	1	×	
Veliidae			
Euvelia Drake, 1957	9	×	
Rhagovelia Mayr, 1865	32	×	×
Stridulivelia Hungerford, 1929	2	×	×
Nepomorpha			
Belostomatidae			
Belostoma Latreille, 1807	3	×	×
Corixidae			
Tenagobia Bergroth, 1899	7	×	×
Naucoridae			
Ambrysus Stål, 1862	13	×	×
Ctenipocoris Montandon, 1897	1	×	
Limnocoris Stål, 1860	121	×	×
Pelocoris Stål, 1876	1	×	
Placomerus La Rivers, 1956	2		×
Nepidae			
Curicta Stål, 1862	1	×	
Ranatra Fabricius, 1790	3	×	
Notonectidae			
Buenoa Kirkaldy, 1904	6		×
Martarega White, 1879	20	×	×
Potomocorinae	1	×	
Total	**263**		

Table 2. BIOENV results for the correlation between the 10 environmental predictors and the communities of aquatic Heteroptera of the 12 streams located in the transition zone between the Amazon and Cerrado biomes in headwaters of Xingu River, Brazil. The selected model is in bold.

Combinations of Environmental Variables	Correlation
Dep	0.409
Cond + Dep	0.470
Cond+ Dep + Pho	0.511
NDVI + Cond + Dep + Pho	0.522
HII + NDVI + Cond + Turb + Dep	**0.524**
HII+ EVI + Cond + Dep + Nitr + Pho	0.522
HII+ EVI + Cond + AT + Dep + Nitr + Pho	0.515
HII+ EVI + Cond + Turb + AT + Dep + Nitr + Pho	0.511
HII+ EVI + NDVI + Cond + Turb + AT + Dep + Nitr + Pho	0.490
HII+ EVI + NDVI + pH + Cond + Turb + AT + Dep + Nitr + Pho	0.463
HII + EVI + NDVI + pH + Cond + Turb + AT + WT+ Dep+ Nitr + Pho	0.436
HII + EVI + NDVI + pH + Cond + Turb + AT + WT + Prof + Wid + Nitr + Pho	0.413
HII + EVI + NDVI + pH + Cond + Turb + AT + WT + DO + Dep + Wid + Nitr + Pho	0.379
HII+ EVI + NDVI + pH + Cond +Turb + AT + WT + DO + Dep + Wid + Nitr + Pho + Mg	0.345
HII + EVI + NDVI + pH + Cond + Turb + AT + WT + DO + Dep + Wid + Nitr + Pho + TH + Mg	0.231
HII + EVI + NDVI + pH + Cond + Turb + AT + WT + DO + Dep + Wid + Nitr + Pho + TH + Ca + Mg	0.088

HII—habitat integrity index; EVI—enhanced vegetation index; NDVI—normalized difference vegetation index; pH—potential of hydrogen; Cond—conductivity; Turb—turbidity; AT—air temperature; WT—water temperature; DO—dissolved oxygen; Dep—depth; Wid—width; Nitr—nitrate; Pho—phosphorus; TH—total hardness; Ca—calcium; Mg—magnesium.

The PCoA demonstrated 34% of the explanation in the first axis and 20% of the explanation in the second axis (Figure 2). The composition of forest and agricultural environments was different, with the forested streams presenting similar compositions between them.

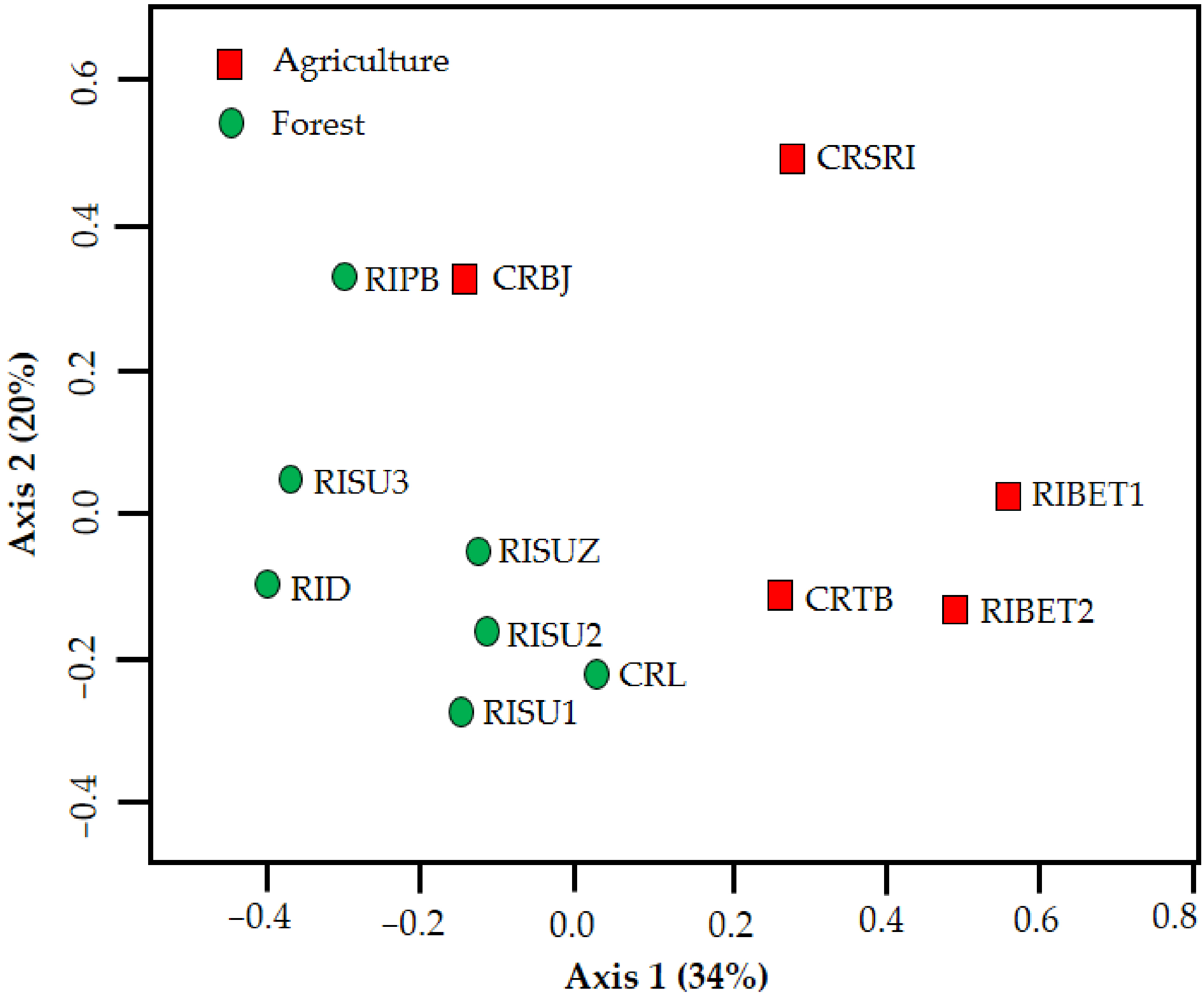

Figure 2. PcoA analysis of the similarity between investigated sites due to Heteroptera community in Xingu River basin streams in the Cerrado–Amazon ecotone, Brazil.

4. Discussion

The relationship among environmental variables with aquatic communities has been well documented in streams of the Amazon, Cerrado, and in transition areas [16,46,47]. These studies found that changing the surrounding matrix of streams directly affected the availability of habitats for aquatic organisms, increased the entry of light, and changed the water quality, e.g., increasing temperatures and decreasing oxygen [17,48–52]. The relationship between environmental variables—HII, NDVI, conductivity, turbidity, depth, and Heteropterans' aquatic and semi-aquatic compositions corroborated with other studies based on Odonata, Trichoptera and Ephemeroptera in the Suiá-Miçu basin [16,17,48] and with the studies carried out with the Heteroptera in the Cerrado and in the Amazon rainforest where the composition responded to environmental changes [24,53,54].

The HII, NDVI, and water depth were related to the physical structures of these streams and were directly affected by the removal of riparian vegetation, which caused an imbalance in these streams. As a result, this increased the abundance of generalist individuals and reduced the abundance of specialist organisms [33,55,56]. On a local scale, changes in the riparian forest led the decrease of the quantity and quality of habitats available in streams by aquatic communities [24,33,57]. For this reason, the increase of sediments at the channel and the reduction of allochthone material might affect the basis of food chains [4,58]. Thus, the reduction in the availability of niches favored competition for resources and the entry of generalist species into the group, changing local biodiversity [5,24,59].

Previous studies have indicated that the suppression of riparian vegetation and the form of land use altered the environmental and structural qualities of streams, affecting the structure of the aquatic insect community—leading to a loss of biodiversity and function [7,60,61]. In addition, these land use changes could alter the natural conditions of some water variables, such as conductivity, turbidity, water hardness, pH, and nutrients due to the contribution of sediments from the surroundings into the stream. Thus, in the results, the variation in hardness (Ca) may have been associated with the presence of the agricultural areas that used calcium for soil correction, or even due to the natural characteristics of the drainage basin. For example, a study on Cerrado streams indicated that the variation in total hardness was related not only to the drainage basin but also to streams without riverside vegetation and the entry of pollutants from human activities in the surrounding area [62].

Previous studies claimed that environmental variables could drive changes in aquatic insect communities' compositions [63]. For example, conductivity is one of the most important environmental variables for the structure of aquatic communities in lotic environments [64,65]. The relationship between conductivity and Heteroptera composition was highlighted by Goulart et al. [66] in their study at Parque Estadual Serra Rola-Moça (Minas Gerais state, Brazil), and by Cunha & Juen [24] in Amazonian streams. Several factors changed the conductivity of the water, for example, the organic matter supplied by riparian vegetation to small streams decomposed, and the organic material could change the composition of ions in the water, thus increasing the conductivity [67]. In addition, the modification of the matrix surrounding the stream might contribute to the entry of agricultural inputs and other pollutants, changing the water quality [68,69].

Turbidity might be related to the increase in the carrying of the soil and consequently to the silting of the aquatic environments. These two factors were closely related to habitat loss and the reduction of aquatic communities [70,71]. Activities such as the removal of riparian vegetation combined with agriculture and cattle ranching helped in the appearance of these variables. Many studies have indicated that the structuring of the aquatic insect communities was related to the interaction between species and physical conditions of the habitat (for example, substrate, riparian vegetation, width, etc.), combined with limnological variables (e.g., conductivity, turbidity, pH, etc.) [2,72,73]. Thus, a study evaluating the insect community (EPT) in streams corroborated the relationship between the presence of riparian vegetation and the community, because many groups used this vegetation as a source of refuge and food [74,75].

The difference in the composition of the Heteroptera between streams of agricultural areas and forests can be attributed to the absence of or reduced riparian vegetation in most streams of agriculture. The presence of riparian vegetation minimized the effects of land-use change on habitat and, consequently, on the fish community [15] and on the Heteroptera [21,75,76]. The change in land use and cover, especially for economic purposes, had the consequence of reducing water quality and the availability of habitats as a result of the removal of riparian vegetation [2,77]. These changes are more intense in headwater streams, because they are more dependent on riparian vegetation and less stable [4]. One of the processes that depends on riparian vegetation is the entry of allochthone material, such as branches, leaves, and fruits [78,79]. This process tends to increase the heterogeneity of habitats and local conditions, because the presence of organic substrates (leaves, fruits, and branches) is home to different species. Additionally, the trunks can form areas of ripples and allow organisms adapted to this type of condition to establish themselves. In addition, the presence of riparian vegetation provides patches of shade and sun, which allows species with different physiological characteristics and specificities to coexist in these environments [5].

5. Conclusions

The Heteroptera community presented relations to variables that could be used to indicate habitat quality and to variables used to indicate water quality. These results demonstrated that these organisms responded to environmental changes that occur in the Cerrado–Amazonian stream, and the importance of maintaining riparian vegetation in streams for the maintenance of aquatic communities and the ecosystem services they provide. They also demonstrated that the composition of genera is capable of providing answers to changes in the quality of streams, as demonstrated in our results, and supported by other studies. Thus, one must consider, in monitoring and conservation programs for aquatic organisms, evaluating both on a local and large scale (i.e., landscape) this relationship between environmental variables, physical environment variables, and how these relationships structure the Heteroptera community aiming at the conservation of streams in the Cerrado.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/arthropoda1010004/s1, Table S1: Environmental variables of the twelve streams located in the transition zone between the Amazon and Cerrado biomes in headwaters of Xingu River, Brazil. (HII—habitat integrity index; EVI—enhanced vegetation index; NDVI—normalized difference vegetation index; pH—potential of hydrogen; Cond—conductivity; Turb—turbidity; AT—air temperature; WT—water temperature; DO—dissolved oxygen; Dep—depth; Wid—width; Nitr—nitrate; Pho—phosphorus; TH—total hardness; Ca—calcium; Mg—magnesium).

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References

1. Allen, J.D. Landscapes and riverscapes: The influence of land use on stream ecosystems. *Annu. Rev. Ecol. Evol. Syst.* **2004**, *35*, 257–284. [CrossRef]
2. Juen, L.; Cunha, E.J.; Carvalho, F.G.; Ferreira, M.C.; Begot, T.O.; Luiza-Andrade, A.; Shimano, Y.; Leão, H.; Pompeu, P.S.; Montag, L.F.A. Effects of oil palm plantations on the habitat structure and biota of streams in Eastern Amazon. *River Res. Appl.* **2016**, *32*, 2081–2094. [CrossRef]

3. Allan, J.D.; Castilho, M.M. *Stream Ecology: Structure and Function of Running Waters*, 2nd ed.; Springer: Amsterdam, The Netherlands, 2007; 436p.
4. Vannote, R.L.; Minshall, G.W.; Cummins, K.W.; Sedell, J.R.; Cushing, C.E. The river continuum concept. *Can. J. Fish. Aquat. Sci.* **1980**, *37*, 130–137. [CrossRef]
5. Thorp, J.H.; Thoms, M.C.; Delong, M.D. The riverine ecosystem synthesis: Biocomplexity in river networks across space and time. *River Res. Appl.* **2006**, *22*, 123–147. [CrossRef]
6. Brito, J.G.; Roque, F.O.; Martins, R.T.; Nessimian, J.L.; Oliveira, V.C.; Hughes, R.M.; De Paula, F.R.; Silvio, F.B.F.; Hamada, N. Small forest losses degrade stream macroinvertebrate assemblages in the eastern Brazilian Amazon. *Biol. Conserv.* **2020**, *241*, 108263. [CrossRef]
7. Dala-Corte, R.B.; Melo, A.S.; Siqueira, T.; Bini, L.M.; Martins, R.T.; Cunico, A.M.; Pes, A.M.; Magalhães, A.L.B.; Godoy, B.S.; Leal, C.G.; et al. Thresholds of freshwater biodiversity in response to riparian vegetation loss in the Neotropical region. *J. Appl. Ecol.* **2020**, *57*, 1391–1402. [CrossRef]
8. Bacellar, L.A.P. O papel das florestas no regime hidrológico de bacias hidrográficas. *Geo. br* **2005**, *1*, 1–39.
9. Bispo, P.C.; Oliveira, L.G.; Bini, L.M.; Sousa, K.G. Ephemeroptera, Plecoptera and Trichoptera assemblages from riffles in mountain streams of Central Brazil: Environmental factors influencing the distribution and abundance of immatures. *Braz. J. Biol.* **2006**, *66*, 611–622. [CrossRef]
10. Martins, R.T.; Couceiro, S.R.M.; Melo, A.S.; Moreira, M.P.; Hamada, N. Effects of urbanization on stream benthic invertebrate communities in Central Amazon. *Ecol. Indic.* **2017**, *73*, 480–491. [CrossRef]
11. Bonada, N.; Prat, N.; Resh, V.H.; Statzner, B. Developments in aquatic insect biomonitoring: A comparative analysis of recent approaches. *Annu. Rev. Entomol.* **2006**, *5*, 495–523. [CrossRef]
12. Lammert, M.; Allan, J.D. Assessing biotic integrity of streams: Effects of scale in measuring the influence of land use/cover and habitat structure on fish and macroinvertebrates. *Environ. Manag.* **1999**, *23*, 257–270. [CrossRef] [PubMed]
13. Brando, P.M.; Coe, M.; Defries, R.; Azevedo, A.A. Ecology, economy and management of an agroindustrial frontier landscape in the southeast Amazon. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2013**, *368*, 20120152. [CrossRef] [PubMed]
14. Marques, A.; Martins, I.S.; Kastner, T.; Plutzar, C.; Theurl, M.C.; Eisenmenger, N.; Huijbregts, M.A.J.; Wood, R.; Stadler, K.; Bruckner, M.; et al. Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. *Nat. Ecol. Evol.* **2019**, *3*, 628–637. [CrossRef] [PubMed]
15. Montag, L.F.; Winemiller, K.O.; Keppeler, F.W.; Leão, H.; Benone, N.L.; Torres, N.R.; Prudente, B.S.; BeGot, T.O.; Bower, L.M.; Saenz, D.E.; et al. Land cover, riparian zones and instream habitat influence stream fish assemblages in the eastern Amazon. *Ecol. Freshw. Fish* **2019**, *28*, 317–329. [CrossRef]
16. Nogueira, D.S.; Cabette, H.S.R.; Juen, L. Estrutura e composição da comunidade de Trichoptera (Insecta) de rios e áreas alagadas da bacia do rio Suiá-Miçú, Mato Grosso, Brasil. *Iheringia Sér. Zool.* **2011**, *101*, 173–180. [CrossRef]
17. Shimano, Y.; Cabette, H.S.R.; Salles, F.F.; Juen, L. Composição e distribuição da fauna de Ephemeroptera (Insecta) em área de transição Cerrado-Amazônia, Brasil. *Iheringia Sér. Zool.* **2010**, *100*, 301–308. [CrossRef]
18. Fischer, J.; Lindenmayer, D.B. Landscape modification and habitat fragmentation: A synthesis. *Glob. Ecol. Biogeogr.* **2007**, *16*, 265–280. [CrossRef]
19. Rosenberg, D.M.; Resh, V.H. *Freshwater Biomonitoring and Benthic Macroinvertebrates*; Chapman & Hall: New York, NY, USA, 1993; 488p.
20. Giehl, N.F.; Dias-Silva, K.; Juen, L.; Batista, J.D.; Cabette, H.S.R. Taxonomic and numerical resolutions of Nepomorpha (Insecta: Heteroptera) in cerrado streams. *PLoS One* **2014**, *9*, e103623. [CrossRef]
21. Dias-Silva, K.; Brasil, L.S.; Veloso, G.K.O.; Cabette, H.S.R.; Juen, L. Land use change causes environmental homogeneity and low beta-diversity in Heteroptera of streams. *Ann. Limnol. Int. J. Lim.* **2020**, *56*, 9. [CrossRef]
22. Moy, K.M.; Brasil, L.S.; Oliveira-Junior, J.M.B.; Juen, L.; Vieira, T.B.; Dias-Silva, K. Effects of Environmental Changes on Gerromorpha (Heteroptera: Hemiptera) Communities from Amazonian Streams. *Hydrobiology* **2022**, *1*, 8. [CrossRef]
23. Cordeiro, I.R.; Moreira, F.F. New distributional data on aquatic and semiaquatic bugs (Hemiptera: Heterop-tera: Gerromorpha & Nepomorpha) from South America. *Biodivers. Data J.* **2015**, *3*, e4913. [CrossRef]
24. Cunha, E.J.; Juen, L. Environmental drivers of the metacommunity structure of insects on the surface of tropical streams of the Amazon. *Austral Ecol.* **2020**, *45*, 586–595. [CrossRef]
25. Guterres, A.P.; Cunha, E.J.; Godoy, B.S.; Silva, R.R.; Juen, L. Co-occurrence patterns and morphological similarity of semiaquatic insects (Hemiptera: Gerromorpha) in streams of Eastern Amazonia. *Ecol. Entomol.* **2020**, *45*, 155–166. [CrossRef]
26. Cabette, H.S.R.; Giehl, N.F.S.; Dias-Silva, K.; Juen, L.; Batista, J.B. Distribuição de Nepomorpha e Gerro-morpha (Insecta: Heteroptera) da Bacia Hidrográfica do Rio Suiá- Miçu, MT: Riqueza relacionada à qualidade da água e do hábitat. In *Gestão e Educação Ambiental: Água, Biodiversidade e Cultura*; Santos, J.E., Galbiati, C., Moschini, L.E., Eds.; RiMa: São Carlos, Brazil, 2010; Volume 2, pp. 113–137.
27. Strahler, A.N. Quantitative analysis of watershed geomorphology. *Eos. Trans. Am. Geophys. Un.* **1957**, *38*, 913–920. [CrossRef]
28. Skorupa, L.A.; Costa, U.M.P.; Cunha, P.; Rossete, A.N.; Fidalgo, E.C.C.; Simões, M.; Choueri, R. Monitoramento da Qualidade da Água na Bacia Hidrográfica do Rio Suiá-Miçu. Embrapa Meio Ambiente-Documentos; IN-FOTECA-E: Brasília, Brazil, 2017.
29. Köppen, W. *Grundriss der Klimakunde*; Gruyter: Berlin, Germany, 1931; 338p.

30. Ratter, J.A.; Askew, G.P.; Montgomery, R.F.; Gifford, D.R. Observations on the vegetation of northeastern Mato Grosso II. Forest and Soils of the Rio Suiá-Miçú area. *Proc. R. Soci. Lond.* **1978**, *203*, 191–208. [CrossRef]
31. Domingues, M.S.; Bermann, C. O arco de desflorestamento na Amazônia: Da pecuária à soja. *Ambient. Soc.* **2012**, *15*, 1–22. [CrossRef]
32. Ferreira-Peruquetti, P.; De Marco, P., Jr. Efeito da alteração ambiental sobre comunidades de Odonata em riachos de Mata Atlântica de Minas Gerais, Brasil. *Rev. Bras. Zool.* **2002**, *19*, 317–327. [CrossRef]
33. Dias-Silva, K.; Juen, L.; Cabette, H.S.R.; De Marco, P., Jr. The influence of habitat integrity and physical-chemical water variables on the structure of aquatic and semi-aquatic Heteroptera. *Zoologia* **2010**, *27*, 918–930. [CrossRef]
34. Nieser, N.; Melo, A.L. *Os Heterópteros Aquáticos de Minas Gerais: Guia Introdutório com Chave de Identificação Para as Espécies de Nepomorpha e Gerromorpha*; Universidade Federal de Minas Gerais: Belo Horizonte, Brazil, 1997; 180p.
35. APHA. *Standard Methods for the Examination of Water and Wastewater*, 20th ed.; American Public Health Association; American Water Works Association and Water Environmental Federation: Washington DC, USA, 1998.
36. Nessimian, J.L.; Venticinque, E.M.; Zuanon, J.; De Marco, P., Jr.; Gordo, M.; Fidelis, L.; Batista, J.D.; Juen, L. Land use, habitat integrity, and aquatic insect assemblages in Central Amazonian streams. *Hydrobiologia* **2008**, *614*, 117–131. [CrossRef]
37. Esri. ArcGIS Desktop: Version 10.1. Environmental Systems Research Institute: Redlands, CA, USA, 2014.
38. Prince, S.D.; Becker-Reshef, I.; Rishmawi, K. Detection and mapping of long-term land degradation using local net production scaling: Application to Zimbabwe. *Remote Sens. Environ.* **2009**, *113*, 1046–1057. [CrossRef]
39. Prates-Clark, C.D.C.; Saatchi, S.S.; Agosti, D. Predicting geographical distribution models of high-value timber trees in the Amazon Basin using remotely sensed data. *Ecol. Modell.* **2008**, *211*, 309–323. [CrossRef]
40. Neigh, C.S.; Tucker, C.J.; Townshend, J.R. North American vegetation dynamics observed with multi-resolution satellite data. *Remote Sens. Environ.* **2008**, *112*, 1749–1772. [CrossRef]
41. Justice, C.O.; Vermote, E.; Townshend, J.R.; Defries, R.; Roy, D.P.; Hall, D.K.; Salomonson, V.V.; Privette, J.L.; Riggs, G.; Strahler, A.; et al. The Moderate Resolution Imaging Spectroradiometer (MODIS): Land remote sensing for global change research. *IEEE Trans. Geosci. Remote Sens.* **1998**, *36*, 1228–1249. [CrossRef]
42. Oksanen, J.; Blanchet, F.G.; Kindt, R.; Legendre, P.; O'Hara, R.B.; Simpson, G.L.; Solymos, P.; Henry, M.; Stevens, W.H. Vegan: Community Ecology Package. R package version, 1.17-4. 2010. Available online: http://CRAN.R-project.org/package=vegan (accessed on 20 April 2020).
43. Clarke, K.R.; Ainsworth, M. A method of linking multivariate community structure to environmental variables. *Mar. Ecol. Prog. Ser.* **1993**, *92*, 205–219. [CrossRef]
44. Legendre, P.; Legendre, L. *Numerical Ecology*, 3rd ed.; Elsevier: Oxford, UK, 2012.
45. R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing: Vienna, Austria, 2019. Available online: https://www.R-project.org/ (accessed on 20 April 2020).
46. Ilha, P.; Rosso, S.; Schiesari, L. Effects of deforestation on headwater stream fish assemblages in the Upper Xingu River Basin, Southeastern Amazonia. *Neotrop. Ichthyol.* **2019**, *17*. [CrossRef]
47. De Faria, A.P.J.; Ligeiro, R.; Callisto, M.; Juen, L. Response of aquatic insect assemblages to the activities of traditional populations in eastern Amazonia. *Hydrobiologia* **2017**, *802*, 39–51. [CrossRef]
48. Mendes, T.P.; Cabette, H.S.R.; Juen, L. Setting boundaries: Environmental and spatial effects on Odonata larvae distribution (Insecta). *An. Acad. Bras. Cienc.* **2015**, *87*, 239–248. [CrossRef]
49. Brasil, L.S.; Batista, J.D.; Giehl, N.F.S.; Valadão, M.B.X.; Santos, J.O.D.; Dias-Silva, K. Environmental integrity and damselfly species composition in Amazonian streams at the "arc of deforestation" region, Mato Grosso, Brazil. *Acta Limnol. Bras.* **2014**, *26*, 278–287. [CrossRef]
50. Juen, L.; Oliveira-Junior, J.M.B.; Shimano, Y.; Mendes, T.P.; Cabette, H.S.R. Composição e riqueza de Odonata (Insecta) em riachos com diferentes níveis de conservação em um ecótone Cerrado-Floresta Amazônica. *Acta Amaz.* **2014**, *44*, 223–233. [CrossRef]
51. Voelz, N.J.; Mcarthur, J.V. An exploration of factors influencing lotic insect species richness. *Biodivers. Conserv.* **2000**, *9*, 1543–1570. [CrossRef]
52. Leal, C.G.; Lennox, G.D.; Ferraz, S.F.; Ferreira, J.; Gardner, T.A.; Thomson, J.R.; Berenguer, E.; Lees, A.C.; Hughes, R.M.; Nally, R.M.; et al. Integrated terrestrial-freshwater planning doubles conservation of tropical aquatic species. *Science* **2020**, *370*, 117–121. [CrossRef] [PubMed]
53. Dias-Silva, K.; Juen, L.; Brasil, L.S.; Freitas, P.V.; De Marco, P., Jr. Influence of local variables and landscape metrics on Gerromorpha (Insecta: Heteroptera) assemblages in Savanna streams, Brazil. *Neotropic. Entomol.* **2020**, *49*, 191–202. [CrossRef] [PubMed]
54. Giehl, N.F.S.; Cabette, H.S.R.; Dias-Silva, K.; Juen, L.; Moreira, F.F.F.; Castro, L.A.; Ferreira, V.R.S.; Batista, J.D. Variation in the diversity of semiaquatic bugs (Insecta: Heteroptera: Gerromorpha) in altered and preserved veredas. *Hydrobiologia* **2020**, *847*, 3497–3510. [CrossRef]
55. Liess, S.; Snyder, P.K.; Harding, K.J. The effects of boreal forest expansion on the summer Arctic frontal zone. *Clim. Dyn.* **2012**, *38*, 1805–1827. [CrossRef]
56. Lock, K.; Adriaens, T.; Van De Meutter, F.; Goethals, P. Effect of water quality on waterbugs (Hemiptera: Gerromorpha & Nepomorpha) in Flanders (Belgium): Results from a large-scale field survey. *Ann. Limnol. Int. J. Lim.* **2013**, *49*, 121–128. [CrossRef]

57. Bastos, R.C.; Brasil, L.S.; Oliveira-Junior, J.M.B.; Carvalho, F.G.; Lennox, G.D.; Barlow, J.; Juen, L. Morphological and phylogenetic factors structure the distribution of damselfly and dragonfly species (Odonata) along an environmental gradient in Amazonian streams. *Ecol. Indic.* **2021**, *122*, 107257. [CrossRef]
58. Cummins, K.W.; Wilzbach, M.A.; Gates, D.M.; Perry, J.B.; Taliaferro, W.B. Shredders and riparian vegetation. *BioScience* **1989**, *39*, 24–30. [CrossRef]
59. Giehl, N.F.; Resende, B.O.; Roges, P.F.; Dias-Silva, K.; Nogueira, D.S.; Cabette, H.S.R. Diversidade de presas e predadores (Insecta) em mesohabitats de córregos de Cerrado. *Iheringia Sér. Zool.* **2018**, *108*, e2018042. [CrossRef]
60. Castro, D.M.P.; Dolédec, S.; Callisto, M. Land cover disturbance homogenizes aquatic insect functional structure in neotropical savanna streams. *Ecol. Indic.* **2018**, *84*, 573–582. [CrossRef]
61. Martins, R.T.; Brito, J.; Dias-Silva, K.; Leal, C.G.; Leitão, R.P.; Oliveira, V.C.; Oliveira-Junior, J.M.B.; Ferraz, S.F.B.; De Paula, F.R.; Roque, F.O.; et al. Low forest-loss thresholds threaten Amazonian fish and macroinvertebrate assemblage integrity. *Ecol. Indic.* **2021**, *127*, 107773. [CrossRef]
62. Pimentel, C.S.; Ramos, M.E.P.L.; Dias-Silva, K.; Costa, U.M.P. Avaliação de algumas variáveis limnológicas de três córregos em Nova Xavantina-MT. *Enciclopédia Biosfera* **2014**, *10*, 2023–2035.
63. Brasil, L.S.; Luiza-Andrade, A.; Calvão, L.B.; Dias-Silva, K.; Faria, A.P.J.; Shimano, Y.; Oliveira-Junior, J.M.B.; Cardoso, M.N.; Juen, L. Aquatic insects and their environmental predictors: A scientometric study focused on environmental monitoring in lotic environmental. *Environ. Monit. Assess.* **2020**, *192*, 1–10. [CrossRef] [PubMed]
64. Peeters, E.T.; Gylstra, R.; Vos, J.H. Benthic macroinvertebrate community structure in relation to food and environmental variables. *Hydrobiologia* **2004**, *519*, 103–115. [CrossRef]
65. Godoy, B.S.; Faria, A.P.J.; Juen, L.; Lodi, S.; Oliveira, L.G. Taxonomic sufficiency and effects of environ-mental and spatial drivers on aquatic insect community. *Ecol. Indic.* **2019**, *107*, 105624. [CrossRef]
66. Goulart, M.; Melo, A.L.; Callisto, M. Qual a relação entre variáveis ambientais e diversidade de heterópteros aquáticos em nascentes de altitude? *BIOS Cad. Do Dep. De Ciências Biológicas Da PUC Minas* **2002**, *10*, 63–76.
67. Leitão, R.P.; Zuanon, J.; Mouillot, D.; Leal, C.G.; Hughes, R.M.; Kaufmann, P.R.; Villéger, S.; Pompeu, P.S.; Kasper, D.; de Paula, F.R.; et al. Disentangling the pathways of land use impacts on the functional structure of fish assemblages in Amazon streams. *Ecography* **2018**, *41*, 219–232. [CrossRef] [PubMed]
68. Couceiro, S.R.M.; Hamada, N.; Luz, S.L.; Forsberg, B.R.; Pimentel, T.P. Deforestation and sewage effects on aquatic macroinvertebrates in urban streams in Manaus, Amazonas, Brazil. *Hydrobiologia* **2007**, *575*, 271–284. [CrossRef]
69. Song, Y.; Song, X.; Shao, G.; Hu, T. Effects of Land Use on Stream Water Quality in the Rapidly Urbanized Areas: A Multiscale Analysis. *Water* **2020**, *12*, 1123. [CrossRef]
70. Richter, B.D.; Braun, D.P.; Mendelson, M.A.; Master, L.L. Threats to imperiled freshwater fauna: Amena-zas a la fauna dulceacuicola en riesgo. *Conserv. Biol.* **1997**, *11*, 1081–1093. [CrossRef]
71. Newcombe, C.P.; Jensen, J.O. Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. *N. Am. J. Fish. Manag.* **1996**, *16*, 693–727. [CrossRef]
72. Calvão, L.B.; Nogueira, D.S.; Montag, L.F.A.; Lopes, M.A.; Juen, L. Are Odonata communities impacted by conventional or reduced impact logging? *For. Ecol. Manag.* **2016**, *382*, 143–150. [CrossRef]
73. Herlihy, A.T.; Sifneos, J.C.; Hughes, R.M.; Peck, D.V.; Mitchell, R.M. The relation of lotic fish and benthic macroinvertebrate condition indices to environmental factors across the conterminous USA. *Ecol. Indic.* **2020**, *112*, 105958. [CrossRef] [PubMed]
74. Ongaratto, R.; Loureiro, R.; Restello, R.; Hepp, L.U. Effects of land use and limnological variables on the dissimilarity of common and rare aquatic insects in Atlantic Forest streams. *Int. J. Trop. Biol.* **2018**, *66*, 1223–1231. [CrossRef]
75. Guterres, A.P.M.; Cunha, E.J.; Juen, L. Tolerant semiaquatic bugs species (Heteroptera: Gerromorpha) are associated to pasture and conventional logging in the Eastern Amazon. *J. Insect Conserv.* **2021**, *25*, 555–567. [CrossRef]
76. Vieira, T.B.; Dias-Silva, K.; Pacífico, E.S. Effects of riparian vegetation integrity on fish and heteroptera communities. *Appl. Ecol. Environ. Res.* **2015**, *13*, 53–65. [CrossRef]
77. Benstead, J.P.; Douglas, M.M.; Pringle, C.M. Relationships of stream invertebrate communities to deforestation in eastern Madagascar. *Ecol. Applic.* **2003**, *13*, 1473–1490. [CrossRef]
78. Casatti, L.; Teresa, F.B.; Gonçalves-Souza, T.; Bessa, E.; Manzotti, A.R.; Gonçalves, C.D.S.; Zeni, J.D.O. From forests to cattail: How does the riparian zone influence stream fish? *Neotrop. Ichthyol.* **2012**, *10*, 205–214. [CrossRef]
79. Tanaka, M.O.; De Souza, A.L.T.; Moschini, L.E.; De Oliveira, A.K. Influence of watershed land use and riparian characteristics on biological indicators of stream water quality in southeastern Brazil. *Agric. Ecosyst. Environ.* **2016**, *216*, 333–339. [CrossRef]