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A habitat suitability modeling of *Campylocia burmeisteri* (EPHEMEROPTERA: Euthyplociidae) (Hagen, 1888) and its application on freshwater resources conservation

Modelagem de adequabilidade de habitat de *Campylocia burmeisteri* (EPHEMEROPTERA: Euthyplociidae (Hagen, 1888) e suas aplicações na conservação recursos de água doce

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Abstract: Aim: This paper aims to make inferences about the quality of watercourses, and its conservation, through the habitat suitability model of *Campylocia burmeisteri*. **Methods:** The modelling demanded twenty-five occurrence records, twelve as training data and thirteen as test data. The study area consisted of a 300 kilometers buffer zone applied over the occurrence records. We used a set of twenty-two environmental layers as ambient data, as follows: 19 bioclimatic variables available on Worldclim; altitude from Worldclim; slope, obtained through geoprocessing in ArcGis v10.3 with altitude variable; and drainage density provide by Ambdata. These layers were transformed by the use of fuzzy logic to represent a continuous variation, and thus the most significant data was select after a PCA. To indicated to new surveys areas, we define locations with significant occurrence probability and distant from occurrence points. And, lastly, we observed the environmental integrity to analyze the potential watercourse quality, by using satellite images, in a buffer zone of ten kilometers from Espinhaço Range Biosphere Reserve. **Results:** The chosen regions with the highest occurrence probability, which account for 9 new survey areas, are concentrated in interfluvial areas and near conservation units. We performed an analysis focused on the region of the Espinhaço Range Biosphere Reserve and delimited seven areas that presented good habitat suitability. The region was observed using satellite images, and five of the areas presented high ecological integrity. Two areas showed impacts from mining activity. **Conclusions:** The distribution pattern corroborates the features of the species as a bioindicator of good water quality. It is estimated that this methodology can be adapted and applied to other bioindicators. The areas where headwaters and low-order tributaries are present must be conserved, because they are fundamental for maintaining the quality within the respective watershed.

Keywords: headwater; freshwater; river conservation; bioindication; aquatic insect; benthic macroinvertebrate.

Resumo: Objetivo: Realizar inferências sobre a qualidade dos cursos d'água e sua conservação, através do modelo de adequabilidade de habitat de *Campylocia burmeisteri*. **Métodos:** A modelagem utilizou vinte e cinco registros de ocorrência, sendo doze dados de treino e treze dados de teste. A área de estudo consistiu em uma zona de amortecimento de 300 quilômetros aplicada sobre os registros de ocorrência. Como dados ambientais, usamos um conjunto de vinte e duas camadas ambientais (19 variáveis bioclimáticas disponíveis no Worldclim; altitude do Worldclim; declividade, obtida com geoprocessamento no ArcGis v10.3 usando a variável altitude; e densidade de drenagem fornecida pela Ambdata). Essas camadas foram transformadas pela lógica fuzzy para representar variação contínua, e dados mais significativos foram selecionados após ACP. Para indicação de novas áreas de levantamentos, selecionamos locais com significativa probabilidade de ocorrência e distantes dos pontos de ocorrência. Para analisar qualidade potencial do curso d'água, observamos a integridade ambiental, por meio de imagens de satélite, em zona de amortecimento de dez quilômetros da Reserva da Biosfera Serra do Espinhaço. **Resultados:** Regiões escolhidas com maior probabilidade de ocorrência totalizaram nove novas áreas para levantamento. Estas estão concentradas em áreas de interflúvios e próximas a Unidades de Conservação. Realizamos análise focada na região da Reserva da Biosfera Serra do Espinhaço e delimitamos sete áreas que apresentaram boa adequação de habitat. A região foi observada por meio de imagens de satélite, e cinco das áreas apresentaram alta integridade ecológica. Duas áreas apresentaram impactos da atividade minerária. **Conclusões:** O padrão de distribuição corrobora as características da espécie como bioindicador de boa qualidade de água. Estima-se que essa metodologia possa ser adaptada e aplicada a outros bioindicadores. As áreas, onde estão presentes nascentes e tributários de baixa ordem, devem ser conservadas, pois são fundamentais para manter a qualidade na respectiva bacia hidrográfica.

Palavras-chave: nascentes; água doce; conservação de rio; bioindicação; inseto aquático; macroinvertebrados bentônico.

1. Introduction

With the disclosure and improvement of the ecological niche modelling and the bioindication method with aquatic insects, researches that use these techniques to infer information about the watercourses' quality have been more frequent (Lock & Goethals, 2013; Holguin-Gonzalez et al., 2013). The knowledge generated by these scientific publications has served as a guide to environmental conservation on watercourses' recovery and management. Lock & Goethals (2013), encouraged by conservation politics, used the order Ephemeroptera in habitat suitability models to evaluate the water quality in Flanders (Belgium), mostly its meaning to pollution caused by anthropic impacts. In the Neotropical region, Souza & Delabie (2016) used termite species modelling to understand the spatial distribution and the influence of environmental variables in the formation of densely packed '*murundus*' (earth mounds). Serra et al. (2012) performed the distribution modelling of an endemic bee of hilly regions from Central Atlantic forests to determine some priority areas for new inventories and help to find new communities of this species.

The order Ephemeroptera consists of aquatic insects, which nymphs inhabit all freshwater environments, even that some of them live in brackish waters (Domínguez et al., 2006). Organisms from this order play an important role as a source of food in aquatic and terrestrial ecosystems in both nymph and adult forms (Grant, 2001). The metamorphosis of the nymph into the winged subimago/imago transfers quantities of phosphates and nitrates from the aquatic to the terrestrial habitat, aiding in the removal of pollutants out of watercourses (Edmunds Júnior et al., 1976). Another motive why Ephemeroptera is considered an excellent indicator of water quality is due to its high diversity found in freshwater environments and to the wide ecological answers to environmental degradation (Salles et al., 2004; Domínguez et al., 2006).

Campylocia Needham e Murphy, 1924 is a Neotropical Ephemeroptera genus and it is widely distributed throughout Brazil. After an inconstant systematic history, it went through a taxonomic revision, after which five species were established as valid, being *Campylocia burmeisteri* (Hagen, 1888) endemic to Brazil (Gonçalves et al., 2017). This lineage is mostly spread around in the Southeast region, and it may reach parts of the South and Northeast of the country (Gonçalves et al., 2017).

The literature shows that *Campylocia* specimens founded in the Southeast region are present in lotic environments of weak or medium flows, with water relatively clean and rocky bottom. The nymphs live half-buried between rubbles, leaf litters, and rocks. The subimago does not take distance from the body of water, being confirmed thus by its exuviae found in the vegetation, rocks, and other dry areas nearby. (Domínguez et al., 2006; Gonçalves et al., 2017; Pereira & Silva, 1990).

Concerning the functional feeding group, Cummins et al. (2005) classify the Euthyplociidae family as gathering-collectors. Moreover, Baptista et al. (2006) classify the *Campylocia* genus as an active filterer. In both classifications, it is notable that the individuals search for food in bottom sediments where toxins and pollutants tend to accumulate.

Bispo et al. (2006) collected *Campylocia sp.* at altitudes above 800 meters. It is known that it is more frequent in small order streams. Therefore, it is probable that the watercourses inhabited by *C. burmeisteri* have a high concentration of dissolved oxygen (D.O.). The D.O. rates directly affect biota on physicochemical and biochemical processes. High D.O. levels are characteristic of aquatic environments free from organic pollution (Hauer & Hill, 1996). These ecological, feed and distribution characteristics may classify *C. burmeisteri* as a bioindicator of good water quality.

This work aims to make a spatial analysis of habitat suitability model for *Campylocia burmeisteri,* which can indicate new survey areas to increase the knowledge about this species. It also aims to point out areas that potentially contain good quality watercourses.

The analysis focuses on the Brazilian Southeastern region, in Espinhaço Range Biosphere Reserve (ERBR) (UNESCO, 2019), due to the endemism of *C. burmeisteri* and the hydric importance of the region. The area has a high availability of natural water and can reach 100,000m^3/inhabitant/per year (Porto, 2002), even though it is poorly distributed, showing up areas with severe droughts. Furthermore, the region has three main points, including high population density, high level of industrialization, and high rates of agricultural activities in the country (Porto, 2002). About 60% of Southeastern population inhabits municipalities with less than 2,000m^3/inhabitant/ per year of available water, being them situated in populous cities or drought areas (Rocha et al., 2013). All these factors result in constant water use conflicts (Porto, 2002; ANA, 2017). The Southeastern region also was affected by environmental disaster of the Fundão dam in 2015 and by the water crisis that left the whole country desolate since 2014 (Fernandes et al., 2016; ANA, 2017).

Established in 2005 by UNESCO, the ERBR has over three million hectares and have biological, geomorphological, and historical importance. Furthermore, the region has three main points, including high population density, high level of industrialization, and high rates of agricultural activities in the country. (UNESCO, 2019). The ERBR is located on the northern portion of the state of Minas Gerais and is part of the Espinhaço mountain range on its southern portion, which is a point of endemism and border region of several watersheds, as well as a transition region between the Atlantic Forest and Cerrado biomes. Myers et al. (2000) consider Brazil's Atlantic Forest and Cerrado two of the 25 hotspots to conservation in the world.

2. Methods

2.1. Habitat suitability modelling

The analysis started selecting the occurrence records and separating them into training data (used to build the model) and test data (used to test the predictive performance). Pearson (2007) suggested minimizing bias variable data considering space, time, and collectors. We obtained the occurrence records from the literature on the papers of Salles et al. (2010), and Gonçalves et al. (2017). At the same time, we contacted these authors to verify the precision of the records. The record found in Salles et al. (2010) are at Universidade Federal do Espírito Santo – Campus São Mateus, Esprírito Santo, Brazil (CEUNES). Gonçalves et al. (2017), had recently performed a revision of the genus *Campylocia*, providing a reliable set of records. These records are listed at Coleção Entomológica Prof. José Alfredo Pinheiro Dutra, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil (DZRJ) and at Universidade de São Paulo, São Paulo, Brazil (MZSP).

We also conducted surveys at three Conservation Units (CUs) in the state of Minas Gerais. These records are listed at the Museum of Natural Sciences – Invertebrate Collection at PUC Minas, Minas Gerais, Brazil (MCN-INV). We complemented the records' set with a search on SpeciesLink database (CRIA, 2011). It excluded records with imprecise coordinates and with just the survey site. In this way, from the set record acquired on SpeciesLink database, were selected the records from Sistema de Informação Ambiental do Programa Biota (SINBIOTA) by Fundação de Amparo à Pesquisa do Estado de São Paulo (Fapesp). The coordinates of the records set can be seen in Table 1.

To function as training data, we choose the records from Salles et al. (2010), Gonçalves et al. (2017) and those collected and cataloged in the MCN-INV acquisition. These records have species-level identification and compose a most accurate set. The test data contains the records identified only as Euthyplociidae or as *Campylocia* sp., which

Table 1. Occurrence records using as training data (Ptr) and test data (Pts).

	Id.	Taxonomy	Longitude	Latitude	Collection	Reference
Training data	Ptr 01	*C. burmeisteri*	-42.4180833	-22.4076944	DZRJ	Gonçalves et al., 2017
	Ptr 02	*C. burmeisteri*	-48.6637778	-24.5680000	DZRJ	Gonçalves et al., 2017
	Ptr 03	*C. burmeisteri*	-44.6323333	-22.7272222	DZRJ	Gonçalves et al., 2017
	Ptr 04	*C. burmeisteri*	-42.5356667	-22.4243056	DZRJ	Gonçalves et al., 2017
	Ptr 05	*C. burmeisteri*	-42.5323333	-22.4260000	DZRJ	Gonçalves et al., 2017
	Ptr 06	*C. burmeisteri*	-42.5211667	-22.4127778	DZRJ	Gonçalves et al., 2017
	Ptr 07	*C. burmeisteri*	-45.4600000	-22.6944444	MZSP	Gonçalves et al., 2017
	Ptr 08	*C. burmeisteri*	-44.7831667	-23.3599444	DZRJ	Gonçalves et al., 2017
	Ptr 09	*C. burmeisteri*	-40.5303056	-19.8752222	CEUNES	Salles et al., 2010
	Ptr 10	*C. burmeisteri*	-43.3368333	-18.0876667	MCN-INV	Search in the acquis
	Ptr 11	*C. burmeisteri*	-40.4363056	-19.5916667	MCN-INV	Search in the acquis
	Ptr 12	*C. burmeisteri*	-43.4911110	-20.1144440	MCN-INV	Search in the acquis
Test data	Pts 01	Euthyplociidae	-45.465302	-22.692499	SINBIOTA	SpeciesLink
	Pts 02	Euthyplociidae	-45.461700	-22.691401	SINBIOTA	SpeciesLink
	Pts 03	Euthyplociidae	-45.483898	-22.698099	SINBIOTA	SpeciesLink
	Pts 04	Euthyplociidae	-45.488899	-22.697500	SINBIOTA	SpeciesLink
	Pts 05	Euthyplociidae	-45.488602	-22.698900	SINBIOTA	SpeciesLink
	Pts 06	Euthyplociidae	-48.423299	-24.272200	SINBIOTA	SpeciesLink
	Pts 07	*Campylocia sp.*	-45.451099	-22.663601	SINBIOTA	SpeciesLink
	Pts 08	*Campylocia sp.*	-45.487801	-22.698900	SINBIOTA	SpeciesLink
	Pts 09	*Campylocia sp.*	-45.473900	-22.680599	SINBIOTA	SpeciesLink
	Pts 10	*Campylocia sp.*	-45.464401	-22.692499	SINBIOTA	SpeciesLink
	Pts 11	*Campylocia sp.*	-45.468300	-22.711100	SINBIOTA	SpeciesLink
	Pts 12	*Campylocia sp.*	-45.891102	-23.653900	SINBIOTA	SpeciesLink
	Pts 13	*Campylocia sp.*	-45.846901	-23.639401	SINBIOTA	SpeciesLink

DZRJ: Coleção Entomológica Prof. José Alfredo Pinheiro Dutra, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil. MZSP: Universidade de São Paulo, São Paulo, Brazil. CEUNES: Universidade Federal do Espírito Santo – Campus São Mateus, Esprírito Santo, Brazil. MCN-INV: Coleção de Invertebrados do Museu de Ciências Naturais PUC Minas, Minas Gerais, Brazil. SINBIOTA: Sistema de Informação Ambiental do Programa Biota/FAPESP

were found in the Southeast region and obtained in a search on SpeciesLink database (CRIA, 2011). Although the test data records do not have identification at a specific level, studies had shown that there is only the *C. burmeisteri* lineage in this region (Gonçalves et al., 2017). Both training and test data were composed of records with different locations, collected at different time periods, and examined by different researchers as suggested by Pearson (2007).

In the end, we obtained a set consisted of 12 records of training data and a set consisted of 13 records of test data (Table 1).

The *C. burmeisteri* accurate range of distribution is still lacking. Therefore, to define the modelling analysis area, we created buffers of 300 Km on each occurrence record coordinate. Thus, the area shaped would cover all records and possible dispersion distances to create an estimated biological limit (Figure 1). The 300km buffer may extrapolates the species range distribution for the modelling.

The environmental data used in this research consists of 19 bioclimatic variables, with 30 seconds resolution, available on WorldClim website (Hijmans et al., 2005). These variables infer some aspects and information about the climate. In addition to these bioclimatic variables, we used three variable, altitude, slope and drainage density. The altitude derives from the SRTM elevation data, also acquired on the WorldClim website. It provides the variable of the slope through geoprocessing in Software ArcGis v10.3. We also used the drainage density provided by Ambdata (Amaral et al., 2013). These three variables add hydrological aspects to the model. The 22 variables are presented in Table 2.

The modelling area shape, previously generated through the 300 km buffer of occurrence records, was used as a mask to delimited the environmental variables. We made this delimitation with the "Cut" tool in Software ArcGis v10.3. After it, we transform the environmental data into a 0 to 1 scale through the fuzzy membership tool Software ArcGis v10.3. This operation transforms the input raster into a 0 to 1 scale, indicating the strength of a membership in a set based on a specified fuzzification algorithm. Number 1 indicates full membership in the fuzzy

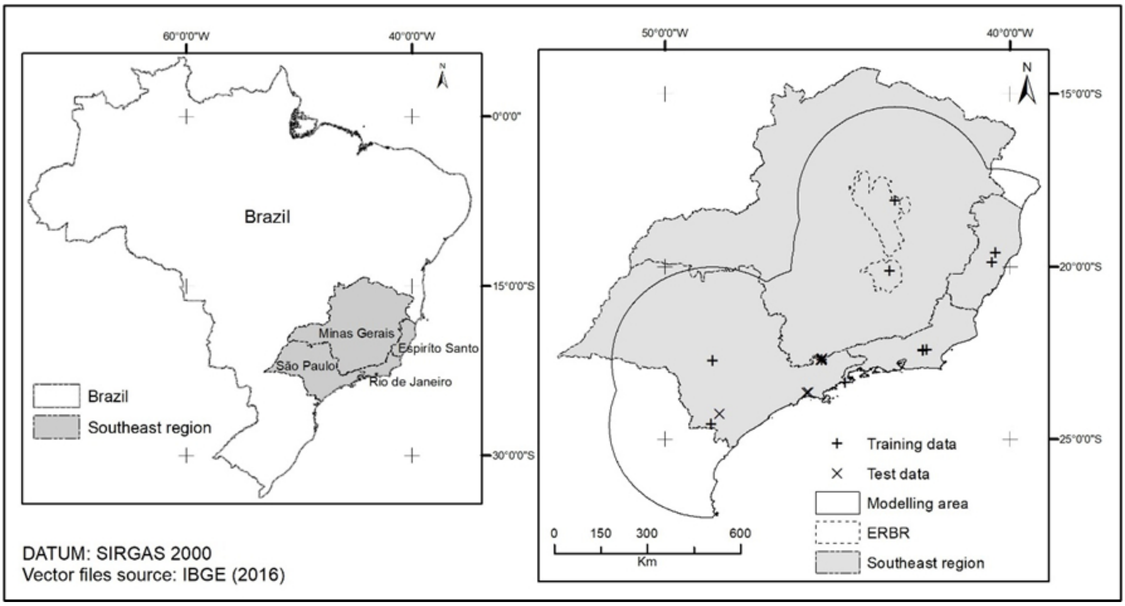

Figure 1. Location of the analyzed area and Espinhaço Range Biosphere Reserve (ERBR) in Southeast Region, Brazil.

Table 2. Environmental variables, reference and source location.

Variable name	Reference	Available at:
BIO1 = Annual Mean Temperature	Hijmans et al., 2005	https://www.worldclim.org/data/bioclim.html
BIO2 = Mean Diurnal Range		
BIO3 = Isothermality		
BIO4 = Temperature Seasonality		
BIO5 = Max Temperature of Warmest Month		
BIO6 = Min Temperature of Coldest Month		
BIO7 = Temperature Annual Range		
BIO8 = Mean Temperature of Wettest Quarter		
BIO9 = Mean Temperature of Driest Quarter		
BIO10 = Mean Temperature of Warmest Quarter		
BIO11 = Mean Temperature of Coldest Quarter		
BIO12 = Annual Precipitation		
BIO13 = Precipitation of Wettest Month		
BIO14 = Precipitation of Driest Month		
BIO15 = Precipitation Seasonality (Coefficient of Variation)		
BIO16 = Precipitation of Wettest Quarter		
BIO17 = Precipitation of Driest Quarter		
BIO18 = Precipitation of Warmest Quarter		
BIO19 = Precipitation of Coldest Quarter		
Altitude		
Drainage sensity	Amaral et al., 2013	http://www.dpi.inpe.br/Ambdata/download.php
Slope	Generated by geoprocessing in Software ArcGis v10.3	

set, with membership decreasing to 0, indicating it is not a member of the fuzzy set (ArcGis, 2016). The fuzzy logic allows the transformation of rigid limits, in a numerical decision surface representing a continuous variation, a numerical spatial dynamic. Representing the complexity of natural phenomena. (Cunha et al., 2011).

To select the most significant data, we run a Principal Components Analysis (PCA) with the 22 environmental variables in Software ArcGis v10.3. The Principal Components Tool is used to transform the data in input bands from the input multivariate attribute space to a new multivariate attribute space whose axes are rotated with respect to the original space. The axes (attributes) in the new space are uncorrelated. The main reason to transform the data in a principal component analysis is to compress data by eliminating redundancy (ArcGis, 2016). The components selected from the PCA represented more than 75% data importance. These components should have a unit value close to or greater than the value of the egalitarian division among the 22 components.

We decided to use the maximum entropy as a modelling algorithm on the MaxEnt software (Version 3.3.3k), with the features on default, because there is no need for absence data and the algorithm uses environmental data as background (Elith et al., 2011; Phillips et al., 2006). As occurrence data were provided from different sources, times and were collected by different researchers, the model validation was satisfactory, despite the overlapping and analysis of test data (Pearson, 2007).

2.2. Identification of new survey areas

To identify new survey areas, we highlighted regions that presented a probability of occurrence higher than 0.5. Although there is a greater possibility of occurrence in areas with higher values, we have established the limit of 0.5 in order to cover larger areas. The objective at this point is to identify possible collection sites. In addition, we created a buffer of 50 km on the occurrence data points, both training and test data. That way, the areas indicated to new surveys must have 0.5 or higher occurrence probability and a distance of 50 km of the known record sites. We described these areas according to the location, the presence or absence of CUs, and the hydrography.

2.3. Watercourses' quality

To analyze the watercourse quality, we observed the environmental integrity of delimited areas in ERBR. We delimited a buffer up to 10 km beyond the limits of ERBR. The limit zone is the boundary that surrounds the core areas of ERBR. The selected areas were the ones with high suitability concentration and not located within CUs. We described it accordingly to their extension, municipalities, hydrographic basins and hydrography. Also, we analyzed the integrity of these areas through satellite images of LandSat8 with 15 meters resolution obtained from the U.S. Geological Survey/EarthExplorer (USGS, 2020). It was done to determine the vegetation coverage, presence of large enterprises and urban networks. We choose satellite images from April to November 2020, when it is the dry season in the area. We processed a multispectral image using bands 1 to 7 and band 9. For a RGB color composition we use the 4,3,2 band pattern, thus obtaining the true color. We fuse this composite color image with a high-resolution panchromatic raster (band 8), obtaining an image with 15 meters resolution.

3. Results

3.1. Habitat suitability model

According to the PCA, five components possessed eigenvalues higher than an egalitarian division (eigenvalue>100/22), and its sum represented more than 75% of importance (accumulative of eigenvalues=83.86%) (Table 3). The model was performed from these five principal components and with the training and test data.

The habitat suitability model shows 75% of training data and 92% of test data within areas with suitability higher than 0.5 (Figure 2). The model performed well, according to the receiver operating characteristic curve (ROC). Moreover, the AUC (area under the curve) was superior to a random prediction, both in training data (AUC = 0.822) and in the test data (AUC = 0.757) (Figure 3).

3.2. New survey areas

The areas proposed as possible new occurrence sites of *C. burmeisteri* (Figure 4) are located nearby or in regions of elevated altitudes, like plateaus or mountain ranges. The altitude varies between the sea level in coastal areas up to 2703 meters, following the distribution pattern of the mountain ranges founded in the Brazilian Southeast.

Area 1 is located in the frontier between Minas Gerais and São Paulo states, near the mountain ranges know as Serra da Canastra. It is a large region with only

Table 3. Percent and accumulative eigenvalues.

PC Layer	EigenValue	Percent of EigenValues	Accumulative of EigenValues
1	1.99E-02	37.9193	37.9193
2	1.28E-02	24.394	62.3133
3	5.21E-03	9.9605	72.2738
4	3.88E-03	7.4169	79.6907
5	2.69E-03	5.1404	84.8311
6	2.21E-03	4.2208	89.0519
7	1.98E-03	3.7829	92.8348
8	9.67E-04	1.8473	94.6821
9	7.81E-04	1.4924	96.1745
10	4.60E-04	0.8786	97.0531
11	3.53E-04	0.6744	97.7275
12	3.04E-04	0.5807	98.3082
13	2.19E-04	0.4192	98.7274
14	2.03E-04	0.3882	99.1157
15	1.75E-04	0.3347	99.4504
16	1.09E-04	0.2077	99.6581
17	5.37E-05	0.1027	99.7608
18	4.20E-05	0.0802	99.8409
19	3.31E-05	0.0632	99.9041
20	2.44E-05	0.0466	99.9507
21	1.55E-05	0.0297	99.9804
22	1.03E-05	0.0196	100

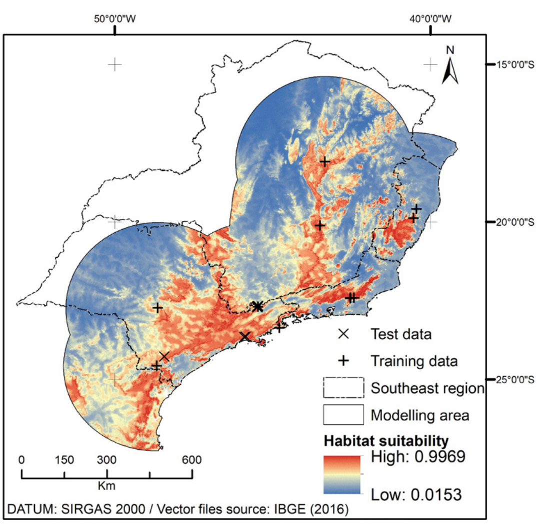

Figure 2. Habitat suitability model of *C. burmeisteri* with the occurrence data (training and test data).

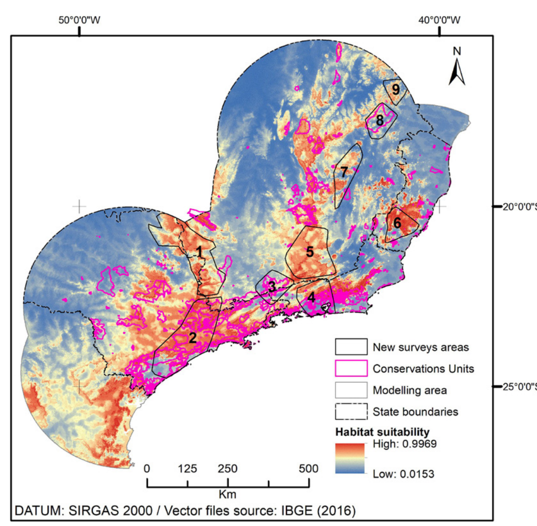

Figure 4. New survey areas proposed on the habitat suitability and conservation units.

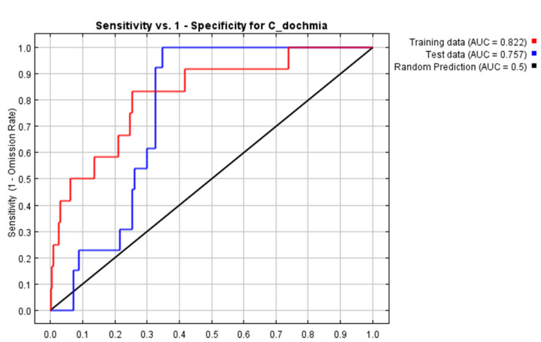

Figure 3. Graph with the receiver operating characteristic curve (ROC) and the AUC (area under the curve) values.

two CUs identified. It is in the Rio Grande basin, and it includes the rivers Mogi-Guaçu and Pardo.

Area 2 is located mostly in São Paulo state (5.61% is located in Minas Gerais state), it has a large extent and reaches the coastal zone. It is a region where mountain ranges of Serra do Mar, mountain ranges Serra da Mantiqueira and Paranapiacaba's plateau encounters. It has several CUs as Serra do Mar State Park and Sistema Cantareira Environmental Protection Area. The Sistema Cantareira is the biggest water supply system in São Paulo state and one of the greatest producing systems in the world. The water crisis of 2014-2015 jeopardized the Sistema Cantareira, generating conflicts about the water use (ANA, 2017). It includes the basins of Paraná/Tietê, Iguape and São Paulo coastal, where the rivers of Itapetininga, Ribeira do Iguape, Sorocaba and Tietê are founded.

Area 3 is between the states of Minas Gerais, São Paulo and Rio de Janeiro. This area has several CUs such as Itatiaia National Park. It is located in the mountain ranges Serra da Mantiqueira and on mountain ranges Serra do Mar. Its cover the Paraíba do Sul basin and Rio Grande basin, and it includes the rivers with the same names.

Area 4 is in the state of Rio de Janeiro and has many CUs, including the Serra dos Órgãos National Park. It is in the mountain ranges Serra do Mar and it covers Paraíba do Sul basin, with a main river, and Rio de Janeiro State Littoral River basins.

Area 5 is the largest of the areas and it is situated in Minas Gerais state, but there are only a few CUs identified. It reaches parts of the mountain range of Serra da Mantiqueira. The area covers the basins of Doce, Paraíba do Sul and Rio Grande along with the rivers Piranga and Rio das Mortes.

Area 6 is in Espírito Santo state, and there are also a few CUs in this area. It is located in mountain ranges Serra da Mantiqueira and it covers the Espírito Santo State Littoral basins, where the Itapemirim river is founded.

Area 7 is located in Minas Gerais, between Espinhaço Range and Serra do Mar. It reaches some CUs, being one of them the Rio Doce State Park. It contains the rivers Suaçuí Grande, Suaçuí Pequeno and Piracicaba, all three from the Doce basin.

Area 8 is situated in the east of Espinhaço Range, in Minas Gerais state. The Alto do Mucuri Conservation Unit occupies almost all extend of this area. It covers, mainly, the basins of Itanhem and São Mateus, with the rivers of Mucuri and Rio de Todos os Santos.

Area 9 is also in Minas Gerais, in the east of Espinhaço Range. No CU was identified in this area that covers the Jequitinhonha basin, and it contains the rivers of São João, Pampa, and Jequitinhonha.

3.3. Potential quality of watercourses

Inside the 10 km buffer of the ERBR, we selected areas with higher suitability (0.75-1) and that were not included in CUs (Figure 5). These areas have high habitat suitability to *C. burmeisteri*, thus they have the potential to encompass watercourses of good quality. To identify it, we denominate these areas as PQW (potential spots for good quality watercourses).

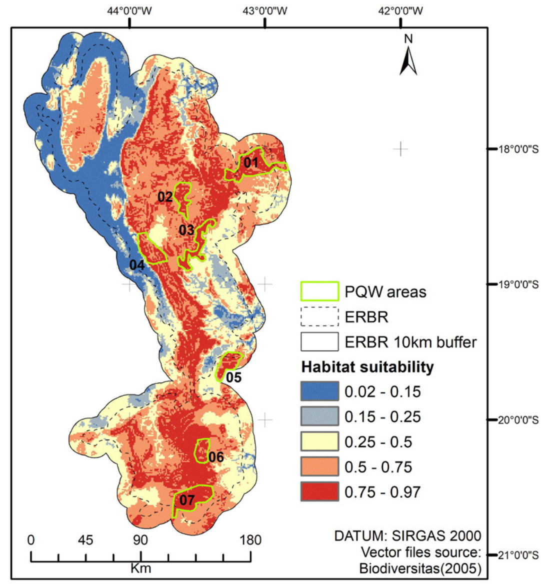

Figure 5. Areas with potential for good quality watercourses (PQW) at the Espinhaço Range Biosphere Reserve.

The area PQW01 has 582.7 km² and is inserted in ERBR, reaching its surroundings. It is between Jequitinhonha basin and Rio Doce basin. In the Jequitinhonha basin, PQW01 encloses the Itamarandiba do Campo river headwater and several first-order rivers and headwaters. In the Rio Doce basin, the area contains Cocais river headwater and others river headwaters that are tributary of Suaçuí Grande. We notice rock outcrops and a considerable plant coverage by interpretation of satellite images.

Area PQW02 has 243.6 km² and is inside ERBR and Jequitinhonha basin. It contains the Jequitinhonha river headwater and some of its first tributaries. Most of the area's surface is characterized by rocky outcrops. At the north end of the area is the city of Diamantina.

The area PQW03 has 319.9 km² and is located between two Conservation Units in ERBR, Pico do Itambé State Park and Intendente State Park. It contains the early section of Peixe river, a tributary of Santo Antônio river (Rio Doce basin), and several headwaters that flow to this. The area also contains some headwaters from the basins of Jequitinhonha and Rio das Velhas. It is possible to see rocky outcrops and plant coverage in the satellite image, although were not detected anthropic activities or considerable urban centers this area.

The area PQW04 is located on the west side from ERBR and has 325.8 km². It's characterized by a rocky hillside where there are headwaters and tributaries of the Parauninha river. The flow goes to Rio das Velhas, the river of the same name of this hydrographic basin.

With 252.6 km^2, the area PQW05 contains some headwaters, including one from Peixe river. Despite having the same name, this is not the same river founded in area PQW03. These two different rivers are part of the Doce basin; this one flows to the Piracicaba river. We observed a large green area coverage by interpreting the satellite images, including the interflow of watercourses and the urban center of Itabira city. On the east side of the region PQW05, it is possible to see a mining site (Figure 6). The mining area is located near river headwaters and in an area with high habitat suitability to *C. burmeisteri.*

The area PQW06 (Figure 7) has 179.4 km^2, and it is inside the ERBR. It reaches the early sections of rivers Gualaxo do Norte and Piracicaba on the Doce basin. Despite the presence of vegetation cover, it was possible to notice, in the middle of the region, the environmental degradation caused by rupture of the Fundão dam in 2015 (Fernandes et al., 2016). This environmental tragedy affected flora, fauna, and aquatic environments. The impacts were continuous throughout the basin (Fernandes et al., 2016), including tributaries of the Doce river presents in this area, for example the Gualaxo do Norte river.

The area PQW07, with 459 km^2, is inside in ERBR, reaching its surroundings. The area is inside of the Doce basin and encloses river headwaters of tributaries of Piranga river. The area and the extension of watercourses present vegetation coverage.

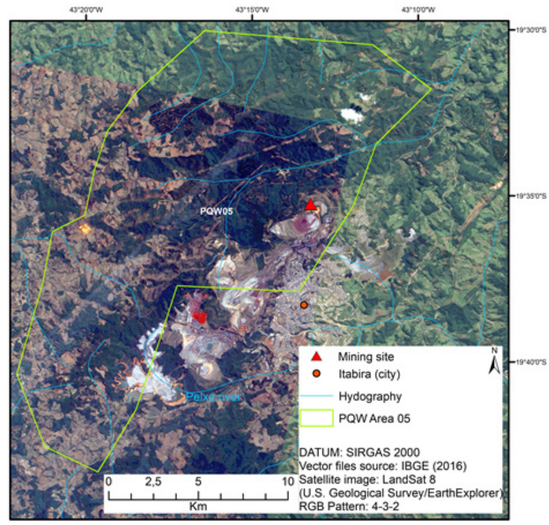

Figure 6. Satellite image of PQW Area 05 with the mining site on the east side.

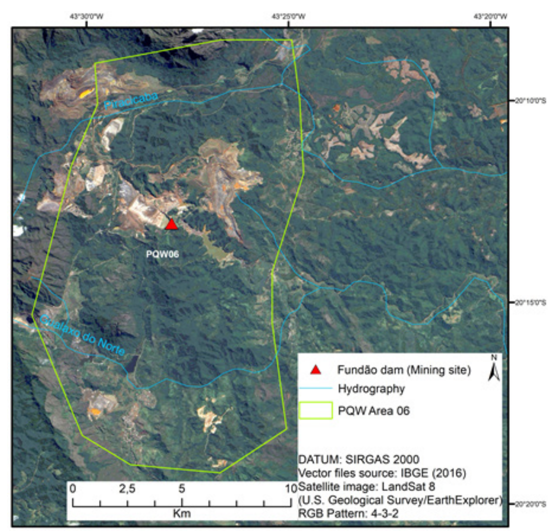

Figure 7. Satellite image of PQW Area 06 with environmental degradation by mining.

4. Discussion

Areas with higher habitat suitability are concentrated in relatively high altitudes, being located in mountain ranges like Espinhaço, Serra da Mantiqueira and Serra do Mar. These are regions with interfluvial zones and river headwaters. Most of those regions are nearby or are inserted in Conservation Units. We assume that river headwaters and watercourses inside CUs tend to have good water quality. This information, plus the ecological features of the species, make us accept that the habitat suitability model to *C. burmeisteri* is also a guideline that indicates areas with good quality watercourses.

According to Pino-Del-Carpio et al. (2014), the knowledge about the diversity that can occur in a certain area is the first step to biodiversity conversation. Thusly, the biosphere reserves are propitious to biodiversity studies, since it is assumed that they are sites with high biodiversity and a data center to studies. However, research on biodiversity should not be carried out only in conserved areas, but also in CUs, industrial regions, and urban areas. The study on biodiversity in different areas supports evaluations about the human impacts on natural resources. Biodiversity knowledge is basic data that environmental managers use to establish conservation actions (Hoffmann et al., 2010), and the same logic applies to natural resources. The areas pointed as suitable to new surveys can support the increase in knowledge and conservation of Ephemeroptera, of related groups, and the natural resources existent, mainly the watercourses in and out of the conservation units.

The areas pointed in this paper represent locations with abiotic features that can sustain good quality watercourses. It is important to notice that anthropic variables are not included in this process. As previously demonstrated, area PQW 06 was rated as one which potentially has good water quality, although it was affected by an environmental disaster. This problem was caused by human activities, resulting in the loss of environmental integrity. In this way, the provided information also can be used to evaluate environmental impacts in regions where there is no previous data. Despite the caveats, the material provided may contribute to the environmental decision about territory conservation and recovery. Headwaters and small order rivers are the rule of thumb in these areas. According to Little & Altermatt (2018), the integrality of headwater areas can influence the spatial dynamics of organic matter in basins. The conservation of these upstream stretches is important because their degradation can reach an entire watercourse and the surrounding environment.

The suitability distribution pattern in more conserved regions, with high altitudes and steep slopes, suggests that the watercourses in these regions have inherent features to integral environments. Based on the observed patterns, we believe that *C. burmeisteri* is an indicator of good water quality. However, due to ecological and biogeographical factors, the use of this species or its model is not applicable in all regions. The method of habitat suitability modeling using a bioindicator species can be adapted to other natural resources or other regions, providing environmental information in a faster and lower cost way.

5. Conclusions

The distribution patterns observed corroborate the use of *C. burmeisteri* as a bioindicator of good water quality. However, due to ecological and biogeographical factors, like the restricted distribution to the southeast of Brazil, the use of this species or its model as an indication tool to watercourses with good quality is not applicable in all regions. Therefore, the methodology used in this paper should be adapted and can be applied to other bioindicators, other natural resources, or other regions providing environmental information in a faster and lower-cost way. Local studies can significantly improve this methodology by analyzing physical and chemical parameters. The authors emphasize that areas, where headwaters and small orders tributaries are present, must be conserved because they are fundamental for maintaining the quality within the respective watershed. Due to the importance of headwaters and river banks, Brazilian legislation classifies these areas as APP (areas of permanent preservation). Conserved headwaters can contribute to the improved degraded water resources, with lesser or greater impact, as shown in the Area PQW 06.

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