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Application and comparison of three Indices of Biotic Integrity in Neotropical streams from South Brazil

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Abstract

We applied and compared different Index of Biotic Integrity *IBI* to each other and to a Rapid Assessment Protocol in five streams in Brazil in order to adapt attributes to ecosystem assessment. Some attributes were robust to evidence environmental differences while others were not applicable due to regional peculiarities. The new IBI will implement attributes that measure species composition and distribution based on our local pool of species and on geomorphological and land-use characteristics.

Keywords: ichthyofauna, environmental assessment, headwater.

Introduction, scope and main objectives

Biological integrity of ecosystems is related to the resilience - the capability to support and maintain balanced communities which are integrated and adapted to regional characteristics and can be accounted for through species composition, diversity and functional traits (Karr 1981, Karr and Dudley 1981). Stream ecosystems balance has been negatively affected over the past few decades due to the replacement of natural forest cover by different land-uses related to anthropogenic changes, and the evaluation of biotic integrity can be a powerful indicator of direct and indirect negative effects over biological communities and to monitor environmental quality over time and space (Fausch *et al.* 1990, Teodósio 2012).

Indices of Biotic Integrity (IBI) were first developed to integrate information of different ecological levels, from individuals to ecosystems, on a single numeric indicator (Karr 1981), providing more robust diagnostics of punctual evaluations or long time monitoring studies (Teodósio 2012). IBI's are useful tools to identify biological conditions of pristine or least impacted systems, providing references for environmental quality evaluation of impacted systems (Tejerina-Garro *et al.* 2005; Ferreira and Casatti 2006) and are especially useful for monitoring low order streams, enabling a decrease in sampling efforts (Teodósio 2012).

Our main objective was to adapt an IBI to our study region in order to provide a methodological tool to evaluate anthropogenic impacts and its effects on first order streams ichthyofauna on South Brazil. We applied three IBI's (Ferreira and Casatti 2006, Pinto *et al.* 2006, Santos and Esteves 2015) previously adapted for different regions in order to analyze which parameters are useful to our region context and to formulate news ones for our methodological needs.

Methodology/approach

STUDY AREA

The study area comprises five streams from Northwest Paraná, South Brazil, which drains to Paranapanema and Ivaí rivers. The area is mainly comprised of sandy soils with homogeneous grain sizes, originated from Caiuá Sandstone geological formation (Torres 2003), and under the domains of the Semi Deciduous Forest (Campos *et al.* 2000).

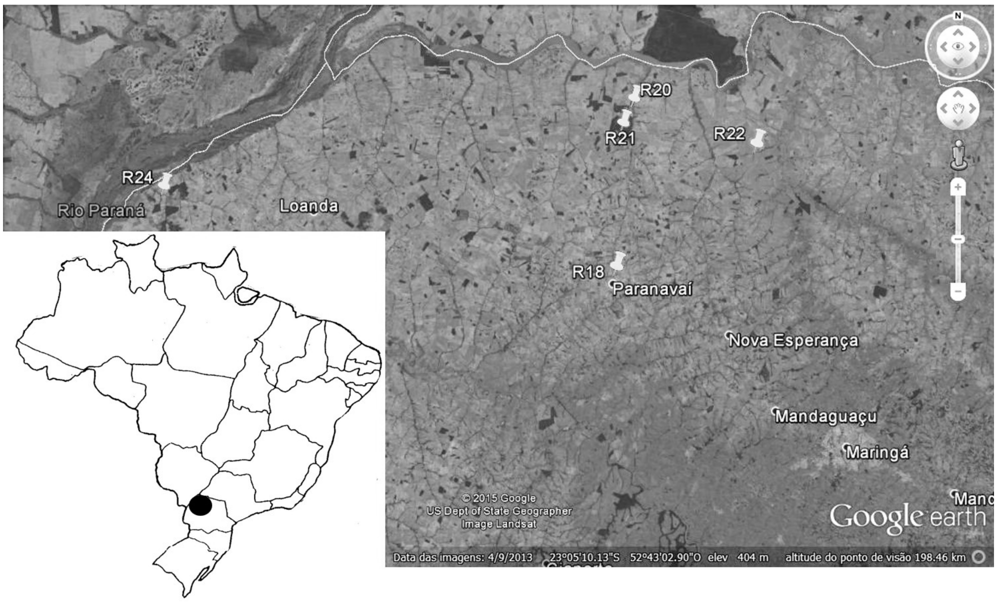

Figure 1. Location of the sampled streams.

SAMPLING

The percentage of land-use in the watersheds was determined by geo-processing in ArcGis® software previously to sampling. Each watershed was classified according to the predominant (<50%) land-use as forested, urbanized, agriculture, and intermediate when there was no land-use predominance. Local environmental quality was determined for each of the five streams in 80-meter stretches with a Rapid Assessment Protocol (RAP) adapted for the study region by Cionek *et al.* (2011). The RAP is a visual-based method to asses: a. underwater substrate; b. underwater habitat complexity; c. variation of depth and water velocity; d. channel sinuosity; e. channel flowing fluctuations; f. channel alterations; g. margin stability; h. vegetation protection on the margins; i. vegetal cover on the margins. Numbers identified the streams, as R18, R20, R21, R22, R24.

Fishes were sampled in July/2014 with electrofishing in downstream sites to improve the evaluation of watershed land-use influence over the stream, in 80-meter stretches (Pease *et al.* 2012). Sampled stretches were seine-blocked to prevent fishes from escaping and three consecutive passages were applied to each site (Mazzoni and Lobón-Cerviá 2000). All individuals were counted and screened on the field, anesthetized in benzocaine (AVMA 2007) and fixed in formaldehyde 10%. From each fish we obtained total weight (g), standard and total length (cm) and identified them with specific literature.

Table 1: Evaluation of Environmental characteristics of stream stretches based on the RAP.

Preservation condition	Character
Very Good – **VG**	Minimally affected. All attribute scores fall above 75% of reference condition.
Good – **G**	Attribute scores fall between 75 and 50% of reference condition.
Regular – **R**	Attribute scores fall between 50 and 25% of reference condition.
Poor – **P**	Highly impacted. Most attribute scores fall below 25% of reference condition.

INDEX OF BIOTIC INDEX (IBI)

We applied the IBI's proposed by Ferreira e Casatti (2006) - $I_{F\&C}$, Pinto *et al.* (2006) - $I_{P.etal}$, e Santos e Esteves (2015) - $I_{S\&E}$ (Table 2) from São Paulo and Rio de Janeiro, Southeast Brazil. We assumed the scores proposed as reference condition for $I_{F\&C}$ and $I_{P.etal}$, and the extreme values proposed by $I_{S\&E}$. Other studies have similar propositions to classify IBI's scores (Ganasan and Hugues 1998, Bozzetti and Schulz 2004), assuming the following equation to standardize reference values were pristine reference sites do not occur: $\left(\frac{O}{R}\right) * 10$; where: R = the best score found in the samples; O = expected score. The following equation was used to correct for attributes with increased scores due to environmental impacts: $\left(\frac{1-R}{O}\right) * 100$; where R = correspond to the best score for the specific attribute.

All IBI attributes were categorized folowing $I_{F\&C}$ e $I_{P.etal}$, consisting in four categories based on the final score of the IBI.

Table 2: Attributes proposed by $I_{F\&C}$ (Ferreira and Casatti, 2006), $I_{P.etal}$ (Pinto *et al.*, 2006) and $I_{S\&E}$ (Santos e Esteves, 2015) used for the streams of South Brazil.

Nº	$I_{F\&C}$	$I_{P.etal}$	$I_{S\&E}$
1	Percentage of Characiform e Siluriform	Nº of native species	Percentage of *Bryconamericus inheringii*
2	Percentage of *Poecilia reticulata*	Nº of characiform species	Percentage of *Phalloceros* spp.
3	Percentage of individuals tolerance to hypoxia	Nº of siluriform species	Biomass (g/m^2)
4	Native species richness	Nº of sensitive species	Total Density (ind/m^2)
5	N° of trophic categories	Percentage of Cyprinodontiform individuals	Dominance (Simpson's index)
6	Nectonic species richness	Nº of dominant species	Percentage of omnivorous species
7	Reofilic species richness	Percentage of omnivorous individuals	Percentage of bentonic species
8	Percentage of reofilic individuals	Percentage of Carnivorous individuals	Percentage of tolerance individuals
9	Dominance (Simpson's index)	----ǁ----	----ǁ----

Table 3: IBI categories adapted for this study, based on Ferreira and Casatti (2006).

Percentage of IBI	Stream Category
80-100%	Good – **G**
60-79%	Regular – **R**
40-59%	Poor – **P**

0-39%	Very Poor – **VP**

Results

We sampled 1.090 fishes, belonging to 20 species, 12 families and 6 orders. The most frequent species were *Poecilia reticulata* Peters, 1859 (69.63%), *Corydoras aeneus* Gill, 1858 (4.5%), *Phalloceros harpagos* Lucinda, 2008 (4,31%), *Knodus moenkhausii* Eigenmann & Kennedy, 1903 (4.04%), *Otothyropsis* sp. (3.3%), *Moenkhausia oligolepis* Günther, 1864 (2.57%) and *Astyanax altiparanae* Garutti & Britski, 2000 (2.29%). The remaining species represented less than 2% of sampled individuals. The most frequent orders were Cyprinodontiforms (73.9%) followed by Siluriforms (13%) and Characiforms (11%). The remaining orders represent less than 2% of all occurrences (Gymnotiforms, Synbranchiforms e Perciforms).

The streams with better IBI scores considering $I_{F\&C}$ and $I_{P.etal}$ where R20 with a forested watershed and R22 with an intermediate land-use of forest and pasture. $I_{S\&E}$ identified R21 as the second best stream score. The lowest score considering the three IBI's were R18 an urban stream with citizens and cattle access (Table 4). The IBI evaluation of R24 revealed good biological condition while a regular evaluation of the RAP. This fact represents an inconsistence of the evaluation of the RAP (Table 4).

Table 4: IBI results of Ferreira and Casatti (2006), Pinto *et al.*, (2006) and Santos and Esteves (2015) applied in five streams of South Brazil, and compared to the RAP of Cionek *et al.*, (2011). Legend: VP = Very Poor, P = Poor, R = Regular, G = Good, VG = Very Good, U = Urban, F = Forest, SC = Sugar cane, I = Intermediary, CAT = Category.

Proposal	$I_{F\&C}$		$I_{P.etal}$		$I_{S\&E}$		PAR/LAND USE
Stream	%IBI	CAT	%IBI	CAT	%IBI	CAT	
18	55,6	P	20	VP	35	VP	R/U
20	82,2	G	55	P	73,9	R	VG/F
21	68,9	R	40	P	65,2	R	VG/F
22	64,4	R	40	P	44,1	P	VG/C
24	82,2	G	45	P	51,3	P	R/I

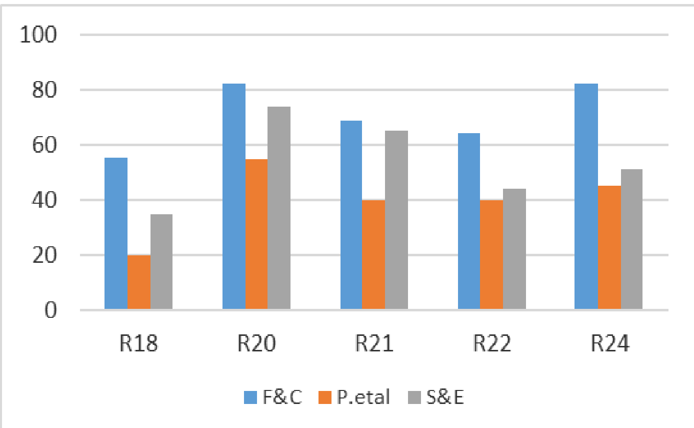

Figure 2. Comparative graph of the results of IBI for the five studied streams.

Discussion

Applying and comparing known IBI's to newly regions are fundamental to help building contextualized attributes (Hocutt *et al*. 1994, Roset *et al*. 2007, Jaramillo-Villa and Caramaschi 2008) and as expected we found different conservation scores for each of the applied IBI's in our study sites. The IBI adapted by Ferreira and Casatti (2006) for Northeast São Paulo was the most tolerant index for our study sites since it presented highest scores relatively to the others, with two maximum scores, possibly because we only evaluated the attributes applicable to first order streams, which represented half of the attributes. The common attributes for the three IBI's (Nº of trophic categories and Reofilic species richness) did not represented adequately our sites since they were all high scored, meaning that the reference sites belong to the applied IBI's and were adapted for another region culminating in an biased result. These attributes represent the trophic structure of biological communities and are an important indicator of ecosystem balance (Araújo 1998), besides richness indicator can be used as Simpson Dominance Index complements (Rodriguez-Olarte *et al*. 2006, Jaramillo-Villa and Caramaschi 2008).

The index proposed by Pinto *el al*. (2006) was the most rigorous, classifying R18 as very poor while the other IBI's classified it as poor. The attributes "Native species richness", "Characiformes richness" and "Siluriformes richness" were not robust enough to detect differences between our streams, showing the inherent regionalism of these tools (Stoddard *et al*. 2005, Paulsen *et al*. 2008, Oliveira *et al* 2009). The attribute "Percentage of carnivorous" is not ideally applicable to our samples since the carnivorous guild tends to be scarce in first order streams (Ferreira e Casatti, 2006) and possible because our systems can present low trophic diversity (Hued and Bistoni 2005, Jaramillo-Villa and Caramaschi 2008)

The most recent IBI applied in our study (Santos and Esteves 2015) gather several methodologies from a 20-year period and it was adapted for a region dominated by sugar-cane farming. The scores from $I_{S\&E}$ were intermediate and closely related to the RAP results, classifying the forested streams (R20 and R21) as minimally impacted, the urban stream (R18) as highly impacted and both the sugar-cane and intermediate streams (R22 and R24) as medium impacted. The attribute "Percentage of *Bryconamericus inheringii*" was not adequate since this species do not occur in our systems leading to the necessity of knowing the specific communities composition for our region Pesce and Wunderlin (2000). The attribute "Total density" showed low scores due to the proposed equation that must be adapted to our region.

The classification of our streams was more robust for the most impacted one (R18), since its characteristic impacts were adequately measured by all IBI's and was in concordance with the RAP classification. On the other hand, considering a forested stream (R20), the scores from the IBI's ranged from good to poor, even though RAP's classification pointed it as locally good, which represents a gap to be adapted for our own IBI, considering the regional characteristics and impacts. The study region is dominated by agriculture and pasture, which leads to the absence of pristine systems and to a scarcity of minimally impacted systems and these must be incorporated in our analyses. The presented results represents just a fraction of an complex research project and will be further improved and adequately related to ecological and social context of the Northwest Paraná, Brazil.

Conclusions/outlook

The Rapid Assesment Protocol for local environmental assessment was previously adapted and consolidated for our study region and its association with the three IBI's was most helpful to interpret and comprehend regional responses and to guide the adaptation of the regional IBI. Local ecological and social characteristics are to be implemented to our IBI proposal and the validation of its robustness will be tested during different research projects of our research team. Some of the attributes that must be integrated to our proposal, that belong to the different IBI's are: "Reofilic species richness", "Native species richness", "Characiforms richness", "Siluriforms richness", "Percentage of *Bryconamericus inheringii*" and "Totoal density".

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