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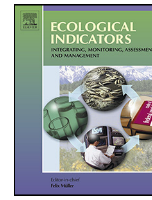

An index to evaluate the fluvial habitat degradation in lowland urban streams

Joaquín Cochero[a,b,*], Agustina Cortelezzi[b,c], Alan Santiago Tarda[a,b], Nora Gómez[a,b]

[a] Instituto de Limnología "Dr. Raúl A. Ringuelet"—Facultad de Ciencias Naturales y Museo—Universidad Nacional de La Plata, 1900 La Plata, Argentina
[b] CONICET—Consejo Nacional de Investigaciones Científicas y Tecnológicas, Argentina
[c] Instituto Multidisciplinario sobre Ecosistemas y Desarrollo Sustentable (UNCPBA, Tandil), Argentina

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ABSTRACT

The objective of the present article is to propose an index that allows the assessment of the fluvial habitat quality in lowland streams that run through urbanized areas, by the use of metrics related to the quality of the watercourse, the river banks, the riparian zone and the fluvial geomorphology. The metrics retained in the index (USHI, Urban Stream Habitat Index) include the cover percentage and quality of the aquatic vegetation; the main features of the river banks; the presence of exotic trees, of litter, of permanent structures (such as buildings) in the riparian zone and other major geomorphological alterations, such as dredging or channelization. The index is related to physical-chemical parameters that are linked to water quality, the imperviousness of the watershed and to other biotic descriptors, particularly the macroinvertebrate and diatom assemblages. The values of the index for the sites in the studied area revealed that 41.2% have a bad or very bad habitat quality, 27.8% a moderate habitat quality, while 31% have a good or very good habitat quality. The main issue detected in the studied sites involved the dredging or partial channelization of the reaches. Unlike other indices that evaluate the quality of the physical habitat through the use of the diatoms or macroinvertebrate communities, the USHI can be interpreted as a measure of the overall quality of the habitat, and uses indicators that do not require the identification of taxa, making it more accessible to non-specialists. Therefore it provides with a tool to evaluate the fluvial habitat quality of lowland streams that can be easily applied, particularly by professionals that take part in the management and decision making process regarding urbanized watersheds.

1. Introduction

The continued growth of the human population and the conversion of natural landscapes to urban uses have resulted in the degradation of ecosystems worldwide. Urbanization can dramatically impact watershed health through increased runoff from impervious surfaces, changes in sediment delivery, and increased pollutant and nutrient loads from nonpoint sources (Mayer et al., 2010; Yannopoulos et al., 2015; Valipour et al., 2015). These issues have led in the last decades to an intensification of efforts to develop methods to assess not only the water quality but the fluvial habitat as well, including the alluvial valley, the fluvial terraces, the riparian zone and the subterranean aquifer to which the river is connected to (Ordeix et al., 2012).

The aquatic habitat can be defined as the physical, chemical and biological characteristics that provide an environment for the biota (Jowett, 1997). Characterizing the physical structure and assessing the habitat quality of rivers is becoming more important in the context of environmental planning, appraisal and impact assessment (Raven et al., 2002). The fluvial habitat is affected by the features of the water body and the surrounding topography, and the structure and composition of the biological communities are related to the quality and quantity of available habitats (Aadland, 1993; Callow and Petts, 1994; Bortone, 2005; Borja et al., 2009).

A large variety of methodologies have been proposed to characterize the fluvial habitat or some of its components, in response to diverse environmental goals. These were implemented mainly for European (LAWA, 2000; Raven et al., 1998; Buffagni et al., 2004; Pedersen and Baattrup-Pedersen, 2003; Bonada et al., 2002; Munné et al., 2003; Pardo et al., 2002) North American (Barbour et al., 1999)

* Corresponding author at: Instituto de Limnología "Dr. Raúl A. Ringuelet"—Facultad de Ciencias Naturales y Museo—Universidad Nacional de La Plata, 1900 La Plata, Argentina.
E-mail address: jcochero@ilpla.edu.ar (J. Cochero).

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and Oceanian (Davies et al., 2000; Parsons et al., 2004; Jansen et al., 2005; Brierley et al., 2005) water bodies.

In South America some of these indices have been translated and/or adapted for their proper use (e.g. Segnini and Chacón, 2005; Miserendino et al., 2008; Kutschker et al., 2009; Gualdoni et al., 2011; Villamarín et al., 2014), and some regional indices, although very scarce, have been developed to assess the habitat quality of specific habitats such as estuaries (Gómez and Cochero, 2013). However, due to the lack of a standardized methodology to assess the hydromorphological quality that would allow the comparison of physical characteristics of rivers among regions or at continental level (e.g. Raven et al., 2010), the application of "allochthonous" indices can be impracticable.

The Pampean streams in Argentina are characterized by their low water velocity, low slope (1 m/km), reduced or no rithron, abundant clay and silt substrates, a riparian vegetation dominated by grasslands and a diverse and abundant aquatic vegetation (Giorgi et al., 2005). Despite previous efforts to implement existing habitat indices (Barbour et al., 1999; Raven et al., 2002) the variables they include are not necessarily applicable for Pampean streams. For instance, the habitat index proposed by Barbour et al. (1999) for low-gradient streams considers ten river channel features, the first four being the sediment characteristics (epifaunal substrate, pool substrate characterization, pool variability and sediment deposition), while there are no parameters that consider the instream aquatic vegetation cover; in Pampean streams the habitat heterogeneity is usually the result of submerged vegetation rather than the result of different type and size of substrata (Giorgi et al., 2005), so the inclusion of this community to the index is of great importance.

The objective of the present study was to select and combine metrics related to the fluvial habitat of Pampean streams into an index that allows the assessment of the habitat detriment in lowland urbanized streams. This index aims to provide with a tool to evaluate the fluvial habitat quality of lowland streams that can be easily applied, particularly by those professionals that take part in management and the decision making process in urbanized watersheds, without the need of specialized sampling of biotic communities.

2. Materials and methods

2.1. Study area

Habitat data from 39 sampling sites was collected in different seasons from 2008 to 2015, for a total of 158 cases (Table 1). Sampling sites were located near the cities of Buenos Aires ("*Matanza-Riachuelo*" basin, 2008–2014), La Plata ("*El Gato*" basin, 2014–2015; "*Baldovinos-Don Carlos-Martin*" basin, 2008); and Tandil ("*Langueyú*" basin, 2012) (Fig. 1). In each of these sites, physical-chemical, biological and habitat data was collected simultaneously to test their correlation to the index.

2.2. Physical-chemical data

Temperature, dissolved oxygen, conductivity and pH were measured with a multiparametric sensor (Horiba U-10). Samples for Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), $P{-}PO_4^{-3}$, $N{-}NO_3^-$, $N{-}NO_2^-$ and $N{-}NH_4^+$ were collected at each site using 500 mL bottles. For inorganic nutrients, samples were filtered through Sartorious GF/C filters in situ before transport to the laboratory at 4 °C. Inorganic phosphate, nitrite, and ammoniacal nitrogen were determined colorimetrically by standard methods (American Public Health Association, 1981); nitrate was reduced to nitrite before colorimetric measurement (Mackereth et al., 1978), and dissolved inorganic nitrogen (DIN) was calculated as the sum of nitrates, nitrites and ammonium.

Table 1
List of the sampling sites showing their nearest urban centers, their coordinates (Lat. = latitude and Long. = longitude), the% impervious surface (%Imp.) of their surrounding areas and the number of times each site was visited (N).

Nearest city	Code	Lat. (°S)	Long. (°W)	% Imp.	N
Buenos Aires	ArroAgui	34°49′35.29″	58°34′45.62″	12.20	6
	ArroCanu	34°54′53.39″	58°37′53.87″	7.91	5
	ArroCanu1	35°0′41.22″	58°42′34.78″	7.91	6
	ArroCanu2	34°55′28.34″	58°36′35.21″	7.91	6
	ArroCeb	35°3′16.34″	58°46′59.16″	10.14	5
	ArroChac	34°52′55.24″	58°40′3.83″	14.24	6
	ArroChac1	34°54′17.93″	58°46′2.5″	14.24	5
	ArroCild	34°40′47.6″	58°26′25.33″	69.13	8
	ArroMora	34°47′47.87″	58°38′10.75″	11.19	6
	ArroMora1	34°50′16.4″	58°50′2.65″	11.19	5
	ArroRod	34°59′10.5″	58°53′3.48″	8.58	5
	ArroSCat	34°44′8.12″	58°28′49.04″	33.52	7
	AutoRich	34°44′50.6″	58°31′19.81″	16.83	6
	DepuOeste	34°43′0.7″	58°30′28.51″	16.79	7
	MatyRuta3	34°55′26.22″	58°43′16.75″	16.79	6
	PteAvell	34°38′17.09″	58°21′24.52″	69.13	6
	PteColor	34°43′35.8″	58°28′58.15″	16.79	7
	PteLaNor	34°42′17.14″	58°27′41.11″	69.13	6
	PteUribu	34°39′37.66″	58°25′5.74″	69.13	6
	PteVicto	34°39′43.24″	58°23′19.14″	69.13	6
	RLP-Taxco	34°49′35.72″	58°37′1.2″	16.79	5
La Plata	B1	34°50′58.99″	58°10′54.98″	86.11	2
	B2	34°50′8.02″	58°10′21″	76.55	2
	B3	34°48′7.99″	58°7′28.99″	88.22	2
	DC1	35°54′9″	58°1′35″	89.33	2
	DC2	35°53′35.99″	58°1′23.02″	56.12	2
	DC3	35°52′36.98″	58°1′32.02″	22.08	2
	Martin1	34°53′15″	58°4′16″	10.12	2
	Martin2	34°52′27.98″	58°4′10.99″	26.11	2
	Martin3	34°51′34.99″	58°3′50″	18.62	2
	G1	34°58′48.94″	58°3′8.96″	82.44	1
	G2	34°57′53.1″	58°0′17.57″	46.08	1
	G3	34°53′21.73″	57°59′34.94″	10.33	1
Tandil	L1	37°17′58.63″	59°7′50.92″	ND	1
	L2	37°17′51.22″	59°7′50.7″	ND	1
	L3	37°17′20.8″	59°7′37.27″	ND	1
	L4	37°17′0.89″	59°7′37.09″	ND	1
	L5	37°16′22.26″	59°7′36.7″	ND	1
	L6	37°13′53.15″	59°7′34.61″	ND	1

2.3. Benthic diatoms and chlorophyll-a

In Pampean streams the principal substrate of the streambed is composed of fine sediments (clays and silts), where the epipelic biofilm develops. At each site, five subsamples of the surface layer (0.5 cm) of sediment were collected by pipetting (area 1 cm^2), pooled, and preserved with 4% (v/v) formalin (Gómez et al., 2009). Diatoms were cleaned with H_2O_2, washed thoroughly with distilled water, and mounted on microscope slides with Naphrax®. In order to determine the relative abundance of the diatom species in each sample, a total of 400 diatom valves were examined under an Olympus BX 51 microscope at a magnification of ×1000 with phase contrast and Normarski-DIC optics. For the determination of chlorophyll-*a* water samples were filtered immediately with Sartorious GF/C filters and were then transported to the laboratory in the dark at 4 °C. Chlorophyll-*a* was determined spectrophotometrically using 90% (v/v) aqueous acetone after Clesceri et al. (1998).

2.4. Macroinvertebrates

Three sediment sample replicates were taken at each sampling site with an Ekman grab covering an area of 100 cm^2. In the laboratory, the benthic samples were washed on a 500-μm-mesh sieve