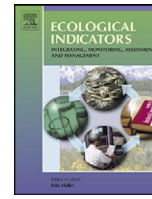
Ecological Indicators 11 (2011) 1204–1215

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind



Development of metrics based on fish body size and species traits to assess European coldwater streams

Maxime Logez[a,*], Didier Pont[b]

[a] Cemagref, UR HYAX, 3275 Route de Cézanne–CS 40061, F-13182 Aix-en-Provence, France
[b] Cemagref, UR HBAN, Parc de Tourvoie BP 44, 92163 Antony Cedex, France

ARTICLE INFO

Article history:
Received 17 March 2010
Received in revised form 4 November 2010
Accepted 31 December 2010

Keywords:
Coldwater streams
Size classes
Metric
Fish assemblages
Species traits
Multimetric index

ABSTRACT

During the last decade multimetric indices (MMIs) have been greatly improved by the use of appropriate criteria to define reference conditions and by the use of statistical analysis to select a consistent set of metrics. Among the large number of MMIs developed to assess the ecological status of streams based on fish communities, the emphasis was mainly put on warmwater assemblages. When compared with warmwater fish assemblages, coldwater assemblages present depauperate faunas with a limited suit of traits. Thus, very often the number of metrics used to compute MMIs for coldwater streams is lower than for warmwaters. The objective of this study was to develop new metrics specific to European coldwater assemblages that integrate both the species traits and the body size of fish. Indeed, whereas the use of size or age classes has been highly advocated for developing MMIs, it remains largely underrepresented. Therefore, we used eight biological and ecological traits to characterize species and two size classes: small and large individuals. Among the 96 metrics tested, four were successfully related to environmental gradients and three displayed a significant response to anthropogenic pressures: the number of small rheophilous individuals, the number of small oxygen-intolerant individuals, and the number of small-habitat-intolerant individuals. These results demonstrate that metrics based on size classes could be used in the development of MMIs for coldwater streams and more generally for low-species rivers.

1. Introduction

Since the first index of biotic integrity (IBI) developed by Karr (1981), the concept of multimetric indices (MMIs) to assess stream ecological conditions using various fish assemblage attributes has been successfully extended to different regions in the United States (Angermeier and Schlosser, 1987; Angermeier et al., 2000; McCormick et al., 2001; Mebane et al., 2003; Wang et al., 2003) and various countries (Oberdorff and Hughes, 1992), and MMIs are now used on almost all continents (An et al., 2002; Bramblett et al., 2005; Hughes and Oberdorff, 1999; Hugueny et al., 1996; Lyons et al., 1995; Oberdorff and Hughes, 1992; Pont et al., 2006).

The concept of IBI, and more generally of MMIs, is based on the statement that using diverse aspects of assemblages to assess system conditions (biotic integrity, health, ecological condition, etc.) would provide a more reliable or robust estimation than when only considering one attribute (Karr and Chu, 1999). Indeed, individually, each metric (assemblage attribute measured) integrated in an MMI is expected to represent a singular assemblage attribute (Karr et al., 1986) responding to specific human pressure, with varying sensitivity along the pressure gradient (Angermeier and Karr, 1986; Karr et al., 1986). In this way, encompassing multiple metrics into a unique index would make it sensitive to a broad array of alterations. Moreover, under severe degradation, several metrics should be modified, reinforcing the accuracy of the estimation (Karr, 1991).

During the last decade, selecting appropriate metrics has became a key process in the development of multimetric indices (Karr and Chu, 2000), which led to the development of rigorous selection protocols integrating several criteria and statistical analysis (Hering et al., 2006; Hughes et al., 1998; Pont et al., 2006, 2009; Roset et al., 2007; Stoddard et al., 2008). To be useful, metrics would be representative of the region for which the MMIs are developed; for example, using the metric percent of green sunfish (*Lepomis cyanellus*, Rafinesque) integrated into the first IBI (Fausch et al., 1984; Karr, 1981) to assess European streams would not be consistent as its distribution area is restricted to North America (Lee et al., 1980; Nelson, 2006). A metric only slightly represented in a region should not discriminate consistently between sites (Harris and Silveira, 1999). Metrics should also reflect different aspects and

Abbreviations: MMI, multimetric index; INTOL, general intolerant; O2INTOL, oxygen-intolerant; HINTOL, habitat-intolerant; RH, rheophilous; INSEV, insectivorous; POTAD, potamodromous; LITH, lithophilic; SINREP, single reproduction; EFT, European fish type; SED, bottom sediment structure; CAL, calibration sites; SID, slightly or not impacted sites.

* Corresponding author. Tel.: +33 04 42 66 69 86; fax: +33 0 4 42 66 99 34.
E-mail addresses: maxime.logez@cemagref.fr (M. Logez), didier.pont@cemagref.fr (D. Pont).

1470-160X/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecolind.2010.12.023

provide singular information of assemblages. To avoid redundancy, several authors have used correlation criteria to select a metric or have chosen the most efficient metric between two redundant ones (Hering et al., 2006; Pont et al., 2006). The signal reflected by metrics should only display the variability of human pressure between sites and not the environmental differences between them (Hering et al., 2006; Hughes et al., 1998; Karr and Chu, 2000; Pont et al., 2006; Stoddard et al., 2008). Finally, the most important criteria are the ability of a metric to detect human pressure and to discriminate degraded sites from reference sites (Bailey et al., 1998; Hering et al., 2006; Hughes et al., 1998; Karr and Chu, 1999; Pont et al., 2006, 2009; Southerland et al., 2007; Stoddard et al., 2008). Since the original set of metrics used in the first IBI for warmwater streams of the Midwestern United States (Karr, 1981), a wide variety of metrics have been used in MMIs (e.g., Simon and Lyons, 1995) to cope with different species pools (Hughes and Oberdorff, 1999; Hugueny et al., 1996; Lyons et al., 1995; Mebane et al., 2003; Oberdorff and Hughes, 1992), specific regional environmental conditions (Angermeier et al., 2000; Magalhaes et al., 2008), river types (Matzen and Berge, 2008; Mundahl and Simon, 1999), specific pressures (Oberdorff and Porcher, 1994; Wang et al., 2003), and system functioning. For example, Magalhaes et al. (2008) and Bramblett et al. (2005) used a specific set of metrics to develop MMIs for Mediterranean and semi-arid streams.

Coldwater streams have received particular attention because they display both specific environmental conditions and associated fish species communities (Hughes et al., 2004; Lyons et al., 1996; Mebane et al., 2003; Mundahl and Simon, 1999; Wang et al., 2003). Compared to most of warmwater streams, coldwater streams present depauperate faunas (Hughes et al., 2004; Lyons, 1996; Matzen and Berge, 2008; Mebane et al., 2003) mainly composed of intolerant species (Halliwell et al., 1999; Zaroban et al., 1999). The low species richness commonly observed in coldwater streams limits the amount of metrics available and their variability (Lyons, 1996; Simon and Lyons, 1995). The particular relationships between metrics and human pressures in coldwater streams are also a key factor supporting the development of coldwater-specific MMIs (Hughes et al., 2004; Lyons et al., 1996; Mundahl and Simon, 1999; Wang et al., 2003). Indeed, several metrics displaying a relatively well-known pattern of variation in warmwater streams displayed opposite patterns in coldwater streams (Lyons, 1996; Mebane et al., 2003). Species richness, one of the most common metrics include in MMIs, very often decreases with human pressure in warmwater streams, whereas it could increase with human alteration in coldwater streams (Lyons, 1996; Mundahl and Simon, 1999).

To describe these various constraints, authors developing MMIs for coldwater streams have either integrated metrics based on other vertebrate groups (Hughes et al., 2004), used fewer metrics than for warmwater MMIs (Langdon, 2001; Lyons et al., 1996; Southerland et al., 2007), or used other components of fish assemblages such as species age or length classes (Breine et al., 2004; Hughes et al., 2004; Langdon, 2001; Oberdorff and Porcher, 1994). Although the use of age or length structure has been advocated by several authors (Breine et al., 2004; Karr, 1991; Roset et al., 2007) and by the Water Framework Directive (European Union, 2000), the number of MMIs using such assemblage attributes remains low.

The main purpose of this study was to develop specific metrics for coldwater streams dominated by intolerant species that take into account individual fish body size. To achieve this objective, we used information on species biological and ecological traits and on fish size. Individuals were classified into two size classes (small and large) by comparing fish lengths with different arbitrary thresholds. Once metrics were computed and standardized by the environment, we assessed their ability to detect anthropogenic disturbances.

2. Material and methods

2.1. Fish sampling and site characterization

We used data from the fish surveys of 12 European countries (Fig. 1) conducted by several laboratories and governmental environmental agencies (1981–2007, 95% after 1990). Sites were sampled using electrofishing methods either by wading or by boat, depending on stream depth. All sites were located in small permanent streams (drainage area less than 500 km^2, mean air temperature in July lower than 20 °C) and were sampled during low-flow periods. The species of each individual collected was identified and its total length (mm) was measured. To homogenize the sampling effort between regions, only fish collected during the first pass were considered.

To characterize the local environmental conditions, we used the slope, July mean air temperature, and the thermal amplitude between January and July, as they are fundamental descriptors of river habitat at the reach scale (Pont et al., 2005). In addition, we considered bottom sediment structure (SED) in a simplified manner because it is difficult to obtain more precise and comparable information for such a large data set. We thus used three classes: small (sand, silt), medium (cobble, pebble), and large (rock, block).

Hydrogeomorphic processes are also a major factor controlling river habitat and fish assemblage structure (Junk et al., 1989; Petts and Amoros, 1996; Poff and Allan, 1995; Poff et al., 1997). Therefore, we also considered the river size (surrogates by drainage area and distance from source), the hydrological regime (pluvial dominated vs. glacial-nival), the geomorphologic types (meandering, braided, or constraint), and the presence of a floodplain. To reduce the amount of variables and their multicolinearity, we used the first two axes of a multivariate analysis (Hill and Smith, 1976) as synthetic geomorphic variables (SYNGEO1 and SYNGEO2). The method developed by Hill and Smith (1976) is designed to handle both quantitative and qualitative variables. It acts as a principal component analysis on the correlation matrix if all variables are quantitative and as a multiple correspondence analysis if all variables are qualitative. SYNGEO1 describes the stream size gradients and the presence of floodplain downstream, whereas SYNGEO2 contrasts meandering rivers with pluvial regime to the others (Fig. 2).

2.2. Definition of metrics

To develop specific metrics for European coldwater streams, we selected eight species traits that are highly represented in these streams (Noble et al., 2007): general intolerant (INTOL), oxygen-intolerant (O2INTOL), habitat-intolerant (HINTOL), rheophilous (RH), insectivorous (INSEV), potamodromous (POTAD), lithophilic (LITH), and single reproduction (SINREP). Each of the 68 species was either assigned to these traits or not (e.g., Table 1) depending on its biological and ecological characteristics. The European fish species were classified during the EU EFI+ project (http://efi-plus.boku.ac.at/) and was a revision of the classification developed in a previous European project (http://fame.boku.ac.at, Noble et al., 2007).

In combination with species traits, we considered two size classes: small and large individuals. Each fish was assigned to one of the two classes by comparing its length with an arbitrary threshold (Table 2). All fishes with a length lower than the given threshold were considered small and all the others large. As our study was a preliminary step in the development of such metrics, we tested three arbitrary thresholds to define the size classes: 100, 150, and 200 mm (Table 2). For each of the eight traits, we computed the