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A novel approach to an ecofunctional fish index for Mediterranean countries

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ABSTRACT

The implementation of the European Water Framework Directive, especially regarding the establishment of fish indexes for riverine habitats, has taken different paths in different countries. For example, in Italy previous efforts have been directed towards a taxonomy-based index, contrarily to most other European countries where an ecofunctional approach took place. Taxonomical indexes are particularly hard to apply to Mediterranean countries, where fish taxonomy is often revised causing problems in practical implementation. Alternatively, ecofunctional characteristics of fish communities could be exploited to inform on river habitat quality and to detect anthropogenic impacts, thus reducing the index sensitivity to the taxonomical variability of the fish fauna. We therefore proposed a new, multimetric index based on ecofunctional traits of fish species (EFFI, EcoFunctional Fish Index) and tested it on 208 river sampling stations of the Emilia-Romagna region, northern Italy. Using theoretical reference communities, ecological quality ratios were estimated for the whole area expressing the ecological distance of each site from reference conditions. Perhaps unsurprisingly, this work underlined how fish communities were more degraded at lower altitudes than at higher ones. EFFI scores were remarkably close to two already-established indexes for chemical (LIM) and macrozoobenthos communities (IBE) alteration. Further work should explore the validity of this approach over a wider geographical range as well as investigate the definition of environmental class boundaries and its potential intercalibration with other indexes.

1. Introduction

Fish can be readily used as indicators of aquatic environmental status, as their communities are sensitive to habitat quality and because they respond to anthropogenic pressures such as pollution, eutrophication or habitat alteration (Fausch et al., 1990). Based on this characteristic, several indexes have been developed through the years with a variety of approaches (Schmutz et al., 2007). The general aim of these indexes is to provide a measure that summarizes a complex ecosystem and to allow an evaluation of the condition of the environment (Whitfield and Elliott, 2002). A variety of approaches are available to the investigators, but most indexes follow Karr's Index of Biotic Integrity (1981) and use multimetric indexes, exploiting either historical information (Kleynhans, 1999) or relatively undisturbed reference conditions to measure the effects of anthropogenic impacts (Bailey et al., 1998).

In Europe, directive 2000/60/EC, more commonly known as the Water Framework Directive (WFD), sets indications in its Annex B to build indexes for several biological and chemical parameters of European rivers (EU, 2000). According to these indications, species composition and abundance, as well as age structure of the fish community, should be taken into account when building an index for riverine habitats. WFD has slowly been transposed to national legislation of Member States (e.g. in Italy, with legislative decree 152/06) but several difficulties, mainly related to a lack of systemic approach, were encountered during the implementation of such legislations (Voulvoulis et al., 2017) and several different approaches have been elaborated (Birk et al., 2012). Accordingly, the EU has funded research efforts to jointly address the problems that arose in defining indexes: a prime example of these efforts was the FAME consortium, led by France and including a total of 12 EU countries, which developed the European Fish Index (EFI), an index that exploits some ecological characteristics of fish assemblages to infer ecological status (Pont et al., 2006). However, in some countries that were not partners of the FAME consortium, the work on fish indexes has taken a rather different path.

In Italy, for example, two indexes based on taxonomy rather than ecological functionality have been proposed (Forneris et al., 2004; Zerunian, 2004). Taxonomical indexes measure the deviation of the fish community from a reference community, effectively informing on the fish community status, but focus entirely on the taxonomical units. In Mediterranean countries, where the vast majority of rivers host communities which are altered by anthropogenic actions and conservation

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biology has been turned into environmental management, a taxonomy-based index poses two major challenges. First of all, the index needs to be continuously revised, as taxonomy is an ever-shifting ground where consensus is hard to reach, particularly in areas rich in endemism (the taxonomy of trouts in Italy is a prime example of such hard-to-resolve controversies, see e.g. Zanetti (2017)). Secondarily, and more generally, freshwaters are impacted also at the taxonomical level, therefore multimetric indexes based on taxonomy tend to assign much lower scores to sites which would be otherwise ecologically sound but host an altered fish community (i.e. host a number of exotic species, often as a result of human-mediated dispersion or intentional management).

Exotic species do constitute a major problem in the Mediterranean region (Bianco and Ketmaier, 2015; Crivelli, 1995) and have been suggested to drive the local extinction of fish species (Castaldelli et al., 2013; Dias et al., 2017). However, not all exotic species are equally capable of altering the habitat they live in or the fish communities they interact with so their relevance for environmental assessment purposes can vary. Furthermore, even though some exotic species (especially successful invaders) are broad generalists, most have their own ecological niches and tolerances which can be exploited to inform on the environmental status of the rivers, similarly to native species.

It has been argued that establishing an ecofunctional index for Mediterranean countries could be extremely challenging (e.g. Pont et al., 2006; Zerunian et al., 2009), due to the lack of ecological information on several endemic species. Following the work by Aarts and Nienhuis (2003), Welcomme et al. (2006), Pont et al. (2006) and Noble et al. (2007), we argue that an ecofunctional index, if feasible, could provide significant advantages and inform on the status of both the environment and the fish community. If ecofunctional classes are broad enough, species-specific differences would be downplayed in favor of broad genus or family differences, thus providing more information on the river environmental status and the fish community health compared to a taxonomical indicator. An indicator based on ecofunctional characteristics of fish communities would be most informative on anthropogenic pressures such as hydrological alterations (water flow regulation and migration barriers), chemical and nutrient alterations (pollution and eutrophication), habitat alteration (e.g. changes in spawning substrate) and fisheries (both fisheries pressure and introduction of species (e.g. for recreational fisheries).

This study aimed to define a novel approach to define an ecofunctional fish index for the Mediterranean region, utilizing available information on fish species to assess the status of river stretches. We build a new multimetric index that uses information on fish communities' composition and relative abundance to compare reference and current conditions. This EcoFunctional Fish Index (EFFI) was tested on a dataset of 208 river sampling stations in the Emilia-Romagna region of northern Italy and compared to two already-established indexes for chemical and macroinvertebrate community alteration to preliminarily explore its degree of response to anthropogenic pressures.

2. Materials and methods

2.1. Ecological functions

A number of ecological functions have been selected to compose the index, following up on the work by Noble et al. (2007). The criteria for selection were dual: ecological functions must cover the available information on species but also have to be relevant for the purpose of inferring the river environmental status.

The ecological functions selected were: Feeding (based on prevalent diet), Reproduction (based on preferred reproduction substrate), Migration (based on the range of movement of the species), Tolerance (to low oxygen or high temperature), Habitat (based on preferred habitat), Native Biodiversity (based on the native/exotic status, and on the potential of the species to alter the fish community or the environment itself).

The different ecological functions inform on fish community status (e.g. Feeding or Native Biodiversity functions, which inform on the community trophic composition and on the potential of species to alter it, respectively) and river habitat ecological status (e.g. Reproduction or Migration guilds, which inform on the available substrates and the habitat fragmentation) with the aim of recording anthropogenic impacts on these components of the ecosystem.

2.2. Ecofunctional guilds

Each ecological function was divided into guilds that would detail characteristics by which single species could be scored, which also followed largely the work of Noble et al. (2007). As with ecological functions, guilds were defined based on their ability to inform on the status of the environment and the availability of information for fish species. For instance, in the Tolerance ecological function, guilds were chosen based on their ability to inform on the river fluctuations of oxygen and temperature or, in the habitat ecological function, to inform on the river current strength and turbidity. All these parameters are affected by anthropogenic disturbances such as nutrient pollution and eutrophication, thermal pollution, damming and water abstraction, and watershed erosion, respectively.

In the feeding ecological function, as most fish species have rather wide trophic niches and exhibit ontogenetic diet shifts, we considered the prevalent diet of adult individuals for the definition of guilds. Fish were divided into planktivores (exhibiting specific adaptations for plankton filtering, such as gill rakers), herbivores (exhibiting specific adaptations for plant feeding, such as pharyngeal teeth), benthivores (exhibiting specific adaptations for bottom feeding, such as downturned mouths or barbels), invertivores (specifically adapted to or predating prevalently on insects and other invertebrates), piscivores (with specific adaptations for feeding largely on fish), parasites (ematophages, limited to lampreys in Italian waters) and generalists (with unspecialized mouthparts and digestive systems, feeding on a broad range of items).

In the reproduction ecological function, fish were assigned to one guild, separated into lithophils (spawning on stones and gravel), phytophils (spawning on submersed vegetation), phytolithophils (spawning both on stones and vegetation), psammophils (spawning on sand or mud), ostracophils (spawning in molluscs), pelagophils or live breeding (pelagic spawners or live spawners) and polyphils (generalist spawners).

In the migration ecological function, guilds were based on the range of movement reported in literature for the species. This included both ranging movements during feeding/life history and spawning migrations. The guilds included short (within the river zones), medium (up and downstream or into flooded areas) and long (true anadromous and catadromous species) ranges of movement.

In the tolerance ecological function, fish species were divided into two mutually exclusive guilds of tolerance/intolerance to low oxygen (indicatively below 3 ppm) and to high temperature (indicatively above 20 °C), based on available information.

In the habitat ecological function, fish species were divided into two broad guilds based on current speed and water transparency. Within the first guild, fish were either identified as rheophils (preferring fast flowing water), limnophils (preferring slow or no current) or eurytopic (having no particular preference). Within the second guild, fish were either adapted to clear water, turbid waters or adaptable to a wide range of water turbidity.

In the Native Biodiversity ecological function, fish were divided in mutually exclusive native and exotic (i.e. introduced by human action, irrespective of time) guilds. Exotic species capable of modifying the environment or fish communities were also assigned to a separate guild. Additional remarks in the last column of the matrix (Supplementary Table 1) further detail whether some species native to the national territory have been introduced in areas where they were not formerly present, so that this can be accounted for in specific hydrographic areas