Science of the Total Environment 586 (2017) 502–511

Contents lists available at ScienceDirect

Science of the Total Environment

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

Response of fish communities to multiple pressures: Development of a total anthropogenic pressure intensity index

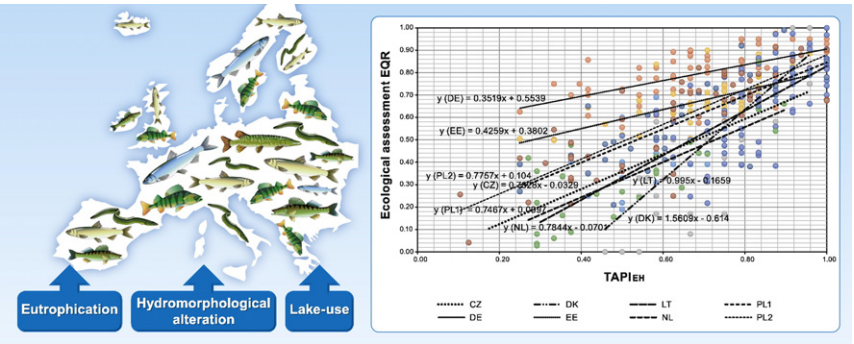
Sandra Poikane [a,*], David Ritterbusch [b], Christine Argillier [c], Witold Białokoz [d], Petr Blabolil [e,f], Jan Breine [g], Nicolaas G. Jaarsma [h], Teet Krause [i], Jan Kubečka [e], Torben L. Lauridsen [j], Peeter Nõges [i], Graeme Peirson [k], Tomas Virbickas [l]

[a] European Commission Joint Research Centre, Directorate for Sustainable Resources, Water and Marine Resources Unit, I-21027 Ispra, VA, Italy
[b] Institute of Inland Fisheries, Im Königswald 2, 14469 Potsdam-Sacrow, Germany
[c] Irstea, UR RECOVER, 3275 Route de Cézanne CS 40061, 13182 Aix en Provence Cedex 5, France
[d] Inland Fisheries Institute, Oczapowskiego 10-719, Olsztyn, Poland
[e] Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, Na Sádkách 7, 370 05 České Budějovice, Czech Republic
[f] Faculty of Science, University of South Bohemia, Branišovská 31, 370 05 České Budějovice, Czech Republic
[g] Research Institute for Nature and Forest, Dwersbos 28, B-1630 Linkebeek, Belgium
[h] Nico Jaarsma E&F, Klif 25, Den Hoorn, Texel, The Netherlands
[i] Centre for Limnology, Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Kreutzwaldi 5, 51014 Tartu, Estonia
[j] Department of Bioscience, Aarhus University, Vejlsøvej 25, 8600 Silkeborg, Denmark
[k] Environment Agency, Kidderminster DY11 7RA, UK
[l] Nature Research Centre, Akademijos 2, LT-08412 Vilnius-21, Lithuania

HIGHLIGHTS

- Creating a common fish-based assessment system for European lakes has failed so far.
- Fishes react in a holistic way to a broad range of cumulative pressure impacts.
- We created a combined pressure index (TAPI) that reflected fish ecological quality.
- TAPI includes eutrophication, hydromorphological alterations and lake-use intensity.
- TAPI correlated well with 8 out of 10 national lake fish indices tested.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 17 December 2016
Received in revised form 27 January 2017
Accepted 27 January 2017
Available online 14 February 2017

Editor: D. Barcelo

ABSTRACT

Lakes in Europe are subject to multiple anthropogenic pressures, such as eutrophication, habitat degradation and introduction of alien species, which are frequently inter-related. Therefore, effective assessment methods addressing multiple pressures are needed. In addition, these systems have to be harmonised (i.e. intercalibrated) to achieve common management objectives across Europe.

Assessments of fish communities inform environmental policies on ecological conditions integrating the impacts of multiple pressures. However, the challenge is to ensure consistency in ecological assessments through time, across ecosystem types and across jurisdictional boundaries. To overcome the serious comparability issues between national assessment systems in Europe, a total anthropogenic pressure intensity (TAPI) index was

* Corresponding author.
E-mail address: sandra.poikane@jrc.ec.europa.eu (S. Poikane).

http://dx.doi.org/10.1016/j.scitotenv.2017.01.211

Keywords:
Aquatic ecosystems
Bioassessment
Fish assemblages
Fish-based assessment system
Lakes
Multiple pressures
Pressure-response relationships
Water Framework Directive

developed as a weighted combination of the most common pressures in European lakes that is validated against 10 national fish-based water quality assessment systems using data from 556 lakes.
Multi-pressure indices showed significantly higher correlations with fish indices than single-pressure indices. The best-performing index combines eutrophication, hydromorphological alterations and human use intensity of lakes. For specific lake types also biological pressures may constitute an important additional pressure. The best-performing index showed a strong correlation with eight national fish-based assessment systems. This index can be used in lake management for assessing total anthropogenic pressure on lake ecosystems and creates a benchmark for comparison of fish assessments independent of fish community composition, size structure and fishing-gear.
We argue that fish-based multiple-pressure assessment tools should be seen as complementary to single-pressure tools offering the major advantage of integrating direct and indirect effects of multiple pressures over large scales of space and time.

1. Introduction

More than half of the surface waters in Europe are degraded due to human activity, i.e., support less than "good" ecological status, and will need mitigation and/or restoration measures to reach 'good' status. The pressures reported to affect most surface waters are nutrient enrichment, hydromorphological alterations, invasion of alien species and chemical pollution (EEA, 2012). These pressures significantly affect the capacity of ecosystems to provide the services on which humans depend (MEA, 2005). In the years to come, these impacts may be exacerbated by climate change which can counteract attempts to restore water bodies, and prevent them from reaching "good" status (Jeppesen et al., 2012). Therefore, effective methods are needed to assess, protect and help to restore the ecological integrity of inland and coastal waters (Birk et al., 2012; Karr, 1991). In addition, these systems have to be compared and harmonised (i.e. intercalibrated) to ensure consistency in ecological assessments through time, across ecosystem types, and across jurisdictional boundaries (Birk et al., 2013; Cao and Hawkins, 2011; Poikane et al., 2014b).

It has been proven that fish are sensitive indicators of environmental degradation (Fausch et al., 1990; Karr, 1981). Fish show predictable reactions to eutrophication (Blabolil et al., 2016; Jeppesen et al., 2000; Lyche-Solheim et al., 2013; Mehner et al., 2005), habitat destruction and fragmentation through hydromorphological modifications (Sutela et al., 2011), acidification (Hesthagen et al., 2008; Tammi et al., 2003) and climate change (Jeppesen et al., 2012).

The first fish-based ecological assessment methods were developed for US rivers (Karr, 1981) and have later been adopted to lakes (Whittier, 1999).

In Europe, the development of biological assessment systems has been stimulated by the implementation of the Water Framework Directive (WFD; EC, 2000). The WFD obliges all member states of the European Community to achieve a 'good' ecological status of their surface waters, and stipulates that 'good' or 'not good' should be measured with biological assessment systems. In addition, the 'good' status boundaries should be harmonised via 'intercalibration' exercise (Birk et al., 2013; Poikane et al., 2014b).

Therefore, several European countries including Belgium (Breine et al., 2015), the Czech Republic and France (Blabolil et al., 2016; Launois et al., 2011), Germany (Ritterbusch and Brämick, 2015), Lithuania (Virbickas and Stakėnas, 2016) and Sweden (Holmgren et al., 2007) have developed fish-based tools to assess ecological status. Several cross-European studies have been carried out to develop common fish metrics (Argillier et al., 2013) and intercalibrate (i.e. compare and harmonise) fish-based assessment systems (Poikane et al., 2015).

However, there are two still unresolved issues: (1) Intercalibration of fish-based assessment systems (i.e. harmonisation of the results of biological assessment methods) among the member states; (2) Developing of pressure-response relationships which is a key for any ecological assessment tool applied in river basin management (Birk et al., 2012; Brucet et al., 2013b; Poikane et al., 2015). There are several reasons for these difficulties:

- Member states use very different sampling methods and their combination: multi-mesh gillnets, electrofishing, hydro-acoustics, trawling, seine netting and fyke nets (e.g., Blabolil et al., 2016; Breine et al., 2015). These differences hinder comparison of assessment systems across boundaries (Benejam et al., 2012; Lepage et al., 2016). Two approaches have been adopted for intercalibration: direct comparison of classification outcomes applying each method to a common dataset and indirect comparison where boundary values of each assessment method is converted to common biological metrics (Birk et al., 2013). Both these approaches have been proven to be unsuitable for comparisons of fish assessment due to a variety of sampling gears and protocols, as particular species and dominant functional groups tend to be gear-specific (Chow-Fraser et al., 2006);
- Fish communities in lakes are subjected to multiple pressures and, being at the upper levels of the trophic cascade, integrate effects of pressures acting at any level below. On the other hand, fish communities exert a homeostatic effect on lower trophic levels and thus can contribute to delayed recovery in aquatic ecosystems after anthropogenic pressures have been reduced (Jeppesen et al., 1991). This means that simple relationships between single pressures and fish-metrics may be lacking (e.g., Breine et al., 2015).

We hypothesize that because of the broad spectrum and holistic character of fish sensitivity, the total anthropogenic pressure intensity would show stronger and more consistent relationships with various fish metrics throughout an ecoregion than any single pressure index. A total anthropogenic pressure index could be used for developing pressure-response relationships and for comparing and harmonising fish-based assessment systems across an ecoregion independent of fish community composition, size structure and fishing-gear. The principle of intercalibration using a common pressure index is to translate the incomparable national fish assessment results into a comparable common index. A similar approach was used to intercalibrate ecological classification tools in transitional waters of the North East Atlantic (Lepage et al., 2016).

Therefore, the purpose of this research is to develop a multiple pressure index for lakes in the Central-Baltic ecoregion[1] which can be used to characterize the total anthropogenic pressure on lake ecosystems, develop pressure-response relationships and intercalibrate fish-based assessment tools. Firstly, the fish-based lake assessment systems in different member states are briefly reviewed focusing on the human pressures addressed and metrics included. Next, the construction and

[1] An ecological region for inland waters in Europe delineated for river basin management purposes comprising the Baltic States, Benelux Countries, Poland, Germany, Denmark, Czech Republic, Slovakia, Hungary, and part of France and the UK.