Fisheries Research 173 (2016) 70–79

Contents lists available at ScienceDirect

Fisheries Research

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

Composition of fish communities and fish-based method for assessment of ecological status of lakes in Lithuania

Tomas Virbickas*, Saulius Stakėnas

Nature Research Centre, Akademijos 2, LT-08412 Vilnius-21, Lithuania

ARTICLE INFO

Article history:
Received 19 November 2014
Received in revised form 13 August 2015
Accepted 13 August 2015
Available online 2 September 2015

Keywords:
Fish community index
Lake status
Thermal stratification
Nutrient concentration

ABSTRACT

Multiyear data collected in Lithuanian lakes (Europe ecoregion 15) using standardized methods formed the basis for an analysis to determine interrelations between lake fish community composition and environmental variables. Mean and maximum depths have significant impact on fish community structure in Lithuanian lakes, therefore lakes were classified into polymictic, stratified and deep stratified. The relative abundance of stenothermic fishes such as vendace (*Coregonus albula)* and burbot (*Lota lota)* was found to correlate positively with lake depth, while tench (*Tinca tinca*), rudd (*Scardinius erythropthalmus*) and bream (*Abramis brama*) correlated negatively. Nutrient concentration in lakes positively correlated with roach (*Rutilus rutilus*) and bream abundance and negatively with abundance of perch (*Perca fluviatilis*). In different types of lakes only seven non-redundant candidate fish metrics showed a significant correlation with variables describing human pressure. Those metrics were used to develop fish-based method for the assessment of the ecological status of lakes — the Lithuanian lake fish index LEZI (*Lietuvos Ezeru Zuvu Indeksas*). In all types of lakes, LEZI values most significantly correlate with the concentration of chlorophyll a and Secchi depth.

1. Introduction

Fish are highly responsive to changes in the trophic status of lentic water bodies (Persson et al., 1991; Jeppesen et al., 2000; Mehner et al., 2005; Garcia et al., 2006) and serve as indicators of changes in the hydromorphological status of lakes (Launois et al., 2011). The European Union (EU) water policy recommends fish as a biological quality element for the assessment of the ecological status of lentic waters (European Commission, 2000). Up to now, a number of fish-based systems have been developed for the assessment of European lakes (Appelberg et al., 2000; Gassner et al., 2003; Holmgren et al., 2007; Rask et al., 2010; Launois et al., 2011; Volta et al., 2011; Kelly et al., 2012). Equally a fish-based index designed to assess the eutrophication status of lakes at the European scale was developed based on the fish data collected using a standardized protocol (Argillier et al., 2013). However, data for development of this index were mainly collected in North and Western Europe.

Many principal factors affecting fish community composition in temperate climate lakes were identified: surface area, dissolved oxygen levels, the acidity of the system (Matuszek and Beggs, 1988; Robinson and Tonn, 1989; Jackson et al., 2001; Olin et al., 2002; Lehtonen et al., 2008); turbidity, macrophyte coverage and compexity (Brazner and Beals, 1997; Eadie and Keast, 1984); nutrient load (Matuszek and Beggs, 1988; Olin et al., 2002; Lehtonen et al., 2008), commercial and amateur fishing and stocking (Lehtonen et al., 2008), piscivory and isolation (Robinson and Tonn, 1989), substrate diversity (Eadie and Keast, 1984). Among natural variables, characteristics of thermal stratification were recognized as important factors determining fish community structure and species composition in lakes of ecoregion (thereafter ER) 14 (Illies, 1978; Holmgren and Appleberg, 2000; Diekmann et al., 2005; Mehner et al., 2005, 2007). Diekmann et al. (2005) and Mehner et al. (2007) found that mean depth criterion can be used for differentiation of polymictic (thereafter POLY) lakes from stratified lakes (thereafter S), and for differentiation of S lakes dominated by different fish species. Ritterbusch et al. (2014) proposed maximum depth in addition to mean depth to divide lakes into types for fish communities' characterization and estimation of fish metrics, because combined use of both criteria makes it possible to classify lakes according to stratification peculiarities more precisely. Garcia et al. (2006) also used maximum depth to differentiate fish assemblages in shallow lakes from those in deep lakes. Selection of proper variables for differentiation of lake types and fish communities is crucial for assessment of lake status using fish metrics. Therefore, it seems

* Corresponding author.
E-mail address: tvirbickas@takas.lt (T. Virbickas).

http://dx.doi.org/10.1016/j.fishres.2015.08.015
0165-7836/

appropriate to test the depth criterion for fish based typology of lakes in ecoregions, neighboring ER14.

The new data collected using standardized methods enabled us to analyze the dependence of the fish community composition in lakes in Lithuania (ER15) on environmental variables and human pressures in more detail. The objectives of the current study were (1) to determine interrelations between lake fish community composition and environmental variables; (2) to test the validity of lake classification into types in accordance with mean and maximum depth; (3) to determine fish metrics that are the most responsive to changes in environmental quality due to pressure from human activities; (4) to develop a fish-based method for the assessment of the ecological status of lakes.

2. Methods

The area studied covers the southern part of Water Framework Directive (thereafter WFD) ER 15. In this part of ER 15, all lakes lie below 200 m a.s.l. and, in terms of geology, almost all of them are calcareous (>1.0 meq/lg; Ca > 15 mg l^{-1}). During the 2005–2013 state monitoring of water quality and biological indicators, fish were sampled in 142 natural lakes with an area exceeding 50 ha. In some of the lakes, investigations were carried out several times every 6 year, thus data for our study were obtained from 162 fishing occasions.

All lakes studied are natural in origin. Hydromorphological characteristics are close to natural in 53 lakes and altered in 89 lakes. The most common hydromorphological changes include water level increase due to impoundment (39 lakes) and partial or complete destruction of riparian vegetation (49 lakes). Significant morphological alteration of different kinds were recorded only at 9 lakes: 25% of the shoreline was found to be embanked or eroded at 5 lakes; 25–50% of the shoreline was embanked or eroded at 2 lakes, the water level lowered due to land reclamation in 1 lake. The majority of lakes were relatively small (median – 124 ha). There were just 9 lakes with the area exceeding 1000 ha. The maximum depth in the deepest lake of Lithuania (Lake Tauragnai) is 60.5 m, but the maximum depth of the majority of lakes does not exceed 15 m (Table 1). The annual mean value of TN most often varies within 560–1200 μg l^{-1} (with maximum of 3800 μg l^{-1}) and that of TP within 18–45 μg l^{-1} (maximum 140 μg l^{-1}). Natural land cover most often constitutes from 29% to 59% of the lake catchment area.

Fish were captured with multimesh benthic gillnets, each of which was 40 m in length and 3 m in height. Mesh size varied every 5 meters and was 14, 18, 22, 25, 30, 40, 50, 60 mm. Fishing was carried out in the second half of summer – at the beginning of autumn with water temperature being >15° C. Depending on the lake area, at least 12 (<200 ha lakes), 16 (<500 ha), 24 (<1000 ha) or 32 (>1000 ha) benthic nets were used following the standardized method by the Ministry of Environment of Lithuania (20-10-2005 Order No.D1-501). Nets were positioned randomly to cover different parts and lake depths of each lake. In deep (>17 m maximum depth) lakes, 8 or 12 m height multimesh benthic gillnets for vendace *Coregonus albula* and smelt *Osmerus eperlanus* (14, 18, 22 and 26 mm mesh size) were also used as fish catches with standard height benthic gillnets fail to reflect the abundance of these pelagic fishes representatively (Diekmann et al., 2005). Nets remained in lakes for at least 12 hrs during the night covering sunset and sunrise periods.

For the fish caught, species, number, total length (mm), and wet weight (±1 g) were determined. Catches from benthic gillnets for vendace and smelt were re-calculated to standard area of the section of the same mesh size and then merged with catches from standard benthic gillnets. The catch per unit of effort was standardized in relation to the benthic gillnet's area (m^2).

Four eutrophication variables were analysed for assessment of human pressure, and considerably simplified version of the Scotish lake habitat survey method (Rowan et al., 2003) was used for the assessment of hydromorphological changes in lakes. The most common hydromorphological pressures in Lithuania are change of water level (water level elevation, as water level lowering was recorded only in two lakes in the whole country), natural riparian vegetation destruction and, on a much lesser extent, shoreline stabilization or erosion. Therefore only these hydromorphological metrics were measured and the dominant bottom substrate of the littoral zone was determined in order to compute the hydromorphological index (thereafter HMI) (Table 2). Each of the metrics were scored, summed and translated into the 0–1 scale. HMI was computed according to the formula:

HMI = (sum of scores–maximal sum of scores)/(minimal sum of scores–maximal sum of scores)

Lakes with altered water level (due to impoundment of the outflow or amelioration of the catchment) and lakes water level alterations (m) were determined based on the information available in the State register of Rivers, Lakes and Ponds of the Republic of Lithuania (https://uetk.am.lt). The length of the natural riparian vegetation (forest) belt and the scope of changes in the shoreline as a result of lake shore embankment or erosion were estimated visually by analyzing high resolution (50 cm) aerial photos (www.maps.lt). The composition of substrate in the littoral zone was determined visually in the course of the study.

Data on lake area, the mean and maximum lake depths (thereafter Z mean and Z max) and on eutrophication variables — the mean annual concentrations of total phosphorus (thereafter TP), total nitrogen (thereafter TN), chlorophyll α (thereafter Chl α) and Secchi depth were obtained from state authorities (Lithuanian Environmental Protection Agency). According to the state monitoring program variables are measured every 3rd or 6th year (depending on the WFD monitoring type), at least four times per year (from April till October) in the deepest part of the lake. Depending on lake depth and stratification, several samples are collected during each measurement, but only those taken in the euphotic layer were used to calculate average annual concentrations. Variables measured in the same year as fish sampling, or measured in the previous or next year (if sampling year did not coincide) have been used for analysis.

Two datasets were used in testing the impact of environmental factors on fish community structure. The first dataset included data from all lakes, whereas the second one contained data only from reference status lakes. Lakes falling into the category of potentially reference status lakes were selected by common intercalibration criteria (Poikane, 2009). When selecting lakes, an exception was made to the criterion of natural land cover, i.e. lakes with >50% of their catchment area covered by natural vegetation were also attributed to potentially reference status lakes because in Lithuania there are just a few lakes with >90% of their catchment covered by natural vegetation, i.e.forests.

Principal component analysis (PCA) was carried out on both data sets separately, with the relative abundance of fish species selected as an active variable and maximum and mean depths of lakes, area, Secchi depth, mean annual concentrations of TN, TP and Chl a, and the hydromorphological index as suplementary variables. Mean data from lakes that were studied several times was used for analysis. Non-native fish species and typical riverine (rheophilic) fish species were not included in the analysis.

The correspondence between the fish community composition and lake types derived only on the basis of mean depth (Z mean <3, 3–9 or >9 m; national typology) or maximum depth (Ritterbusch et al., 2014) combined with mean depth criterion (Z max <11 m polymictic lakes, Z max 11–30 and Z mean >3 stratified lakes, and Z max >30 deep lakes) was tested by discriminant analysis (thereafter