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A littoral fish index that responds to eutrophication in boreal lakes

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ABSTRACT

Littoral fish assemblages were sampled by electrofishing at 70 nearshore sites in the Kitka lake group (lakes Ala-Kitka, Yli-Kitka and Posionjärvi) in northeastern Finland. Fish assemblages were usually dominated by littoral fish species, especially minnow (*Phoxinus phoxinus*) and alpine bullhead (*Cottus poecilopus*). Young individuals (mainly 0+ and 1+) of other fish species, such as burbot (*Lota lota*) and perch (*Perca fluviatilis*) were also recorded frequently. A littoral fish index (LiFI) was developed to respond to the degree of eutrophy. Of the candidate metrics, three were chosen for the index: (1) proportion of minnow and alpine bullhead individuals in the electrofishing catch, (2) density of perch, and (3) average weight of all individual fish in the catch. The index value responded to the extent of eutrophy; total phosphorus explained 55.3% of the variation in LiFI index values. A test of the index with data from other Finnish lakes suggested that the index is feasible for use in a broader context. Finally, the index values from the Kitka lakes were classified from bad to high in assessing the ecological status of the littoral sites around the studied lakes. We recommend the use of littoral electrofishing and LiFI index in lakes where detailed, bay-specific information is needed about the ecological status, and in all situations where the littoral zone is in focus.

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1. Introduction

After the pioneering work of Karr (1981), several fish indices have been developed to assess the biotic integrity of waterbodies. Indices usually combine several metrics derived from total standardised catches, catches or relative abundances of species, catches or relative abundances of groups of species (guilds), size metrics and presence/absence of sensitive species. Indices respond to a single stressor (such as eutrophication) or several stressors. Implementation of the Water Framework Directive (WFD) stimulated the development of the indices in Europe in the 2000s (Argillier et al., 2013; Brucet et al., 2013).

In order to implement a WFD compliant fish based assessment method in Finland, the assessment of the ecological status of lakes has primarily been based on the use of Standard Nordic gillnets and the multi-metric EQR4 index (Tammi et al., 2006; Olin et al., 2013). Gillnets are set at the surface, mid-water and bottom, and fishing effort is allocated to the entire lake area. The EQR4 index contains four metrics, and it has been designed to respond to eutrophication in the assessment of the ecological status of lakes (Olin et al., 2013).

Littoral fish assemblages sampled by electrofishing have been used in the WFD to assess the ecological status of regulated lakes, where the stress from altering water level is mainly directed to the littoral zone (Sutela et al., 2011). Nearshore electrofishing has been found to be effective in catching littoral fish species, e.g. bullheads (*Cottus* spp.) and stone loach (*Nemacheilus barbatulus*), which are usually not caught with gillnets (Sutela et al., 2008). From an ecological point of view, littoral biota have a significant role in whole-lake food webs, and thus form an inherent constituent of lake ecosystem structure and function (e.g. Hampton et al., 2011; Vander Zanden et al., 2011).

Lakes Ala-Kitka (surface area 49 km^2) and Yli-Kitka (237 km^2) in northeastern Finland have been assessed as having a high ecological status based on fish assemblages sampled by Standard Nordic gillnets (WFD, National database Hertta, Finnish Environment Institute). Still, in some parts of the lakes, there is some diffuse and point-source nutrient loading coming from agriculture and a large ski resort, for example. Local fishermen have complained about changes in fish species composition and sliming of gillnets in some parts of the lakes.

We speculated that in large lakes, the first signs of eutrophication may be found earlier in littoral areas of shallow and/or

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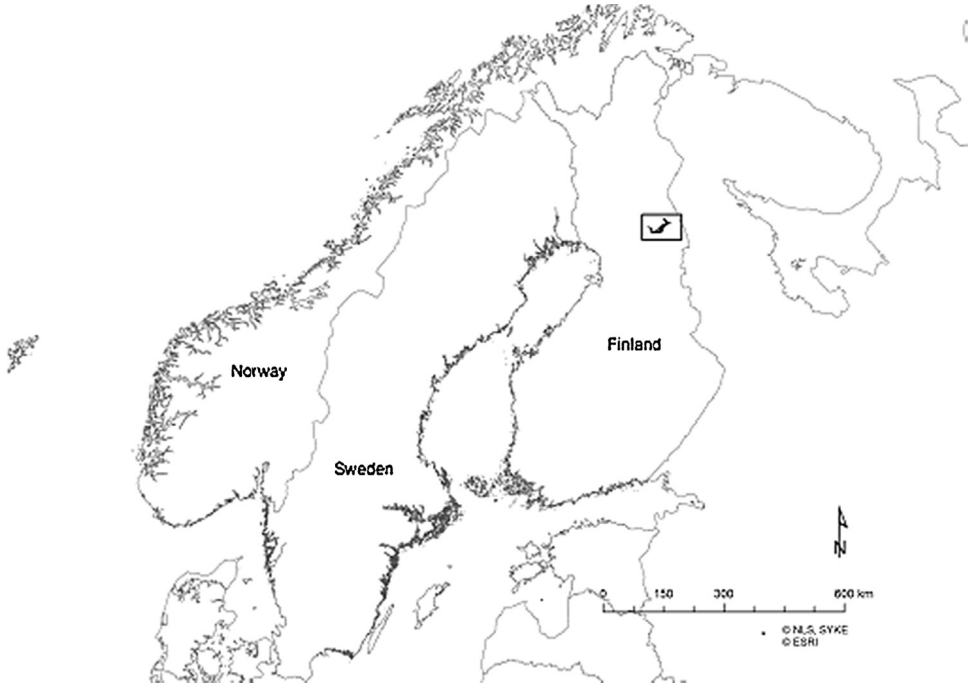

Fig. 1. Location of the Kitka lakes in northeastern Finland.

narrow bays subjected to nutrient loading, than in the pelagic zone. Identifying of littoral sites with degraded ecological status was considered to be a worthy goal. Therefore, we chose to study nearshore fish assemblages around the lakes by electrofishing. Littoral fish species might contain good indicator species for eutrophication.

The main objectives of the study were to (1) develop a littoral fish index that responds to eutrophy in the sampled Kitka lakes, (2) assess the ecological status (biotic integrity) of littoral areas around the Kitka lake group on the basis of the fish assemblages, (3) test the feasibility of the index in other Finnish lakes, and (4) evaluate the potential of littoral electrofishing and LiFI index within WFD.

2. Methods

2.1. Field work

Littoral fish were sampled in August 2013 from the Kitka lake group (Lakes Ala-Kitka, Yli-Kitka and Posionjärvi, total lake area 305 km^2) in northeastern Finland by electrofishing in daytime (Fig. 1). Altogether 70 nearshore stony sites around the lakes were sampled. The average depth in the sampled 100 m^2 areas (5 × 20 m stripes parallel to the shoreline) was 30 cm, and average maximum depth 67 cm. Substrates in the sampled areas were cobbles (64–256 mm; 37.6%), boulders (256–1024 mm; 22.4%) and pebbles (16–64 mm; 22.3%). Macrophyte coverage at the sampled areas was usually low (average 2.0%, range 0–22%). Fish were captured with Hans Grassl Gmbh ELT 6011 GI Honda GXV50 electrofishing gear using pulsed (50 Hz) DC current with 700–1000 V voltage adjusted by gas throttle (voltage selector in position 2) for water conductivity. Each area was fished once by two waders, one using the anode and an assistant collecting the stunned fish with a dip-net. Escape nets were not used. All captured fish were identified and counted. Total length (TL) of every fish was measured to the nearest 1 mm and pooled individuals of each fish species were weighed to the nearest 0.1 g. A littoral water sample was taken for analyses from every electrofishing site. Presented fish densities (ind./100 m^2) represent the catch of one electrofishing run.

2.2. Littoral fish index development

At the outset, we sought metrics which should respond to eutrophy. Concentration of total phosphorus (TP) in the littoral water was chosen to represent nutrient enrichment and the associated degree of eutrophy. Candidate metrics were searched for by an iterative process guided by responsiveness to total phosphorus. For a possible future usage, we also aimed at consistence with Water Framework Directive (WFD) in developing the index. The WFD requires that the ecological status of lakes should be primarily measured by taxonomic composition and abundance, presence of type-specific sensitive species, and the age structure of fish fauna (2000/60/EC). Our candidate metrics included total fish density, total fish biomass, densities and biomasses of fish species (scaled according to their maximum density to 0–1), density and biomass proportion of each fish species and their combinations in groups, such as sensitive and insensitive species, proportion of 0+ individuals within the main species, and average weight of all fish specimens in the catch. In qualifying the final metrics, we used correlative comparisons to avoid redundancy among the metrics (Roset et al., 2007).

Three candidate metrics derived from the Kitka lakes data were chosen for the index: (1) proportion of minnow and alpine bullhead individuals in the electrofishing catch, (2) density of perch at the electrofished site in relation to its maximum recorded density at all sites (transformed to inverse number) and (3) average weight of all fish individuals in the catch in relation to corresponding maximum average weight recorded among the sites studied (transformed to inverse number). Compliance of the final metrics with WFD criteria was not fully achieved since weight of fish in the metric 3 is not identical to age. Values of all metrics ranged from 0 to 1, and the littoral fish index (LiFI) value was calculated as an average of these three metrics.

In testing the index with electrofishing catch data from other Finnish lakes, the observations of alpine bullhead (*Cottus poecilopus*) and Eurasian bullhead (*Cottus gobio*) were pooled because of their closely related ecology (Koli, 1969). However, in the final version of the index, bullheads were dropped from metric 1 because of

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