Limnologica 42 (2012) 19–30

Contents lists available at ScienceDirect

Limnologica

journal homepage: www.elsevier.de/limno

Comparing long term sediment records to current biological quality element data – Implications for bioassessment and management of a eutrophic lake

Tommi Kauppila[a,*], Antti Kanninen[b,c], Matias Viitasalo[d], Johanna Räsänen[e], Kristian Meissner[f], Jukka Mattila[g]

[a] Geological Survey of Finland, P.O. Box 1237, 70211 Kuopio, Finland
[b] Centre for Economic Development, Transport and the Environment, P.O. Box 1199, 70211 Kuopio, Finland
[c] University of Jyväskylä, P.O. Box 35, 40014 Jyväskylä University, Finland
[d] Savo-Karjalan Ympäristötutkimus Oy, Yrittäjäntie 24, 70150 Kuopio, Finland
[e] Finnish Environment Institute, Mechelininkatu 34a, P.O. Box 140, 00251 Helsinki, Finland
[f] Finnish Environment Institute, Survontie 9, 40500 Jyväskylä, Finland
[g] Kymijoen vesi ja ympäristö ry, Tapiontie 2C, 45160 Kouvola, Finland

ARTICLE INFO

Article history:
Received 27 August 2010
Received in revised form 19 June 2011
Accepted 1 July 2011

Keywords:
Water Framework Directive
Sediment
Chironomids
Diatoms
Cyanobacteria
Green algae
Ecological status assessment
Management
Restoration

ABSTRACT

Defining reference conditions for lakes situated in areas of human settlement and agriculture is rarely straightforward, and is especially difficult within easily eroding and nutrient rich watersheds. We used diatoms, cyanobaterial akinetes, remains of green algae and chironomid head capsules from sediment samples of Lake Kirmanjärvi, Finland, to assess its deviation from the initial ecological status. These site-specific records of change were compared to current type-specific ecological status assessment. All paleolimnological data indicated deviation from natural conditions and mirrored the current, monitoring-based assessment of "moderate" ecological lake status. However, the sediment data showed that the lake should be re-typified as a naturally eutrophic lake. Sediment records as well as current monitoring data indicated temporary improvement in water quality in response to extensive fish manipulation. Our results suggest that paleolimnological records can be used to derive site-specific reference conditions and that extensive restoration efforts can result in gradual, observable improvements of water quality and ecological status.

Introduction

Decision making in lake management is based on the interplay between current policy, the availability of resources and the environmental conditions at the site. One of the most challenging tasks for lake management and restoration is the selection of the target level, i.e. the desired level of attainable water quality. Target levels are often normatively specified in environmental legislation (e.g. U.S. Clean Water Act, EU Water Framework Directive, WFD) and set close to the estimated pre-disturbance conditions. In the European Union, the WFD (European Commission 2000) defines the management goal of 'good status' as a minor deviance of selected biological and abiotic quality elements from their respective reference states. In the ecological classification of lakes the assessment of this deviance is based on four biological quality elements (BQEs): phytoplankton, aquatic macrophytes and phytobenthos, benthic macroinvertebrates, and fish.

While intuitively simple, defining and quantifying pre-disturbance reference conditions in lakes is demanding because anthropogenic impacts often predate direct observations on the BQEs. Reference conditions can be based on data from lake type-specific pristine monitoring sites, predictive modelling or temporal changes i.e. historical changes or paleoreconstruction (European Commission 2003). Recent advances in studies of sediment records have promoted the use of paleolimnological methods to obtain information on past lake characteristics (Leira et al. 2006; Räsänen et al. 2006a). These quantitative paleoecological inference methods allow reconstructions of past lake nutrient levels, pH, conductivity, etc. and enable comparisons with direct observations. Current paleoecological inference models often use phytoplankton or chironomids as proxies. When compared to water samples, the sediment record of phytoplankton communities is often incomplete due to the poor preservation of certain types of algae. However, many important taxa deposit resistant, identifiable remains (e.g. Bacillariophyceae) which are sometimes identifiable to species level. Diatom assemblages are functionally important in many aquatic ecosystems and sensitive to environmental changes (e.g. Stoermer and Smol 1999). Similarly, cyanobacteria and green algae

* Corresponding author. Tel.: +358 205503710, fax: +358 2055013.
E-mail address: tommi.kauppila@gtk.fi (T. Kauppila).

0075-9511/$ – see front matter © 2011 Elsevier GmbH. All rights reserved.
doi:10.1016/j.limno.2011.07.001

are important for practical lake management since their blooms often mirror eutrophication and indicate drastic changes in the overall composition of the phytoplankton community. While vegetative cyanobacterial cells do not preserve in lake sediments, certain cyanobacteria produce resting spores, i.e. akinetes, that are resistant to decomposition and have successfully been applied as a paleolimnological proxy (Cronberg 1986; van Geel et al. 1994; Kling 1998; Findlay et al. 1998; van Geel 2001; Eilers et al. 2004; Bradbury et al. 2004; Räsänen et al. 2006b). In Finnish freshwaters *Anabaena* spp. is the most common blooming cyanobacteria with well identifiable akinetes (Lepistö 1999) and *Scenedesmus* spp. and *Pediastrum* spp. are the paleolimnologically most extensively used green algae. A combined study of fossil diatoms, cyanobacteria, and green algae provides a fairly comprehensive picture of past phytoplankton assemblages.

Changes in lakes are not only reflected in phytoplankton but affect higher trophic levels such as chironomids as well. Subfossil head capsules of chironomids are present in all except highly anoxic sediments (e.g. Meriläinen et al. 2001). The composition of the profundal chironomid community is widely used to assess lake trophic status and several paleolimnological chironomid inference models have been constructed (e.g. Brodersen and Lindegaard 1999). In this study we relate past changes in the phytonplankton community to concurrent sediment data for the chironomid community.

The Iisalmi watercourse in Eastern Finland poses a unique challenge to the determination of lake management goals. Located in a geographic area where surface waters generally attain "good" or "excellent" status, these lakes are unexpectedly eutrophic and display phytoplankton blooms and extensive growth of macrophytes. The eutrophic state of these lakes may be related to watershed geology which is characterized by shallow basins and high proportions of fine-grained tills and fine grained sorted deposits. However, since these fertile soils rich in fines also attracted early human settlement and agriculture the main cause of the observed eutrophic state is difficult to determine.

The WFD-compliant ecological classification of Finnish surface waters is based on type-specific reference conditions derived from monitoring data of pristine reference sites for each surface water type (Vuori et al. 2009). The Finnish lake typology differentiates between 14 lake types mainly based on size, humic content, depth and natural eutrophy (Vuori et al. 2006). The exceptionally high amount of fine grained glacial and post glacial sediments in the watershed of the Iisalmi watercourse complicates the exact designation of individual lakes into lake types and, hence, the application of the correct type-specific reference conditions for ecological classification. Closely matching pristine reference lakes also are difficult to find for the region. We therefore used paleolimnological methods to assess the overall changes in the phytoplankton and chironomid community, identify algal blooms, and to infer the past nutrient status within one representative lake from the Iisalmi watercourse. By relating paleolimnological to contemporary monitoring data we further sought to (1) quantify the community changes caused by recent human activities, (2) assess the efficacy of past lake management actions and (3) evaluate the utility of sediment-based data in comparison to current data for reference condition-based ecological classification.

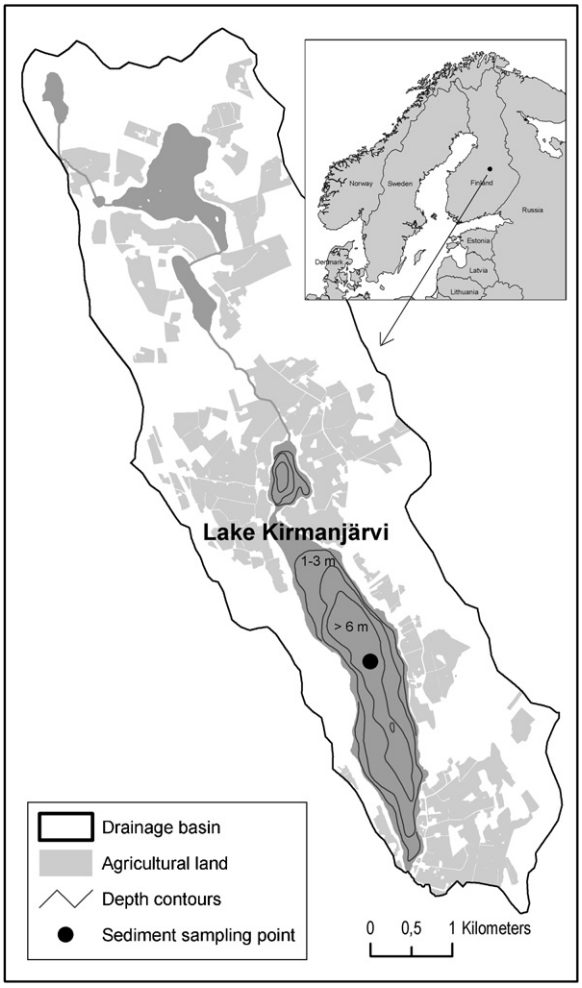

Fig. 1. A map of Lake Kirmanjärvi and its location in Fennoscandia.

Methods

Study site

Lake Kirmanjärvi, located in Eastern Central Finland in the Iisalmi watercourse (Fig. 1), consists of two basins, the smaller Pieni-Kirma (31 ha, maximum depth 7 m) and the larger Kirmanjärvi (280 ha, maximum depth 9.7 m). The Finnish lake typology system (Vuori et al. 2006) categorizes small lakes under 500 ha based on their humic content (measured by water colour), and mean depth. Naturally eutrophic lakes are identified based on their high epilimnetic turbidity (FNU > 5), high alkalinity (>0.4 mmol/l) or other information on natural eutrophy. Using the typology criteria of surface area, mean depth and water colour (area < 500 ha, mean depth > 3 m, water colour 30–90 mg Pt/l) Lake Kirmanjärvi is classified as a small humic lake in the Finnish system. Even though its geographic location suggests possible naturally high productivity Lake Kirmanjärvi does not meet the formal typology criteria for naturally eutrophic lakes. In addition to being representative for the Iisalmi watercourse the lake has regional importance because it serves as a reservoir for the production of drinking water and preserving good water quality (e.g. without toxic cyanobacterial blooms) attracts high public interest. Furthermore, the chemical water quality of the lake has been monitored intensively since 1986 and the lake has undergone different phases of restoration efforts, including intensive fishing period during 1987–1997 and hypolimentic oxygenation since 1986. Further management efforts of the lake are currently being considered.

Coring, sampling and sediment dating

Sediment assemblages predating anthropogenic impacts were analyzed for algal remains and chironomid subfossils extracted from a 150 cm long composite sediment core sequence. Coring was performed from the lake ice on March 27th, 2006. We selected a