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Use of multiple fish-removal methods during biomanipulation of a drinking water reservoir – Evaluation of the first four years

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A B S T R A C T

The improvement of water quality in recreational and drinking water reservoirs has been a main priority of river basin authorities for some time. One measure commonly applied is biomanipulation, which aims to improve water quality by adjusting fish community structure. Effective reduction of cyprinid density, with a resultant increase in filtering zooplankton development, has already proved successful in many lakes. In this paper, we document progress in a project to evaluate the feasibility and efficiency of biomanipulation through parallel use of age-selective fish removal and predator stocking to improve water quality in a 42 ha drinking water reservoir. Between 2009 and 2012, cyprinid and young perch (*Perca fluviatilis*) density was reduced through removal of early-stage planktonophagous fish and perch eggs, along with removal of adult bream (*Abramis brama*) and roach (*Rutilus rutilus*) during spawning. Predatory fish were also stocked to increase juvenile mortality of the target species. As a result, cyprinid biomass was significantly reduced (ca. 2/3 of adult bream removed; biomass now estimated at <25 kg ha^{-1}).

This study showed that biomanipulation was successful at the reservoir and that it is a feasible method for other water bodies of similar area and depth with suitable capture sites. While reduced cyprinid biomass has resulted in a continuous increase in zooplankton density and biomass, however, phytoplankton dynamics appear to be dependent on additional factors such as nutrient input (especially phosphorus). Over the coming years, therefore, attention will focus on both external (catchment) and internal (sediment) nutrient sources, in addition to continuing fish biomanipulation.

1. Introduction

Around the world, lakes and reservoirs in densely populated or intensively cultivated areas have become eutrophic and turbid (Smith, 2003). This also applies to the Czech Republic, where decades of excessive nitrogen and phosphorus loading have provided ideal conditions for excessive phytoplankton production, which in turn have resulted in high turbidity and decreased biological diversity. Since the 1990s in particular, eutrophication has become a serious problem in Czech reservoirs (Bláha et al., 2010).

In recent years, a number of projects have been instigated on Czech reservoirs to address the negative impacts of cyanobacterial blooms, which drastically limit the recreational potential (primarily swimming) of the reservoirs. A range of tools has been applied, including physical (e.g. aeration, de-stratification, partial emptying, and bottom drying), chemical (e.g. liming, inflow phosphate precipitation), and biological (fish reduction, predatory fish stocking) measures, either separately or in combination (e.g. see Moronga et al., 2012).

Biomanipulation, i.e. the removal of benthivorous and zooplanktivorous fish and stocking of piscivorous fish to promote a shift from planktivorous to piscivorous foraging and to reduce nutrient recycling, is now a routinely applied technique for shifting eutrophic lakes away from a turbid phytoplankton-dominated state to a clearer, aquatic macrophyte dominated state. Roach (*Rutilus rutilus*) and common bream (*Abramis brama*) are the primary targets for biomanipulation in North-West European temperate lakes (Hansson et al., 1998; Mehner et al., 2002; Lammens et al., 2002; Van de Bund and Van Donk, 2002; Søndergaard et al., 2008) as they not only feed on zooplankton but also disturb sediment in their search for sediment-dwelling invertebrates (Boll et al., 2012; Adámek and Maršálek, 2013). In addition to fish removal, the density and biomass of predators, such as pike (*Esox lucius*), zander (*Sander lucioperca*) and asp (*Aspius aspius*), are also frequently

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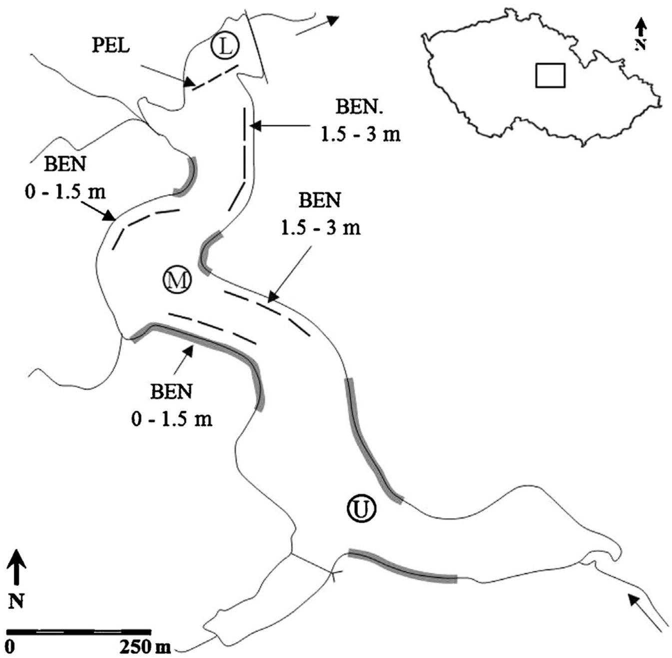

Fig. 1. Map of Hamry reservoir indicating (1) the three zooplankton/phytoplankton monitoring sites (U – upper; M – middle; L – lower profiles), the position of gillnets (PEL – pelagic; BEN – benthic) and sites used for beach seining (thick grey line) between 2009 and 2012.

increased in order to further reduce populations of small planktivorous fish (Lathrop et al., 2002; Skov and Nilsson, 2007; Vašek et al., 2013).

The vast majority of past biomanipulation efforts have taken place on shallow, eutrophic lakes or reservoirs (e.g. Van de Bund and Van Donk, 2002). In deeper, stratified reservoirs, biomanipulation measures (mainly removal of cyprinids) are more complicated as seine nets cannot be used efficiently over their whole area, hence information on biomanipulation efficiency in these water bodies is limited (Seda and Kubečka (1997)). Moreover, biomanipulation usually takes place as part of the management regime in a reservoir. Problems often occur when assessing the success of such exercises, however, as many of these reservoirs are multi-use, recreational bodies, where long-term management for improved water quality through alteration of fish stocks may conflict directly with other uses, such as fisheries (angling) management. As part of a long-term study into the effectiveness of biomanipulation in the Czech Republic, we chose a reservoir that is managed for provision of drinking water only and has never been used for angling, boating, swimming or any other conflicting purpose.

Following a pilot-study in 2008 to assess initial fish status in the reservoir, biomanipulation began in 2009 and continues at the present time. This study presents results from the first four years (2009–2012) of fish removal and subsequent zooplankton/phytoplankton development (as a model for water quality). The main aims of the study were to (1) apply a range of biomanipulation measures to a known biotic (fish/zooplankton/phytoplankton) community, and (2) to evaluate the effects of the biomanipulation measures on water quality.

2. Material and methods

2.1. Study area

This study was undertaken at the Hamry reservoir (Fig. 1; 49°43′52″ N, 15°55′1″ E), near the town of Hlinsko in the Bohemian-Moravian highlands of the Czech Republic. Built in 1929, the 42.3 ha reservoir (catchment area 56.8 km^2; average depth 2 m; max. depth 7.5 m) presently serves as a drinking water source for Hlinsko and its surroundings. About half of the shoreline comprises low-slope bankside meadow with littoral macrophytes (mainly *Glyceria aquatica*) that become inundated at higher water levels. The rest of the shoreline comprises coniferous forest with steep banks with limited macrophyte coverage. The inlet area is shallow with soft sediment and a thick layer of detritus from decaying vegetation. The range of external phosphorus loading to the reservoir is estimated at 0.7–0.9 g P m^{-2} a^{-1} (Elbe River Basin Water Authority, unpublished) and the reservoir was classified as mesotrophic prior to biomanipulation in 2009.

As this reservoir is designated for drinking water supply, no angling is allowed and the fish are strictly protected by the Elbe River Basin Water Authority. Prior to the start of this study in 2008, fisheries management was minimal and biomanipulation limited to occasional stocking of predatory fish such as pike or zander. Occasional drops in cyprinid numbers have occurred during the spawning season due to drying out of eggs when water levels drop.

A pilot study carried out in 2008 indicated that the fish community was dominated by common bream and roach, with lesser amounts of perch and other species occurring only occasionally. Predatory fish were mainly represented by pike, zander and asp.

2.2. Biomanipulation measures

In effect, three basic approaches were taken in an attempt to promote long-term changes in the reservoir's food-web (and ultimately water quality): (1) measures that affect the success of annual cyprinid reproduction (i.e. removal of spawning adults and larvae), (2) measures to increase predation on smaller cyprinids (i.e. stocking with predators), and (3) measures to reduce predation on larger zooplankton (i.e. removal of planktonophagous cyprinids and perch [juveniles, eggs and larvae]). The effectiveness of biomanipulation is assessed through monitoring of the 0+ and adult fish community and changes in long-term water quality reflected through changes in the proportion of larger zooplankton and any subsequent reduction in phytoplankton.

2.2.1. Removal of perch eggs

In April and May, perch egg strips were collected along the whole reservoir shoreline using plankton dip-nets, either from a boat or while wading, and then removed. Removal took 2–3 days with an interval of ca. 1 week, the whole exercise taking approximately 6–9 man-days per year. Each year, the volume of eggs removed was measured and several 20 ml sub-samples collected and fixed in 4% formaldehyde for egg quantification.

2.2.2. Removal of fish larvae

Larvae and early life-stages of both cyprinids and perch were removed each year in June, at which time they concentrated at known locations along the reservoir's shoreline. Removal of early life-stages is more efficient than removing adult fish as large numbers of fish of negligible biomass could be removed with relatively low effort. The larvae were collected using a 1 mm mesh fry dip-net, either from a boat or while wading along the whole reservoir shoreline, and removed. Again, removal took 2–3 days with an interval of ca. 1 week, the whole exercise taking approximately 6–9 man-days per year. Each year, the volume of larvae removed was measured and several 100 ml sub-samples collected and fixed in 4% formaldehyde for species determination and quantification.

2.2.3. Removal of adult cyprinids

Adult cyprinids were sampled during spawning (mid-April to mid-June) using a 100 m beach seine (max. 7 m deep; 2 cm mesh).