First publ. in: Advances in Limnology 60 (2007), pp. 353-360

Re-oligotrophication and whitefish fisheries management – a workshop summary

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Abstract: Following an increase in phosphorus concentrations in many European prealpine lakes during the 1960s and 1970s, levels dropped at the end of the 20th century due to lake restoration measures, a process termed re-oligotrophication. In parallel, the characteristic salmonid fish communities were re-established, which are generally dominated by coregonids. Reduced lake productivity at P_{tot}-levels below 30 µg L^{-1}, however, leads to slower growth of coregonids than under eutrophic conditions. At even lower nutrient levels (<10 µg P_{tot} L^{-1}), cohort size may decrease leading eventually to smaller harvests. To address the concerns of managers and scientists with regard to the perceived or actual impact of re-oligotrophication on whitefish fisheries, a workshop was held prior to the 9th ISBMCF in Olsztyn, Poland. The aims of the workshop were to analyse the effects of re-oligotrophication on whitefish populations, to evaluate and recommend appropriate management options, and to discuss economic aspects and marketing strategies. This paper summarizes the case studies presented at the workshop as well as the conclusions and recommendations reached by the discussion groups.

Introduction

Lake eutrophication was a major issue in the field of basic and applied limnology during the second half of the 20th century. Increased nutrient loading enhanced lake productivity, leading in many cases to profound changes in lake biocenoses and food web structures. Most lakes at the northern fringe of the European Alps were still oligotrophic around 1950, and their fish communities comprised, or were even dominated by, coregonids. When nutrient concentrations in these lakes started to increase after 1950, concerns arose how coregonid population dynamics and subsequently the fishery for coregonids might be affected. As a result of regular monitoring of commercial fisheries and basic research, it was possible to understand the effects caused by higher nutrient concentration, and to take appropriate countermeasures.

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The major effect of eutrophication on coregonids, precipitated by higher food supply, was growth acceleration. Growth rate nearly doubled in several lakes and consequently age-at-catch and age-at-maturity decreased, leading to the risk of recruitment overfishing. This problem was alleviated by increasing the legal size of coregonids through the use of larger gillnet mesh sizes. Effects of eutrophication on year-class strength were generally not pronounced, so that the average number of fish harvested commercially did not change in most cases. Since the fish were heavier at harvest, yields generally increased.

However, there were also negative effects of eutrophication on coregonids, which soon became apparent. Higher primary and secondary production increased the sedimentation of organic matter, leading to higher oxygen consumption in the sediment with negative consequences for coregonid egg survival. It is likely that the significant drop in numbers or even complete disappearance of deepwater coregonids in several prealpine lakes is related to the deterioration of their spawning grounds. The perceived danger of decreasing natural recruitment was the main motivation to start and/or intensify stocking. Hatchery capacities were increased and many hatcheries started to use cooler water for incubation in order to delay hatching so that stocking takes place later in spring under more favourable food conditions. The development of dry diets finally made it possible to stock prefed larvae and in a few cases even juveniles. All in all, even if some coregonid forms might have been lost over the last decades, lake eutrophication had mainly positive effects for the commercial fisheries, or most of the negative effects were successfully combated by adequate management.

When the negative effects of eutrophication on water quality became apparent during the 1960s and 1970s, a series of countermeasures were taken at most European prealpine lakes. These included banning P-containing detergents, collecting sewage water in treatment plants (with mechanical and biological treatment, chemical phosphorous stripping being implemented at a later stage), and reducing fertilizer use in agriculture. These measures started to take effect in the 1980s, causing lake phosphorus concentrations to decline, a process termed re-oligotrophication. By the end of the 20th century phosphorus concentrations were returning or have returned to pre-eutrophication levels. As a result, major changes are to be expected or have already been observed in the coregonid fisheries, challenging both fisheries scientists and managers. For fisheries scientists, lake re-oligotrophication provides excellent opportunities to study the effects of a lake's trophic state on whitefish life-history traits and on the production biology of whitefish stocks, while managers are asked to develop appropriate management strategies to cope with (probably) decreasing yields or to stabilize yields.

To discuss these topics, a short workshop was organized in 2002 by R. Rösch during the 8th ISBMCF at Rovaniemi, Finland, to be followed by a larger workshop at a later date. This workshop was jointly organized by R. Eckmann, R. Müller and R. Rösch, and took place on August 20th–21st at the Centre of Biotechnology, University of Warmia and Mazury in Olsztyn, Poland, prior to the 9th ISBMCF.

Thirteen participants from six countries attended the workshop. Seven presentations were held on the observed effects of lake re-oligotrophication on whitefish fisheries in Austria, Finland, France, Germany, Great Britain and Switzerland, and management measures that have been taken. The following discussion was organized around three major topics: effects of re-oligotrophication on whitefish populations (Rapporteur: Rudi Müller), management options in re-oligotrophicating lakes (Rapporteur: Roland Rösch), and economic aspects and marketing strategies (Rapporteur: Daniel Gerdeaux). The following sections summarize the presentations given at the workshop as well as the conclusions and recommendations of the discussion groups.

Presentations given during the workshop

Rudi Müller showed data on phosphorus content during spring turnover for the major Swiss lakes, which all have undergone the typical sequence of eutrophication followed by re-oligotrophication (LIECHTI 1994). P-levels before, during and after eutrophication, however, differed widely. The restoration target, which was set at 30 µg P_{tot} L^{-1}, had been reached in about half of the lakes by the end of the 20th century. In four of these lakes, P_{tot} concentrations have dropped below 10 µg L^{-1}, and in these lakes whitefish yields have significantly declined obviously due to a reduction of the food base (MOOKERJI et al. 1998, RUHLÉ & GAMMETER 1998). Where two whitefish populations occur in sympatry, it is generally the slow-growing zooplanktivorous form that is most strongly affected by re-oligotrophication. In two lakes there is even evidence that year-class strength decreased, which has been attributed to lower absolute female fertility and a lack of appropriate food for larval fish in early spring (MÜLLER & MBWENEMO BIA 1998, RUHLÉ & GAMMETER 1998).

Daniel Gerdeaux reported on the whitefish fishery in oligotrophic (P_{tot} < 10 µg L^{-1}) Lake Annecy (WOJTENKA et al. 1988, CARANHAC & GERDEAUX 2000, GERDEAUX et al. 2002), where despite a decrease in zooplankton biovolume in recent years, whitefish yields have remained largely unchanged since the 1990s. The management objective is to share the resources equally between anglers and professional fishermen. In 2004, more than 1000 anglers and only 4 professional fishermen harvested approx. 11 and 13 tons of whitefish respectively. Anglers are allowed to take fish larger than 38 cm, while professional fishermen catch fish of more than 42 cm in length using 54 mm (knot-to-knot) gillnets, i.e. fish in gillnets are approx. six months older than those caught by anglers. The selective harvest of smaller fish by anglers leaves enough larger fish for the commercial fishermen, who catch these fish after their first reproduction. This type of management seems to be the main reason for the good growth of the fish and for high yields, since the breeding stock is never too high. But this management strategy involves the risk of overexploitation, and an intensive survey of the stock is necessary. Whitefish from Lake Annecy are marketed under a special label inserted in the opercular bone of fish by commercial fishermen, who are the only ones allowed to sell fish. Through this marketing strategy, much higher prices are obtained than for Lake Geneva whitefish. When the profitability of a commercial fishery decreases during re-oligotrophication, the role of anglers in whitefish fisheries may become increasingly important. The Lake Annecy example might then be taken as a guideline to balance the interests of both stakeholder groups.

Hannu Lehtonen pointed out in his presentation that around 75% of all Finnish lakes > 0.04 km^2 are oligotrophic (< 20 µg P_{tot} L^{-1}), and that, with few exceptions, eutrophication of inland lakes has never been a severe problem in Finland (PELTONEN et al. 1999, RAITANIEMI et al. 1999, TAMMI et al. 1999). Water quality of lakes has even improved during the last ten years, while in the Baltic Sea it diminished slightly in the 1990s. Fishermen are satisfied with lake re-oligotrophication because they catch less cyprinids, and because natural reproduction has started again in some lakes that had been eutrophicated in the past.

Roland Rösch presented the Lake Constance experience (ECKMANN & RÖSCH 1998, RÖSCH 2004), where in Upper Lake Constance P_{tot}-levels had increased from below 5 µg L^{-1} prior to 1950 to more than 80 µg L^{-1} around 1980 and then decreased to 9 µg L^{-1} in 2005, while the restoration target had been set at 30 µg L^{-1}. During eutrophication, whitefish growth rate nearly doubled and the minimum gillnet mesh size was increased from 38/40 mm to 44 mm bar mesh. Average whitefish yields increased during the 2nd half of the 20th century, while year-class strength responded neither to eutrophication nor to re-oligotrophication. Whitefish catches comprised only one or two age classes (mainly 1+ and 2+) in the 1960s and 1970s, whereas the average age-at-harvest and the number of age classes in commercial catches have increased during the last two decades. This is, among others, a result of the drastically reduced fishing intensity (to just 20 % compared to 1961) through fewer nets per fishing licence, fewer fishing nights per week and an overall reduction in the number of licences. Since phosphorus level is still declining but has not yet reached a value at which whitefish yields in Swiss lakes declined markedly, management options for an anticipated further nutrient decline need to be discussed.

Manfred Klein showed trends in whitefish yields from three Bavarian prealpine lakes, in which P-concentrations dropped to less than 10 µg L^{-1} by the beginning of the 21st century. At the same time, over the past decades whitefish growth has generally decelerated, the spectrum of weight-at-age is now broader, and the average age-at-catch has risen from two to four years. Consequently, gillnet mesh sizes have been reduced. Whitefish recruitment did not respond strongly to re-oligotrophication. In Lake Ammer, however, reproduction was extraordinarily successful over a number of years so that whitefish became stunted. Density-dependent effects therefore deserve more attention in future when adapting the fishery management to the particular conditions in nutrient-poor lakes.

Josef Wanzenböck showed an example of a lake where re-oligotrophication has improved habitat suitability for whitefish via higher oxygen concentrations, so that due to the stocking of juveniles, a viable fishery for whitefish was established. By comparing two other lakes he underlined that lake productivity and fish density both influence individual growth (WANZENBÖCK et al. 2002a, b). When average size or weight of a stock is low, this can be either a sign of overfishing or of an excessive fish density relative to lake productivity. The fundamental question, however, how stock density can be reduced once density dependence has been identified as the likely cause of slow growth, remained unanswered. It was suggested harvesting young fish with small mesh sizes, but this measure has not been tested so far.

Ian Winfield and Chris Harrod, finally, reported about whitefish in the United Kingdom. Vendace occur in two lakes and whitefish in seven, mainly in the Lake District and in Scotland, while pollan occur in two lakes in Northern Ireland. The assessment of whitefish and vendace stocks and the identification of possible threats is mainly a species conservation rather than a fisheries issue (WINFIELD & DURIE 2004, WINFIELD et al. 2004a, b). In those lakes where threats have been identified, these refer to lake eutrophication and species introductions. The pollan in Ireland are of interest to the fishery, but both Loughs where they occur are still undergoing eutrophication (HARROD et al. 2002, HARROD & GRIFFITHS 2004).

Recommendations and conclusions

Effects of re-oligotrophication on whitefish populations

There was general consensus that lower nutrient content leads to slower growth and a poorer condition due to the reduced food base. Density-dependent effects, however, need to be considered more thoroughly in the future, as these are probably more important under oligotrophic conditions than meso- or eutrophic conditions. Several case studies agreed that small-type, i.e. pelagic, plankton-feeding coregonids are primarily affected by reduced food supply, whereas large-type, i.e. littoral, benthic-feeding coregonids are probably much less affected, if at all.

Responses of whitefish year-class strength (YCS) to trophic changes have not been uniform across lakes. In some cases, YCS roughly followed the changes in lake trophic state while in others it did not. When YCS decreased under low nutrient conditions, it can be attributed to lower population fecundity and to food shortage for larvae at first feeding.

In lakes where natural reproduction was impaired due to insufficient oxygen supply at the sediment-water interface, it will probably become functional again below a critical phosphorus level of 15–20 μg L^{-1}. Hysteresis effects, however, are likely to occur since the mineralization of organic matter that was deposited under eutrophic conditions generally lags behind the decreasing nutrient content.

The genetic disposition for growth is poorly understood, not only in coregonids but in fish in general. The predominant removal of fast-growing fish by size-selective gillnetting may alter the growth characteristics of populations. This effect needs to be studied by appropriate stocking experiments, through genetic analysis using, for example, scales that have been collected over several decades, or by statistical evaluation of growth patterns in lakes with a long history of size-selective fishing. There are reports that whitefish ecotypes, which had been lost or which were believed to have become extinct during eutrophication, are reappearing in oligotrophic lakes. In the light of the most likely scenario of coregonid evolution in prealpine lakes, the sympatric formation of ecotypes, these observations are fascinating and should be critically assessed.

Warmer climate may lead to a better match between natural hatching of larvae and plankton development in spring, as whitefish spawning grounds are less affected by warmer climate than spring plankton development. Data from Lake Geneva support this hypothesis. Negative effects, however, are also possible as a warmer climate also benefits potential competitors and/or predators of coregonid larvae.

Management options in re-oligotrophicating lakes

The workshop participants agreed unanimously that stocking should be discontinued when natural reproduction is successful. Whitefish most likely choose their mates, the advantages of which are cancelled out by artificial fertilization. This drawback has to be accepted as long as stocking is considered necessary, but stocking should be abolished whenever possible to promote natural reproduction. Further, if stocking increases population size, intraspecific competition becomes more intense and may eventually result in slower growth, particularly under low food supply. The commercial aspects of the spawning fishery, however, need to be considered as well, since this provides income for professional fishermen several weeks after closed season. Stocking can also be viewed as an 'insurance' against reproductive failure in the wild due to e.g. climatic factors. Since the pros and cons of stocking are intuitively convincing but hard data are scarce, it was concluded that there is a lack of knowledge on the efficiency of stocking in (re-) oligotrophic lakes, and more studies on this topic are recommended.

In middle-European prealpine lakes, the optimum age-at-harvest is in the range of 2+ to 5+ (6+). An alternative way to regulate the fishery would be to set the minimum age-at-harvest to one year beyond the age-at-maturity. Mesh size adjustment is probably the most commonly used management measure to achieve this goal. During lake re-oligotrophication mesh sizes are generally decreased to cope with slower growth. Apart from mesh size regulation, fishing intensity can also be adjusted to changes in whitefish production. In many lakes, fewer licenses have already been issued. This measure allows for a reasonable income for the remaining fishermen. Although fishing intensity in oligotrophic lakes is generally lower than under eutrophic conditions, there is an option to remove larger fish and/or to reduce cohort size by increasing the fishing effort in order to promote the growth of the remaining cohort members (as in Lake Annecy, where anglers harvest fish larger than 38 cm while professional fishermen take fish larger than 42 cm).

In several lakes, whitefish yields remained more or less constant despite decreasing nutrient content, or yields even tended to increase during re-oligotrophication. Below ca. 5 $\mu g\ P_{tot}\ L^{-1}$, however, yields are likely to decrease notably as has been observed in some Swiss lakes (growth rate decreased far earlier). In this context, monitoring is vital to adjust fishing pressure and to optimise yields. Hydroacoustics combined with experimental gillnetting are an option for assessing whitefish stocks, and this technique should be further developed.

All participants were convinced that during re-oligotrophication a mere return of whitefish population dynamics or food web interactions to pre-eutrophication conditions seems unlikely, since a wide variety of factors have changed in the meantime: fishing gears are more efficient today, phyto- and zooplankton composition have changed as a result of changes in lake trophic state, neozoa and particularly new fish species have colonized several whitefish lakes, and climate forcing may affect fish communities differently today. Consequently, it was recommended to continue or even increase research efforts towards a better understanding of fish community and food web responses to decreasing lake nutrient contents.

In several prealpine lakes, phosphorus levels are already below the established water management goal, which was set at 30 $\mu g\ P_{tot}\ L^{-1}$ in several countries. Even if drinking water supply and tourism have priority over the fishery (and this seems to be the case in all European prealpine lakes), it was questioned whether it is indeed necessary to reduce P-levels far below the management goal. Drinking water was produced from moderately eutrophicated lakes without major problems, and there are even less problems at P-levels below 30 $\mu g\ L^{-1}$. From a fisheries perspective, a decrease of P-levels below 10 $\mu g\ L^{-1}$ will probably have negative consequences on whitefish harvests and should be avoided. To promote tourism, a healthy sustainable fishery that meets tourists' demands as far as possible is also an indispensable ingredient. The question remained unanswered, however, how the process of re-oligotrophication, which is still continuing in some lakes, might be slowed down or even stopped.

Economic aspects and marketing strategies

A salmonid community in oligotrophic lakes is very attractive for anglers, particularly when fish stocks in rivers, which were the main target of anglers in the past, are declining. Selling angling licenses thus provides an increasing additional income to managers / fishermen (e.g. at Lake Annecy, where the annual harvest of anglers is similar to the harvest of commercial fishermen).

Booms of certain species such as carp, perch or pikeperch, which are not typical representatives of oligotrophic lakes, have recently been observed in several lakes. These booms can be attributed to extreme water levels and/or temperature during spring/early summer. Since the appearance of a strong year-class of an uncommon species is largely unpredictable, it may temporarily provide additional income to fishermen but it does not allow for a sustainable fishery.

Considerable added value can be obtained by processing the catch (filleting, smoking, caviar, etc.). This is, however, not a management issue, it depends entirely on the initiative of the fishermen. If product quality is advertised in a convincing way (fish from clean lakes with healthy fish communities as compared to fish from eutrophic lakes or from aquaculture), a higher price can be obtained. The price for whitefish from oligotrophic Lake Annecy, for example, is 50% higher than for whitefish from nearby mesotrophic Lake Geneva.

The fishery during spawning time should probably be continued even if stocking is considered unnecessary, as it satisfies market demand and provides an additional income to the fishermen. The participants agreed that a spawning fishery is generally not harmful to the stock when it is practiced in a controlled way, as can be seen in several prealpine lakes. Continuing the spawning fishery, however, should not compromise continued stocking. It should rather help to reduce the number of eggs incubated in the lake, which might eventually contribute to diminishing the density dependency of whitefish growth in oligotrophic lakes.

Acknowledgements

The workshop organizers are grateful to P. Brzuzan and M. Luczynski for providing seminar rooms, technical facilities and refreshments at the Centre of Environmental Biotechnology. C.Gordon-Kuehn revised the English text.

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