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Development of the fish stock and its manageability in the deep, stratifying Wupper Reservoir

Wilfried Scharf*

Wupperverband, Untere Lichtenplatzer Str. 100, D-42289 Wuppertal, Germany

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Abstract

Today's fish fauna of Wupper Reservoir is the result of natural development in combination with management. Manageability of the fish stock, a prerequisite for continuing biomanipulation, was limited. Despite protection and stocking, the abundance of the stocked predatory fishes (pike, pikeperch) did never exceed 10% of the total fish biomass since filling in 1988. Contrary to predictions, the "juvenile" cyclical perch population that became dominant after flooding, with the disappearance of gigantic perch in 1997, was not replaced by cyprinids (>60% of total fish biomass). Instead, a strong, non-cyclical piscivorous perch population, plus cyprinids (<40% of total fish biomass) became established, giving rise to low planktivory and high water quality since 1999. There is compelling evidence that the introduction of a self-reproducing pikeperch population was a key-factor in the successful management of this slightly eutrophic reservoir. With the introduction of this new type of predator (pelagic, efficient at low light conditions) there are predators (pikeperch, perch, pike and eel) present in all habitats of the reservoir. Thus, anti-predator behaviour of planktivorous perch and roach was enhanced, resulting in substantial habitat segregation. Consequently, the perch were released from competition and became large enough for piscivory. Hence, predator biomass was substantially enhanced, reaching at least 25% of the total fish biomass which was estimated to be in the range of 90 kg ha^{-1} in August 2003. Ultimately, a high level of piscivory driving the whole lake trophic cascade, and thus a clear-water regime, which seems to be driven and stabilized by internal feed-backs, was established in Wupper Reservoir.

Keywords: Reservoirs; Fish fauna; Biomanipulation; Angling; Perch; Roach; Pikeperch

Introduction

Because natural lake formation processes occur over geological epochs, it would take fish a long time to colonize a new lake. In newly flooded reservoirs, however, fish are always immediately present, either from the autochthonous fish fauna of the impounded river, or from stocking. In the first years after the water body is impounded, reservoirs often experience a "trophic upsurge" due to leaching of soil nutrients and the decay of inundated vegetation (Straskraba et al., 1993). Probably, the newly inundated vegetation not only provides excellent spawning sites for fish but also large densities of benthic invertebrates, and thus food for fish, giving rise to initially high fish production. Subsequently, an ageing process takes place as productivity declines and the fish fauna stabilizes.

*Tel.: +202 583 323; fax: +202 583 118.
E-mail address: scha@wupperverband.de.

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In contrast to most natural lakes, deep, elongated, canyon-shaped reservoirs provide pronounced longitudinal environmental gradients. Structural complexity in the littoral zone typically is low, favouring cyprinids over perch (Persson and Greenberg, 1990). Indeed, irrespective of the nature of the impounded stream and its final trophic state, in Central European reservoirs the fish fauna matures to dominance by cyprinids (Vostradovsky et al., 1989; Kubecka, 1993; Kahl, 2003). This implies a general increase in the number of planktivorous fish and a simultaneous increase in the proportion of smaller species (*Bosmina* spec, *Daphnia cucullata*) in the zooplankton of the reservoir, which are less-efficient grazers compared to larger *Daphnia* species, not able to significantly increase water quality (Vostradovsky et al., 1989; Gliwicz et al., 2000). Therefore, the practical target of fisheries management in these reservoirs is to increase piscivore biomass in order to reduce predation on the zooplankton, thus allowing the development of larger daphnids, as predicted from the size-efficiency hypothesis (Brooks and Dodson, 1965).

Applying stocking with piscivores in combination with restrictions to fisheries as the only food-web management tool is thought to have limited success (Drenner and Hambright, 1999). The stocking of, particularly, smaller piscivorous fish has often been less successful (Grimm, 1982), e.g. in Czech Reservoirs (Seda and Kubecka, 1997; Seda et al., 2000), not preventing cyprinid dominance. Consequently, it seemed questionable whether the introduction of small pikeperch in the deep, slightly eutrophic Wupper Reservoir, Germany, would result in the desired percid rather than cyprinid dominance. Moreover, the almost complete lack of submerged macrophyte cover ($<1\%$ surface area) in Wupper Reservoir's littoral areas should additionally favour roach over perch (Persson and Greenberg, 1990).

Nevertheless, fishery management has been successful in Wupper Reservoir, since the development of the predicted climax-state, with cyprinid dominance, was prevented, (Scharf, 2007). Similarly, in the hypertrophic Bautzen Reservoir a stable percid dominance in the fish community was established by a combination of stocking and catch restrictions (Benndorf et al., 1988; Kasprzak et al., 2007). In order to illustrate the underlying mechanisms, in this paper details are presented concerning the Wupper Reservoir's on-going fishery management, which addresses issues of the development of its fish fauna since it was filled in 1988, and of its manageability. If repeated stocking of smaller predators in combination with restrictions on anglers is to be successful in enhancing stock densities of piscivores, the anglers' catches should track stocking efforts in the long-term (Lathrop et al., 2002). At the same time, due to increased piscivory and decreased planktivory, larger daphnids are expected to appear (Brooks and Dodson, 1965) illustrating the successful biomanipulation. The aim of the paper is to demonstrate the development of the fish community in Wupper reservoir as resulting from the applied fisheries management.

Methods

Site description

Wupper Reservoir is situated in the central area of the Rheinische Schiefergebirge near Cologne in Western Germany and is used for controlling the flood regime of the River Wupper, and for public-recreation. Water levels in the reservoir fluctuate widely, reaching a maximum in April and a minimum in October. The reservoir lies at 250 m above sea level. It is a deep (31 m max. depth), canyon-like, mostly dimictic, slightly eutrophic, soft water reservoir. Macrophytes are nearly absent from the inshore areas. At full capacity, the reservoir has a surface area of 210 ha and a storage capacity of 26 mio m^3, a mean depth of 11 m and a retention time of 0.2 years. Wupper Reservoir does receive treated sewage and storm water effluents from its relatively densely populated catchment area of 212 km^2.

Management options

Prior to its first filling in the winter of 1987/1988 the basin was cleared of vegetation and top-soil layers. Since its first filling the reservoir has been managed both to improve water quality and to support recreational fisheries. With the damming of the River Wupper (1988) northern pike (*Esox lucius*), perch (*Perca fluviatilis*), roach (*Rutilus rutilus*) and bream (*Abramis brama*) entered the slightly eutrophic Wupper Reservoir from its pre-reservoir which had already been built in 1980. Enhancing the piscivorous fish populations has relied mainly upon regular annual stocking with northern pike of 3–7 cm total length (TL) and pikeperch (*Sander lucioperca*) of 12–15 cm TL (Fig. 1) in the years 1988–2003. There was no stocking in 2004 and 2005 and only 20 ind. ha^{-1} pikeperch of 12–15 cm TL per annum since then (Fig. 1). Additionally, dead trees and woody materials have been introduced in the littoral zone to improve spawning habitat. However, density of wood has remained low.

The number of anglers was restricted to approximately 220 and they were obliged to record the numbers, length and weight of all fish caught. However, only half of their notebooks returned at the end of the fishing season. Cyprinid fishing was unlimited. Fishing for predators was opened in 1992 and only artificial baits are allowed. Restrictions placed upon the anglers include minimum sizes of fish (northern pike 55 cm TL,