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Note

The relationship between the spatial distribution of fish, zooplankton and other environmental parameters in the Solina reservoir, Poland

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Abstract – The hydroacoustic estimation of fish abundance and distribution in the Solina reservoir was related to other biological and hydrological parameters. The increase of fish abundance corresponded to increased levels of eutrophication expressed by Secchi-disc visibility and chlorophyll *a* concentration. A negative correlation between fish and zooplankton abundances was observed, with changes in the zooplankton population structure, caused by fish grazing. Vertical distribution of zooplankton and fish were affected by the thermocline. Maximal concentrations were observed in a well-illuminated surface layer at the highest temperature and oxygen concentration. © 2000 Ifremer/CNRS/INRA/IRD/Cemagref/Éditions scientifiques et médicales Elsevier SAS

hydroacoustics / fish / water quality / dam reservoir

1. INTRODUCTION

Hydroacoustic methods provide estimates of fish density on spatial scales that can be related to other limnological measurements, thus enabling a direct comparison between fish, plankton, physical, and chemical characteristics of the water. Although a number of authors have demonstrated the application of such techniques in the marine environment (Swartzman et al., 1994; Castillo et al., 1996; Orłowski, A., 1998; Szczucka, J., 2000), there have been few comparable studies in inland waters (Kalikhman et al., 1992; George and Winfield, 2000). On a few occasions the dependence of fish distribution on oxygen deficiency and the level of water eutrophication were reported (Duncan and Kubecka, 1996).

This study was designed to examine the relationship between the spatial distribution of fish and zooplankton alongside environmental parameters in the Solina, the largest Polish dam reservoir of drinking water supply system, where water quality is the main concern. During the last ten years the Secchi-disc visibility in the reservoir has decreased significantly (Półtorak et al., 1997), and there was a need for a complex environmental study to account for the situation. According to the concept of cascading trophic interactions, predation by fish may have a major impact on the species composition, size structure, and abundance of zooplankton, which consequently may lead to undisturbed phytoplankton development, and deterioration of the water quality. (Shapiro and Wright, 1984; Benndorf, 1987). Thus, it was hoped that if the linkages between zooplankton and fish were better understood, the water quality might be improved by judicious management of the fishery.

2. MATERIALS AND METHODS

2.1. Study site

Solina comprises about 15% of the total water storage in Poland. Its principal morphometric parameters are as follows: length 26.6 km, mean depth 22 m, maximal depth 65 m, surface area 2 105 ha, and a total water volume of 472×10^6 m^3. Due to a power station activity the fluctuation of the water level is up

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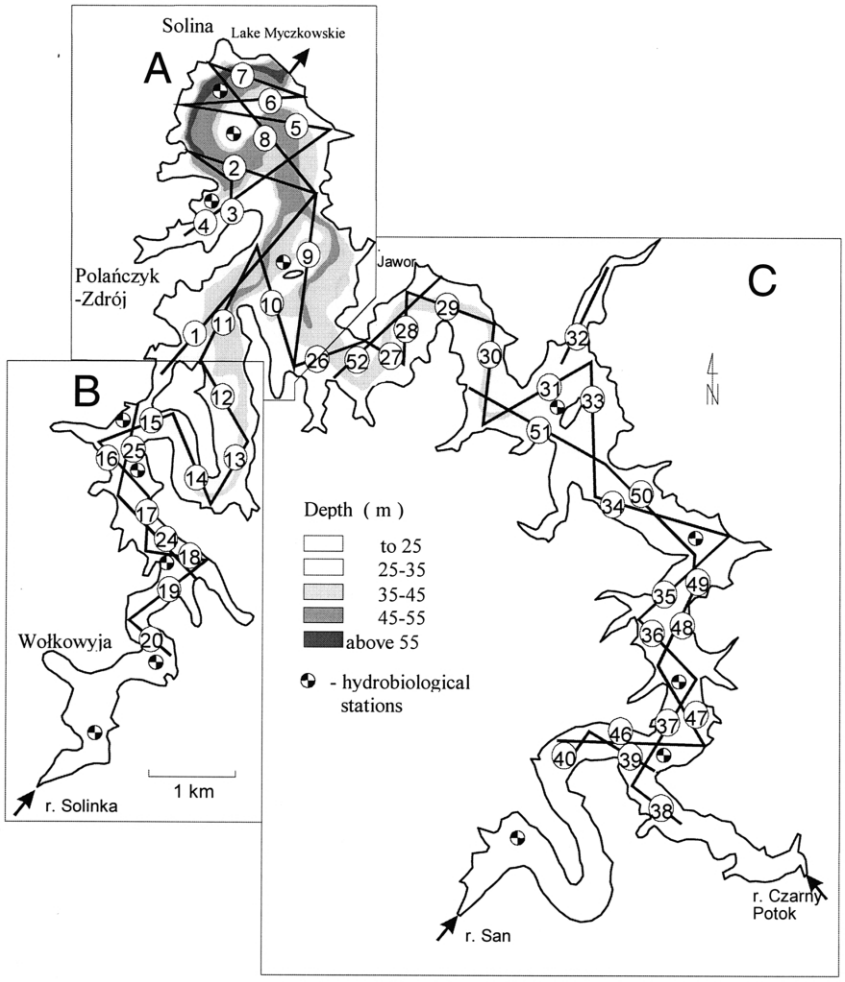

Figure 1. Bathymetry, positions of the hydroacoustic transects and hydrological stations.

to 10 m, which leads to a complete absence of littoral. The total water volume is exchanged about twice a year. Concentrations of phosphorus and nitrogen compounds in the reservoir correspond to mesotrophy. The reservoir fulfills multiple and often contradictory functions such as hydroelectric power generation, flood control, a source of water supply for domestic, industrial and agricultural use, as well as that of tourism and

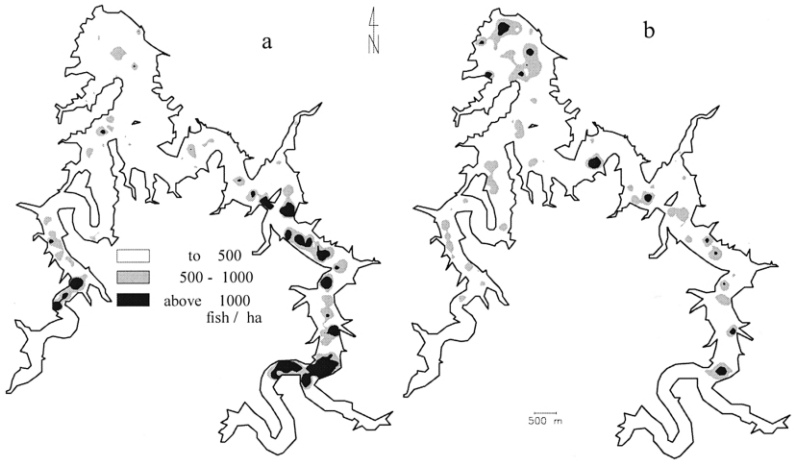

Figure 2. Spatial distribution of fish in the Solina reservoir in September 1999. Day data divided into epilimnion (a) and hypolimnion (b).

Table 1. Fish and zooplankton densities and other environmental parameters in the Solina reservoir measured in September 1999*.

Parameter area	Fish density (ind·ha^{-1})	Total zooplankton (mg·dm^{-3})	Rotatoria (mg·dm^{-3})	Cladocera (mg·dm^{-3})	Copepoda (mg·dm^{-3})	Chl *a* (µg·dm^{-3})	Secchi disc (m)	Eutrophication index
Main basin (A)	231	1.95	0.04	0.38	1.53	2.0	2.90	25
Solinka branch (B)	325	1.25	0.06	0.28	0.92	2.50	1.90	120
San branch (C)	659	0.99	0.05	0.24	0.71	3.46	1.95	164

* The eutrophication index is the ratio of Oligochaeta to Chironomidae from the benthos (Prus, T., Prus, M., Bijok, P., in preparation).

recreational centres. All these activities lead to a permanent deterioration of the water quality and erosion of the banks, and therefore landscape degradation.

There are no commercial fisheries in the reservoir, but angling is very popular there. According to anglers' catches (Bieniarz and Epler, 1993) the most frequent species are *Abramis brama* (57.8%), *Carassius carassius* (16.1%), *Rutilus rutilus* (9.2%), *Stizostedion lucioperca* (4.5%), and *Perca fluviatilis* (4.8%). No hydroacoustic estimation of the resources has been done before.

Further information on the physical, chemical, and biological characteristics of the reservoir may be found in publications by Płużański et al. (1990), Półtorak et al. (1997), Bijok et al. (1999) and Godlewska et al. (2000).

2.2. Field methods

Records of the vertical and horizontal distribution of fish along 52 zigzag transects (*figure 1*) were obtained over 23–25 September 1999 during daytime and nighttime surveys. The acoustic system was routinely calibrated with a –40.4 dB, 23 mm copper sphere (Foot, 1983). The echosounder was a Simrad EY500 120-kHz splitbeam, with a beam width of $4° \times 10°$. At the time of the measurements there was an extremely low water level in the Solina reservoir which caused excretion of gas bubbles from the bottom. To avoid counting of the bubbles, the minimum target strength (TS) was set to –50 dB, which corresponds to a fish length of about 10 cm (Foot, 1987). To estimate fish size distribution the echocounting method was applied with the TVG set to $40 \log R$. The echosounding results were analysed using the EY500 software system which produces estimates of target strengths using a modification of the Craig and Forbes (1969) algorithm. The water samples for chlorophyll *a* analysis, chemical analyses, and zooplankton were taken at nine stations, at which temperature, oxygen concentration, and Secchi-disc visibility were also measured. The stations were situated in the main basin (near the dam) as well as in the two branches of the reservoir, the Solinka and San supply rivers (*figure 1*), which are characterised by a different trophy level. For depth distributions, the analyses of fish density were performed in 2-m layers, temperature and oxygen concentration were measured every 1 m, and other parameters at standard depths: surface (0.2 m), 2, 4, 6, 8, 12, 16, 20 m. Maps of fish density were drawn using the SURFER program.

3. RESULTS AND DISCUSSION

Fish concentrations in the Solina reservoir, estimated hydroacoustically, were generally very low. The mean was only 264 ± 124 fish·ha^{-1} (1.3 fish·10^{-3} m^{-3}) and the maximal value did not exceed 1 500 fish·ha^{-1}. The fish mainly occupied the epilimnion with patchy spatial distribution (*figure 2*), lowest values were registered in the central basin and the maximal concentrations close to the supply rivers. Slightly increased values were observed at locations of agricultural and tourist pollution (being sources of nutrients). Given the fish distribution, all data were analysed accordingly by regions: the central basin (A), the Solinka branch (B) and the San branch (C), all of which have different trophy levels (*table I*). Comparison of the regions shows that the area with the richest fish populations had the lowest zooplankton biomass, and conversly, the highest zooplankton biomass was observed in areas where very few fish were present (*figure 3*). The analysis of the species and size composition of the zooplankton (*figures 4a, b*) clearly shows the results of fish grazing. However, even at the highest fish concentrations, the large boded species in the zooplankton predominated, which means that the fish pressure was not very high.

Fish and zooplankton vertical distributions were related to each other and to the temperature and oxygen concentration profiles (*figures 5a, b*). During

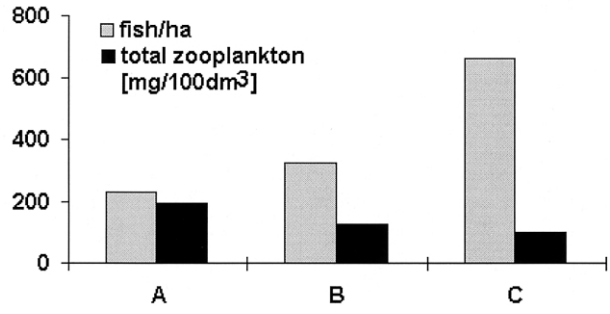

Figure 3. Fish abundance and zooplankton biomass in the three regions of the Solina reservoir: A) the main basin, B) the Solinka branch, C) the San branch.

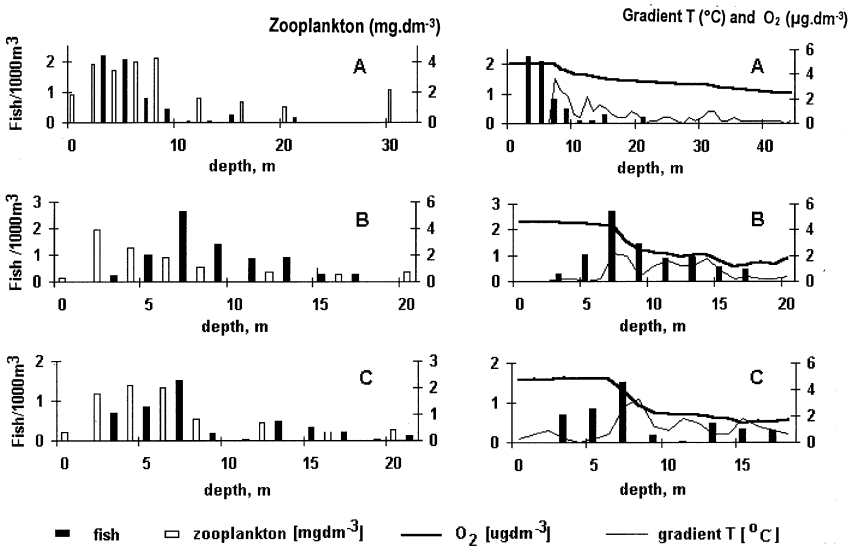

Figure 5. Vertical distributions of the biological and physical parameters in the three regions of the Solina reservoir (annotations as in *figure 3* above). a) fish and zooplankton, b) fish related to temperature and oxygen concentration profiles.

the day both fish and zooplankton were distributed mainly within or just above the thermocline, within the layer of highest oxygen concentrations. It has been widely accepted that animal behaviour results from the search for a right compromise between two conflicting demands: to maximize feeding and to avoid predators (Gliwicz, 1986). Since in the Solina both fish and zooplankton occupied well-illuminated, warmest and richest surface waters during the day, one may assume that in this mesotrophic reservoir with low primary production (600 cal·m^{-3} in 1999, Mienshutkin, personal communication), searching for food is more important than avoiding predators because they are very scarse, in terms of predatory as well as planktivory fish.

No direct relationship between fish distribution and the ratio of the total nitrogen to total phosphorus concentrations (N:P) was observed. This ratio was very variable, fluctuating from 4 to 177, with a mean value of 72, which confirms that the Solina waters belong to the mesotrophy category.

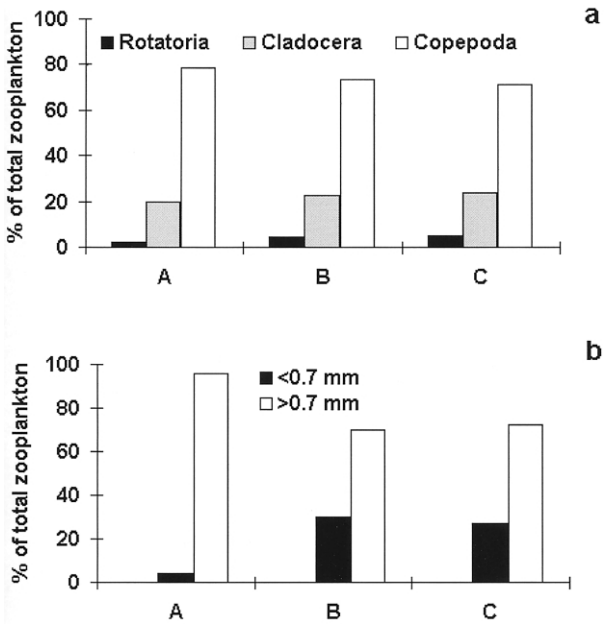

Figure 4. The structure of the zooplankton in the three regions of the Solina reservoir (annotations as in *figure 3* above). a) the species composition of the population, b) the size composition of the population.

4. CONCLUSION

The results show that the water quality in the Solina reservoir is not yet threatened by the fish population, and that there is no need for biomanipulation. The observed lower Secchi-disc visibility is probably a result of physical processes (low water level, wind mixing etc.) rather than biological ones.

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