DIURNAL AND SEASONAL FISH HORIZONTAL MIGRATIONS IN THE SULEJÓW RESERVOIR, POLAND

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Horizontal fish migrations in the Sulejów reservoir were studied acoustically. The SIMRAD EY500 echo sounder was used with transducer looking horizontally at three sites of the reservoir located along its longitudinal axis. Fish began to migrate horizontally in June and stopped in October. The diurnal cycle was very well pronounced, with fish going to open water at night and coming back to littoral in early morning. The timing of migrations was correlated with light conditions; the longer were nights the longer fish stayed off shore. Starting from August, apart from diurnal migrations between pelagial and littoral also some movement of fish towards the upper part of the reservoir was noted. It has been hypothesised that it was caused by unfavourable environmental conditions in the lower part of the reservoir, where the Microicystis aeruginosa bloom was observed, and the oxygen concentrations were much lower than in the upper part. These observations confirm that acoustics provides a good tool for controlling behaviour of fish, that are essential indicators of the water quality.

INTRODUCTION

Eutrophication of inland waters is a worldwide problem, which leads to fast deterioration of the water quality. The shallow lowland reservoirs are especially exposed to the intensive cyanobacterial blooms that are harmful to people and animals [17]. The use of food web manipulation as a method for regulating algal blooms has been extensively studied in the last two decades [3, 10, 11, 14]. Results have shown that efficiency and long-term success were dependent on many factors, such as nutrient load, lake morphometry and biomanipulation measures [1, 9]. For successful biomanipulation understanding of the ecosystem functioning is of crucial importance. This includes the knowledge of abundance and spatial distribution of all organisms in the ecosystem and their dynamic changes.

Fish are heavily influenced by pollution and degradation of aquatic ecosystems and they are essential indicators of the ecological quality of aquatic environments. Several attributes distinguish fish from other biological indicators: 1. they are present in all water bodies and thus enable direct comparison between them, 2. due to their high affinity to distinct habitats they are indicative of habitat quality at different spatial scales, 3. due to their longevity they are indicative for long time periods, 4. they play a central role in lake restoration and management. Thus combining the strategy of nutrient load reduction with traditional inland fisheries management techniques may lead to successful co-management of ecosystem and fisheries [12]. This is in agreement with Ecohydrology concept. that uses integrated approach and combines biota with processes at the basin scale [18, 19]. Especially in shallow reservoirs, which are highly influenced by hydrological conditions the coupling between littoral zone and the pelagic habitat becomes extremely important [13]. The aim of this study was to investigate the diel and seasonal change in habitat use by fish and how it depends on environmental factors. This information is difficult to get by traditional fisheries methods; therefore the hydroacoustical methods were applied. However shallow water ecosystems are not the best environments for acoustical applications. The traditionally used vertically oriented transducer is practically inapplicable due to extended hydroacoustical blind zone and reduced sampling power at short ranges. The use of horizontally oriented transducer is heavily affected by weather conditions due to backscatter from the rough surface, effects of entrained air bubbles and floating aquatic plant material. These problems led us to using stationary fixed position transducer, that is easier to handle and can provide long-term reliable data.

1. MATERIALS AND METHODS

The Sulejów is a shallow lowland reservoir situated in central Poland that supplies drinking water for the city of Łódź (over one million people). It has maximum depth of 11 m and the mean depth of only 3.3 m. The reservoir is highly eutrophic, total phosphorus concentrations of about 150 to 500 μgdm^{-3} and total nitrogen of 1500 to 2500 μgdm^{-3} are maintained through the year [15]. Under such conditions summer blooms of cyanobacteria (mainly *Microcystis aeruginosa*) have been frequently observed during recent years. The fish population is dominated by roach (*Rutilus rutilus*), white bream (*Blicca bjoerkna*), pikeperch (*Stizostedion lucioperca*), perch (*Perca fluviatilis*), ruffee (*Acerina cernua*), bleak (*Alburnus alburnus*) and bream (*Abramis brama*) [4]. Due to water level fluctuations the littoral zone is rather poor in macrophytes. In sparsely vegetated lacustrine parts of the reservoir the following species are found: *Potamogeton lucens, Potamogeton amphibium, Elodea Canadensis, Gallium palustre, Carex gracilis, Equizetum fluviatile, Eleocharis palustris, Gliceria fluitans*, and *Iris pseudoacorus.*

Hydroacoustical measurements were performed at three sites: close to the dam with the littoral zone devoid of vegetation – called Tama, in the lower part with developed littoral vegetation – Tresta, and in the upper part of reservoir, also with some vegetation – Zarzęcin (Fig. 1). Stationary transducer was deployed few m from the shore, 1.5 m above the bottom and was directed horizontally, but perpendicular to the main axis of the reservoir. The insonified range was about 0-20 m and it covered mainly the transition zone between the littoral and pelagial. The analysis of fish abundance and direction of swimming was performed separately in two zones: area from 5 to 10 m was considered as littoral and above 10 m as pelagial. The 5 m distance nearest to transducer was excluded from the analysis. Each site was sampled once or twice a month from April till October, for 15 min every hour starting at 8 PM and finishing at 8 AM. The SIMRAD EY500, split beam echo sounder with frequency 120 kHz was used. The opening angles of the elliptic transducer were 4° and 10°. The pulse duration was set to 0.3 ms, repetition rate to “as fast as possible” and the TS threshold to –50 dB. For data analysis the Simrad EP 500 post-processing software was used. It allows to track passing fish in three dimensions and thus to determine the absolute direction of travel. The database was made in Access and all the data were grouped in four directions: up or down the reservoir, and towards the pelagial or littoral. For estimating fish abundance the echo counting method was used. The calibration of equipment was performed at transducer vertical orientation in the deepest part of the reservoir with standard target situated 8 m below the transducer.

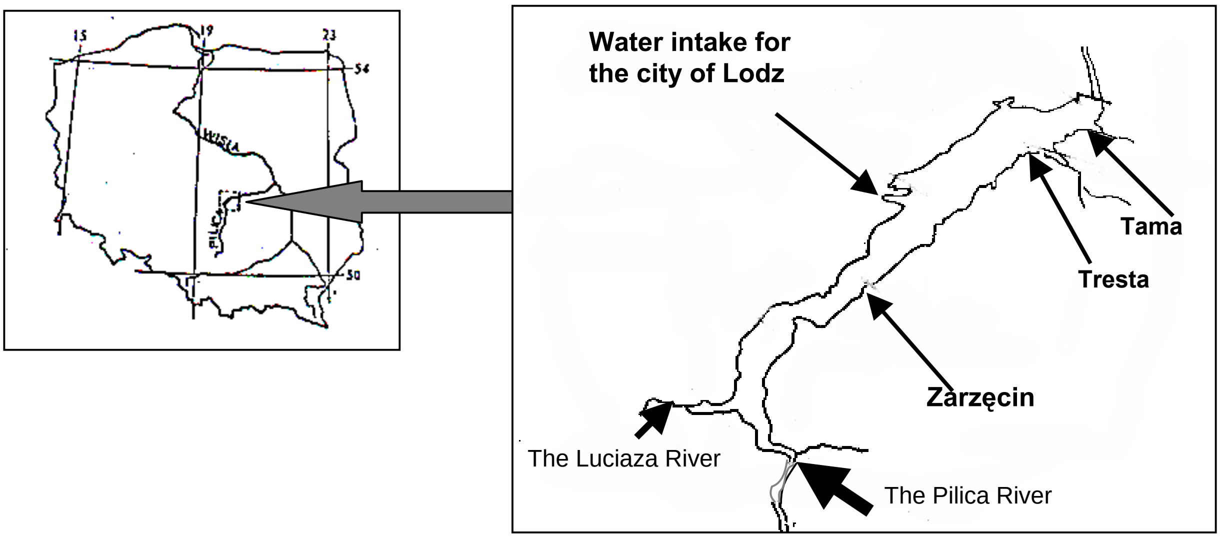

Fig.1 The Sulejów reservoir and sampling positions

Apart from acoustical measurements the basic environmental parameters were also controlled. The weather conditions, oxygen, total phosphorus and total nitrogen concentrations, as well as phyto- and zooplankton samples were taken in areas close to all three sampling sites. Fish population composition was determined from the gill nets set once a month in the littoral and pelagic part of the reservoir.

2. RESULTS AND DISCUSSION

There was a clear seasonal pattern in both the littoral and pelagic zone in fish abundance, similar at all 3 sites; an example of just one site is presented in Fig. 2. The increase of the number of fish observed was most probably result of increased spawning and feeding activity, and also the appearing of new born individuals, which were reaching size enabling acoustical detection. The following decrease was a result of high mortality of the underyearling fish. The fish abundance in early spring (April) was very low at all sites and no sign of horizontal migrations was observed; the number of fish was stable through the day and night. It was increasing during the following months and starting from June clear change in the number of fish was detected at dusk and dawn (Fig. 3).

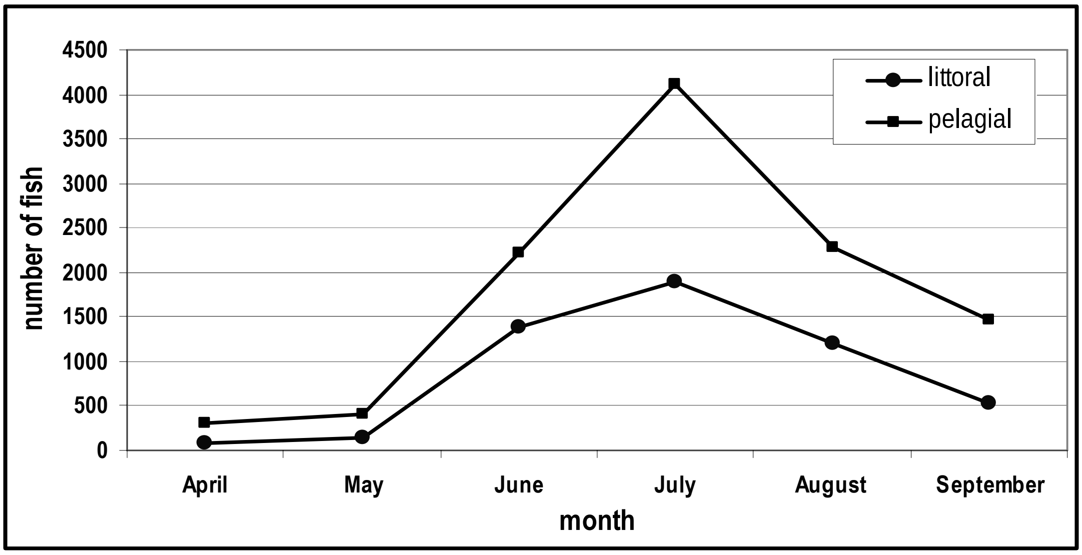

Fig.2 Seasonal changes in fish abundance in littoral and pelagic zone at Zarzęcin

These two peaks of increased activity and the higher fish numbers in the sampling volume of the transducer are connected with diurnal horizontal migrations from the littoral refuge towards open water at dusk, and back to littoral in the early morning. Such phenomenon of daytime sheltering among near shore vegetation has been frequently observed in habitats with an effective off shore piscivore, such as the pikeperch [2] or fish-feeding birds inspecting water surface from above [16]. Diurnal horizontal migration is a typical avoidance behaviour of fish in the presence of pelagic piscivores in their effort to compromise between the need to feed on rich off shore zooplankton under the cover of night, and the need to stay away from the risk of visual piscivore predators under the cover of littoral vegetation during the day [6]. The fish abundance reached its maximum in July, and from August it started to decrease again, having in October the similar or slightly higher level as in April. The highest fish concentrations were detected at the upper part of the reservoir at Zarzęcin, while the lowest at Tresta. Also the intensity of migrations was highest at Zarzęcin, but lowest at Tama. The difference in the intensity of migrations in these two sites can be explained by complexity of the littoral zone. At Zarzęcin and Tresta there were macrophytes beds that were providing shelter and nursing grounds for fish, while at Tama there was no difference between the off shore and in shore shelter conditions, as littoral zone was devoid of macrophytes. At this site the depth was much larger than in the other two sites, and fish could use the deeper water layers to hide from predators. At all three sites the number of fish that were entering pelagial was increasing through the season. With elongating the duration of night, fish were delaying their return to littoral, thus supporting the hypothesis that the horizontal migrations to littoral during the day were avoidance behaviour from visual predators. Regular diel habitat shifts in roach have been earlier described [5, 8], and it was shown that gut contents in roach against distance from shore regression was highly significant [7]. Migrating individuals get a bonus in a form of richer food and higher body growth as compared with non migrants Also roach caught in our gillnets located in the pelagic zone were longer and heavier than the roach caught in the littoral zone, confirming the profitability of such behaviour.

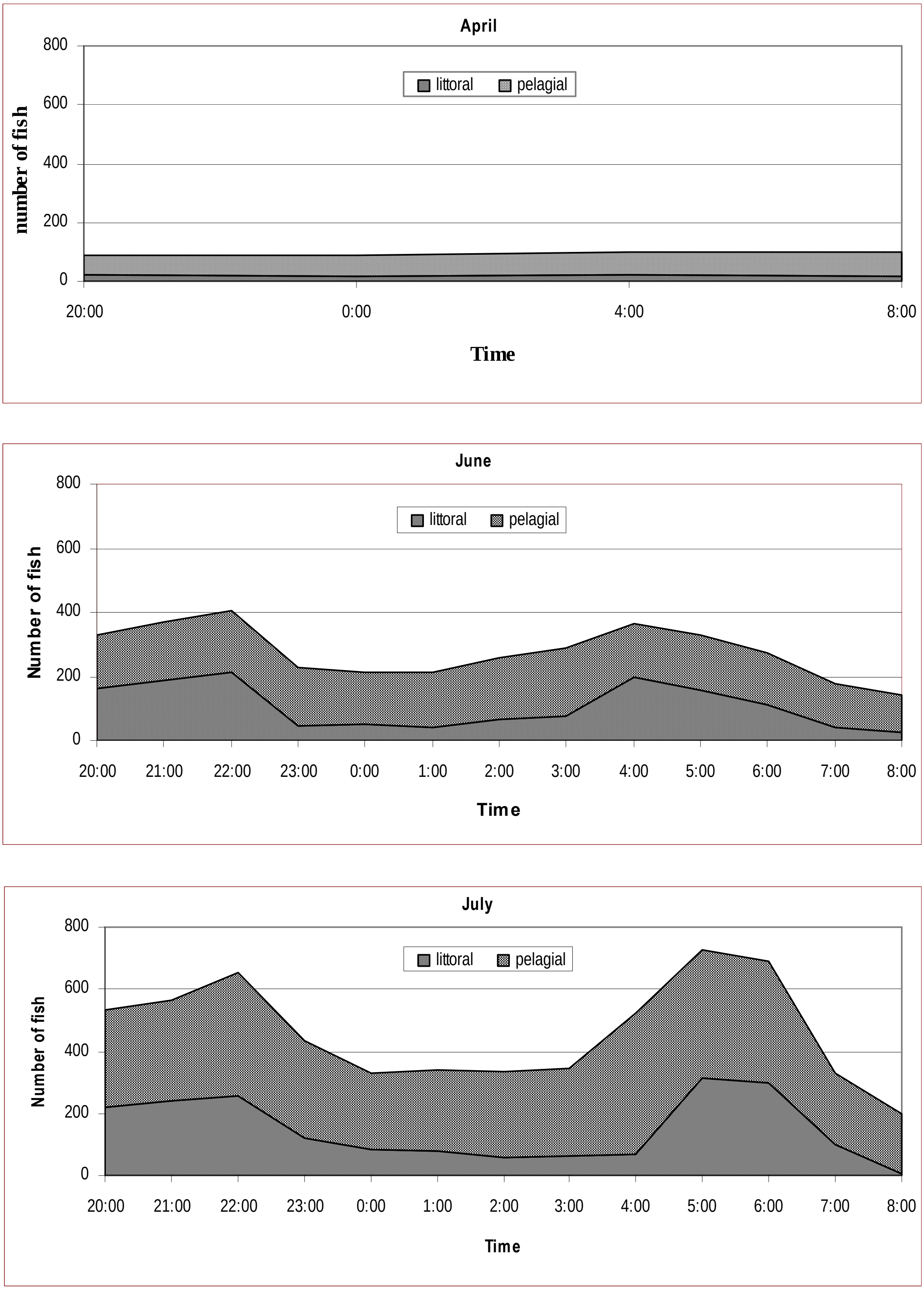

Fig.3 The seasonal changes in diurnal fish distribution pattern at Zarzęcin site

The direction of fish movement can be elucidated from the single fish tracks. As can be seen from Fig. 4 at Tresta site in June and July from 50 to over 70 % of fish were travelling to open water between 11 PM and 2 AM and coming back to littoral between 2 and 5 AM. In August and September the situation changed. Although still there were more fish going off shore in the evening, and in shore in the morning, the dominant direction at all times was towards the upper part of the reservoir. The same seasonal pattern was observed at the dam (Fig. 5); in June and July off shore / in shore migrations dominated, while in August/September the dominating direction was away from the dam. This change of direction of the fish movements might be caused by different reasons. The investigation of environmental parameters suggests that the possible reason for these migrations could be an active avoidance of unfavourable conditions. The intensity of *Microcystis aeruginosa* bloom that appeared in August and lasted through September had a strong gradient along the main axis of the reservoir, with the highest concentrations at the dam (Fig. 6). Also in August the drop of oxygen concentrations was observed, that was most pronounced at the sites closest to dam, and much weaker up the reservoir (Fig. 7). However, it cannot be excluded that some other biological or abiotic factors were responsible for the upward reservoir migrations. More studies are needed to reveal how the distribution and movement patterns of fish depend on environmental factors and which processes shape the fish distribution.

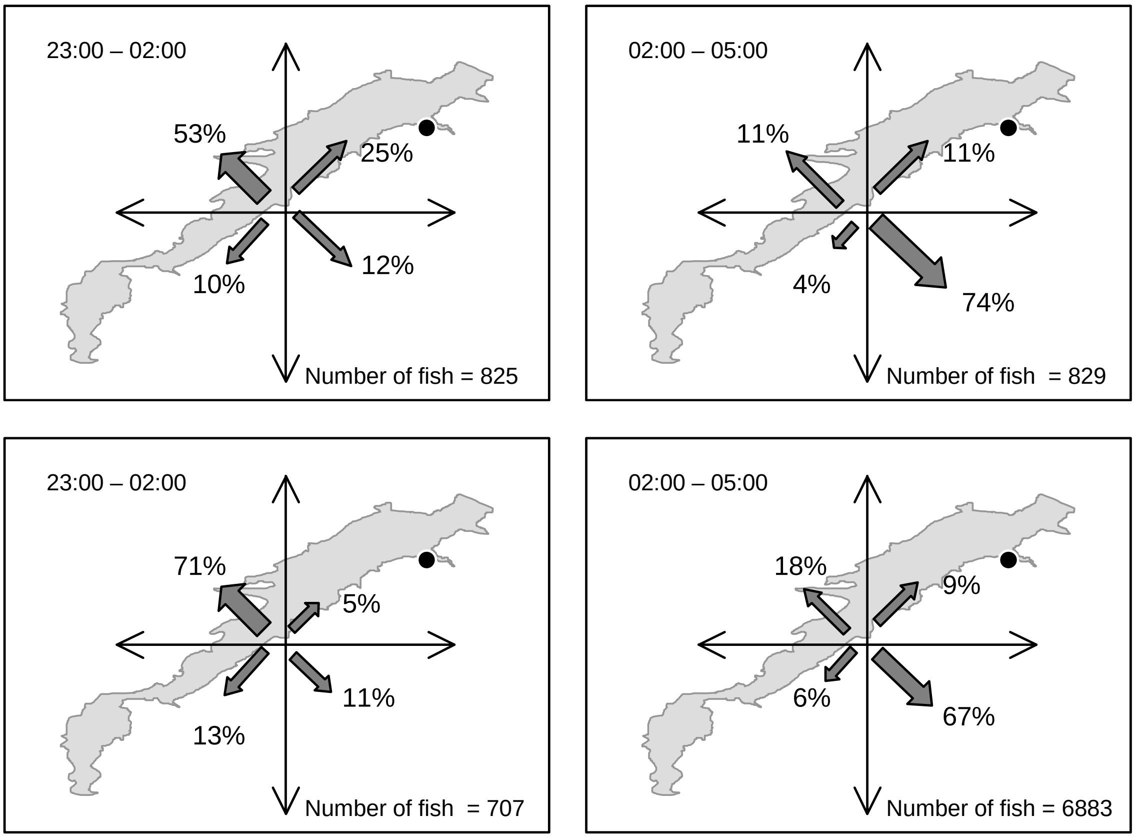

Fig.4 Direction of fish movements at Tresta in June (upper) and July (lower)

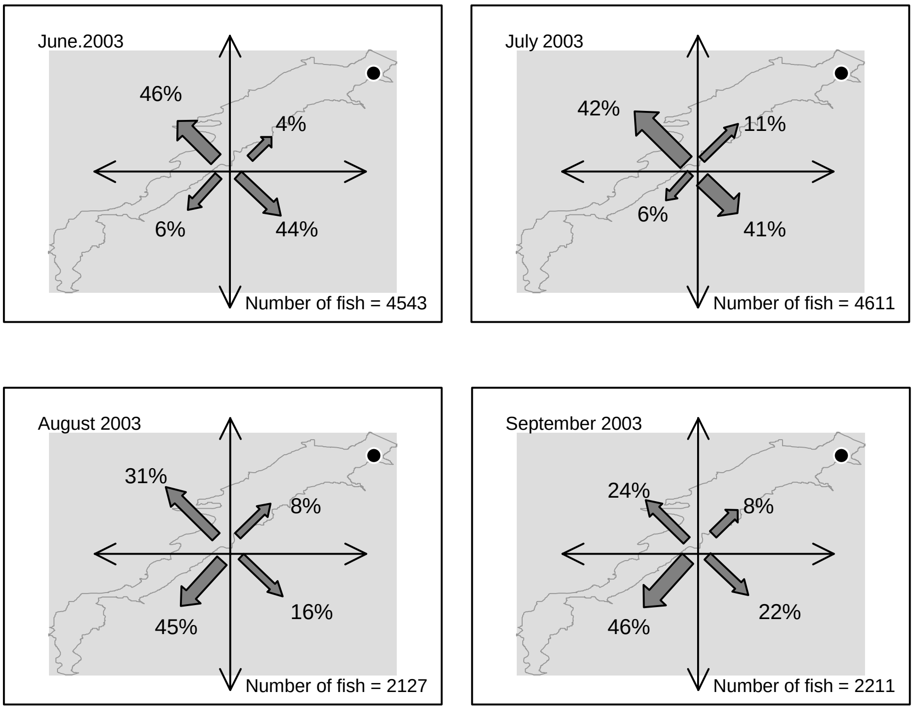

Fig.5 Seasonal changes of fish movement's direction at Tama

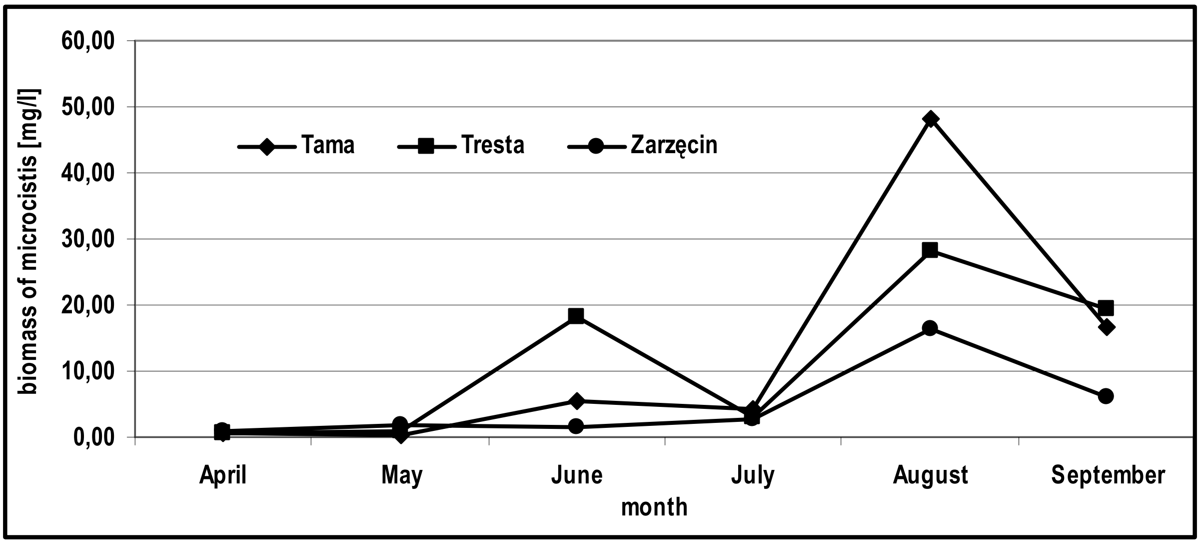

Fig.6 Seasonal changes of *Microcystis aeruginosa* concentrations at three sites [Izydorczyk, unpublished data]

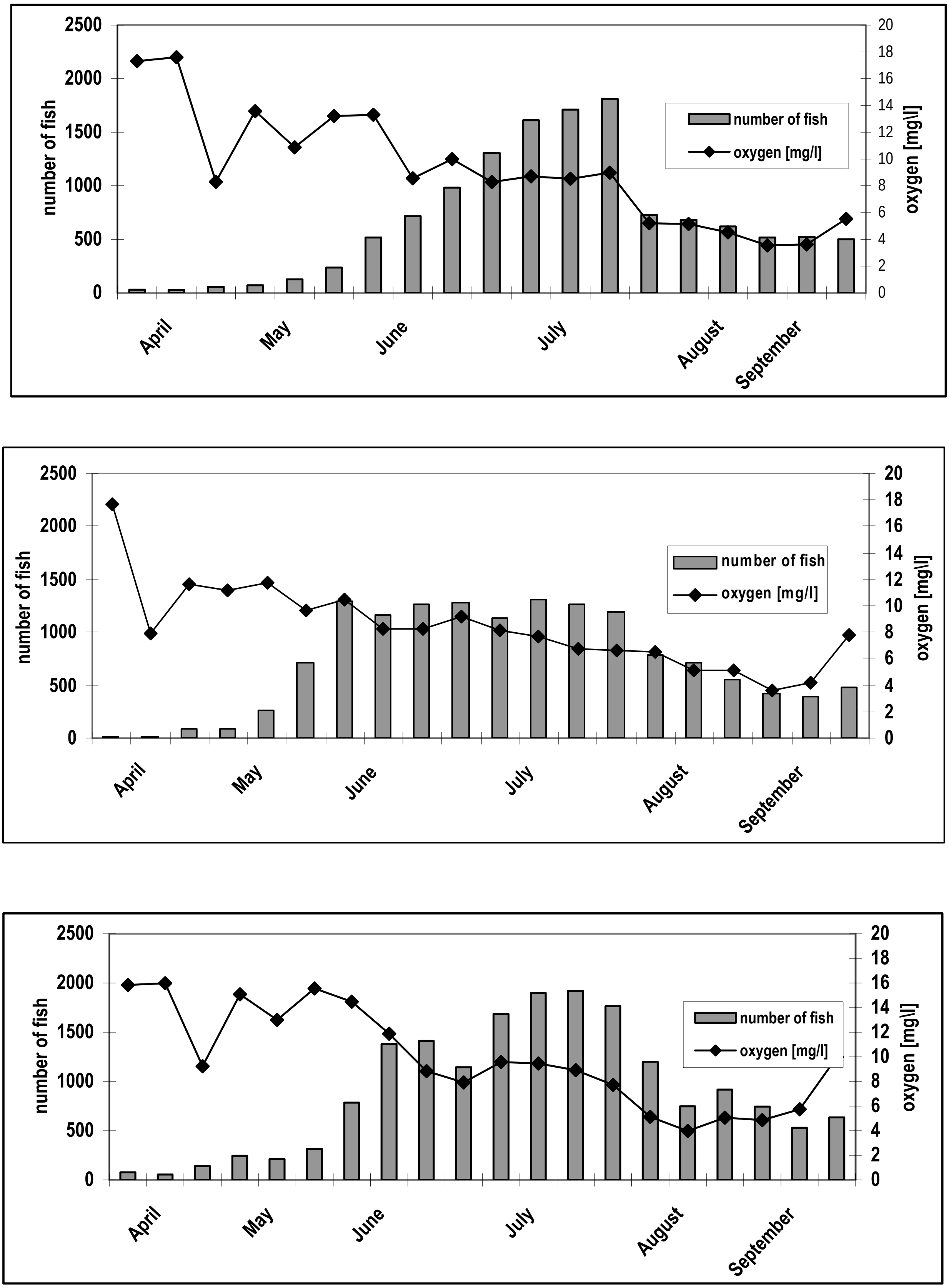

Fig.7 Oxygen concentrations and fish abundance at Tama, Tresta and Zarzęcin

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