ACOUSTICAL MONITORING OF FISH AT AN ELECTRIC BARRIER

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Abstract: Acoustical monitoring of fish at an electric barrier was performed using EY 500 split beam echo-sounder with the transducer directed horizontally. Stationary measurements done during the operating barrier and when the electric power was switched off have shown statistically significant difference in the number of fish approaching the barrier, 11 fish in the first case, and over 280 in the second. The electric barrier affected more strongly large fish than the small ones. Mobile measurements performed in a basin from which fish were approaching barrier revealed the higher fish concentration just in front of the operating barrier than elsewhere.

INTRODUCTION

Harmful influence of the hydraulic engineering plants on fish communities in rivers and their biodiversity is long lasting problem all over the world [Cada 1990, Francroft et al. 1994, Lusk et al. 1995, Kubecka et al. 1997]. While some measures aiming at limitation of this influence are being undertaken, there is still a need in developing innovative technologies which will contribute to improvement of fish conditions in inland waters and assure their protection from being harmed. The fish ladders which are commonly built at majority of dam reservoirs are often ineffective and many fish are killed by the turbines. One of the solutions is using the different type of electrical barriers that are supposed to lead fish into the safe place. In the Wroclaw University of Environmental and Life Sciences a new type of an electric barrier has been developed within a project co-financed by European Union and Polish budget (SPO) "The research on the controlling fish behaviour device leading to the inlet water intake and fish pass effectiveness". The prototype has been mounted at the Krzywaniec reservoir and its performance studied using both fisheries and hydroacoustical methods. The hydroacoustic technique was frequently applied at hydroelectric dams to provide estimates of the portion of fish passing the facility through various routes, such as the turbines, spillways or a bypass system, and to provide an accurate estimate of passage efficiencies [Thorne et al. 1979, Johnston et al. 1993, Thorne 1994].The aim of the present work was to investigate the effectiveness of the barrier to stop the fish, by acoustical monitoring of fish behavior at times, when the electric barrier was operating, and when the electrical current was switched off.

1. MATERIALS AND METHODS

The research was conducted on Krzywaniec reservoir which is a part of Dychow complex hydraulic engineering, created on the river Bobr. The electrical and electronic barrier was placed close to the intake to the channel which is leading water to the Dychow hydro-electric power station. The barrier is composed of two rows of electrodes. The electrodes within particular groups are supplied with impulses, with the parameters of the impulses being defined through the amplitude, frequency and the fullness coefficient. The parameters of the electric field undergo statistical changes to prevent fish from adapting themselves to the parameters of the field.

Hydroacoustical measurements were performed from 24 to 26 September 2007 when the electric barrier was switched on and off. The SIMRAD EY500, split beam echo sounder was used with frequency 120 kHz and the elliptical transducer with opening angles of $4x10^o$ at –3 dB points. The pulse duration was set to medium (0.3 ms), and the TS and Sv thresholds to –56 dB and –70 dB accordingly. For data analysis the Simrad EP 500 post-processing software was used, and the echo tracking method was applied. The single fish criteria were set to min=0.8 and max=1.6 of the initial pulse length. The track was made of min 3 echoes with max one missing and the distance between consecutive echoes no more than 30 cm. Before the study the whole system was calibrated *in situ* according to the procedure described in Foote et al. (1987).

Due to shallow depths only horizontally looking transducer could be used for acoustical monitoring (Godlewska and Gliwicz 1999). Two approaches were used – stationary, in the vicinity of the barrier, and mobile, in the reservoir. Stationary measurements lasted for half an hour each (all together there were 32 such recordings) and they were taken at different beam positions (Fig. 1) and at different times during both day and night. Mobile measurements were conducted only at night from the 5 m long boat "Echo" sailing at the constant speed of 8 $km.h^{-1}$, with the geographical positions recorded by the GPS connected to the sounder. The transducer was fixed on a special frame in front of the boat at the depth of 0.5 m. Four transects were sailed along the main axis of the reservoir (Fig. 7).

2. RESULTS AND DISCUSSION

It was very difficult to perform the stationary acoustical measurements in front of the barrier, due to the proximity (only 2 m apart) of the foot-bridge made of material strongly reflecting sound (concrete with grating), as well as immediately after the barrier, due to nets extending behind the electrodes to catch the passing fish. Therefore the position of the acoustic beam had to be very carefully regulated to look either directly between the two sets of electrodes, or behind the nets, but not touching them (Fig. 1).

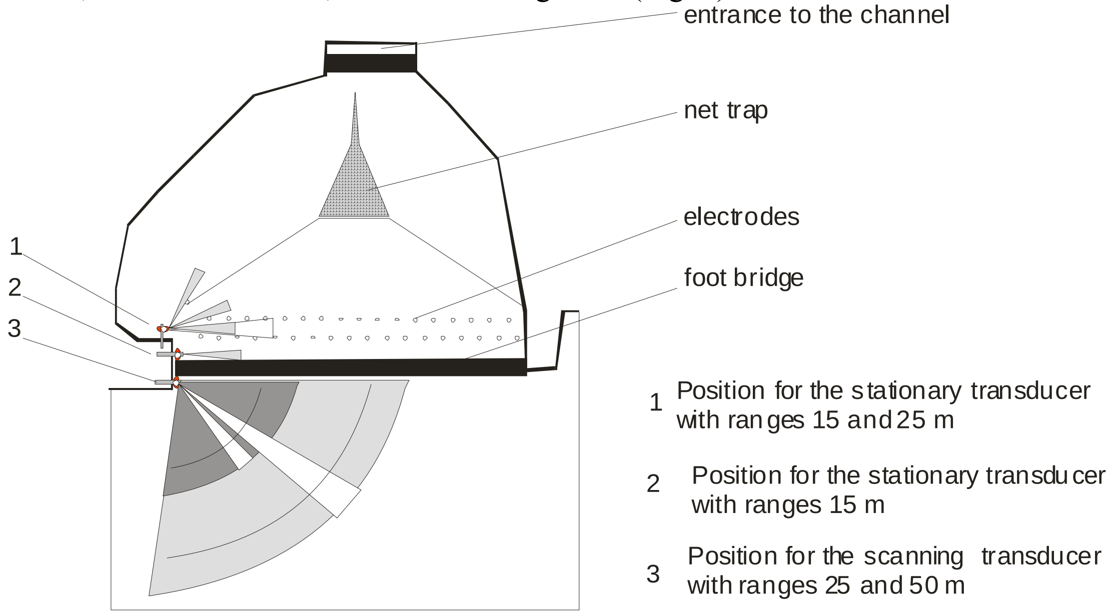

Fig.1 Scheme of the study area with transducer positions for the stationary measurements

The echograms for these two situations are presented in Fig. 2 and 3.

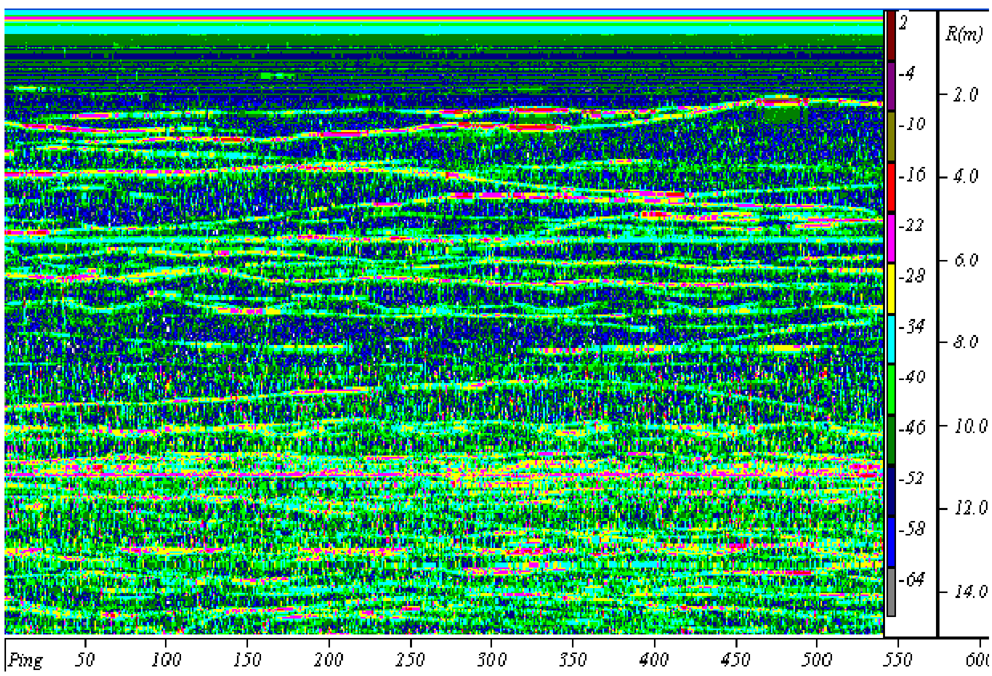

Fig.2 Echogram from the horizontally looking transducer at position 1 (Fig. 1), beam most to the left. Numerous fish traces are clearly seen. Electric barrier on

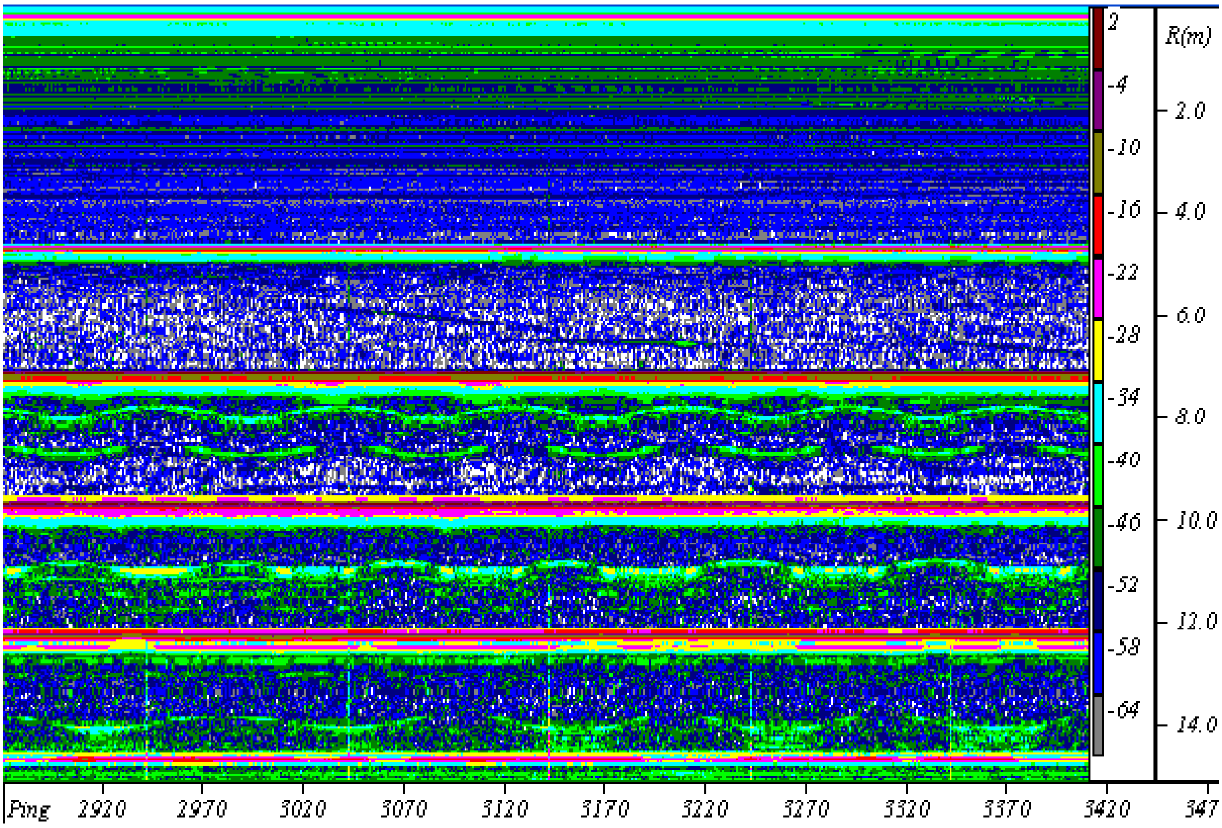

Fig.3 Echogram from the horizontally looking transducer at position 1 (Fig. 1), beam between the electrodes. Reflections from 5 electrodes are clearly seen as strong red lines, however there are no fish echoes between the electrodes. Electric barrier on

In the area to the left of the barrier there are many fish traces (Fig. 2, green-yellow-red long lines), which only slightly change their position, keeping close to the barrier. They are probably the fish that were travelling against the current and were stopped by the barrier or the nets. When the echo-sounder beam was directed exactly between the two lines of electrodes, and the electric current was on, there was a clear reflection from electrodes themselves (Fig. 3, strong red lines) and regular weaker scatters from their elements (green), but no echoes from fish were detected. Since only the area between the two first electrodes (from 5 to 7 m) was free of disturbances, only this area was used for fish analyses. When the electric current was switched off, without changing the position of the beam, clear fish echoes appeared between all of the electrodes (Fig. 4). After the electric current was switched off, the number of fish entering the area between the electrodes was increasing with passing time, reaching some stabilized value after about one hour and a half (Fig. 5).

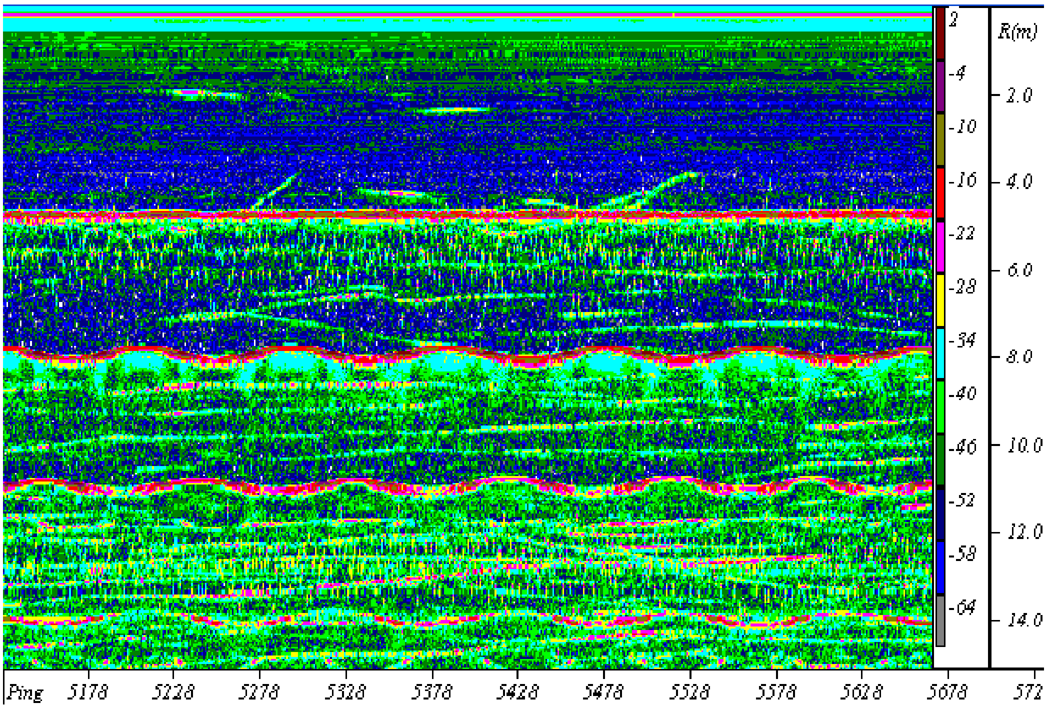

Fig.4 Echogram from the horizontally looking transducer at position 1 (Fig. 1), beam between the electrodes. Reflections from 4 electrodes are clearly seen as strong red lines (some look sinusoidal due to electrodes movements caused by wind), with clear fish echoes between the electrodes. Electric barrier off

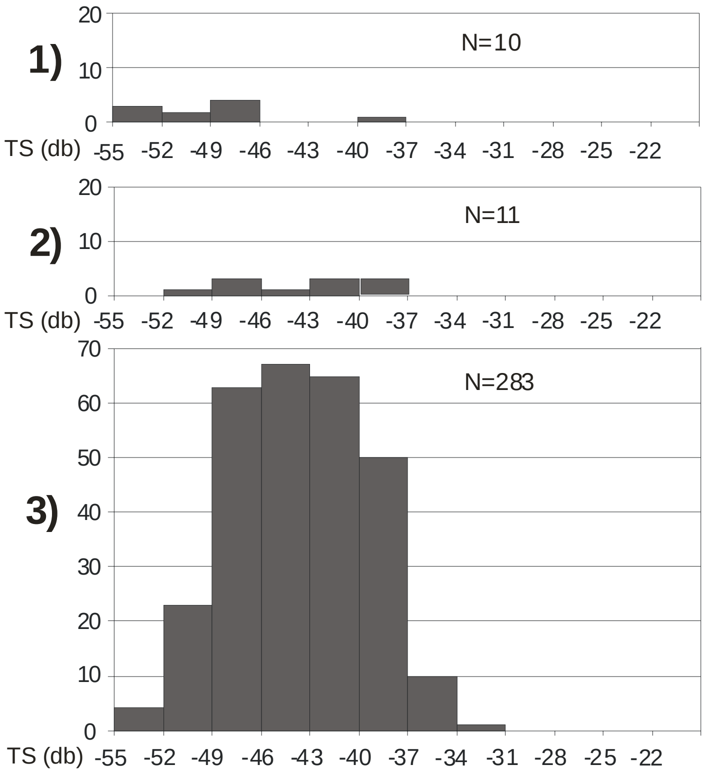

Fig.5 Number of fish and their size distribution between the electrodes when 1) the electric barrier was on, 2) 20 min after it was switched off and 3) 1 hour 30 min after the barrier was switched off

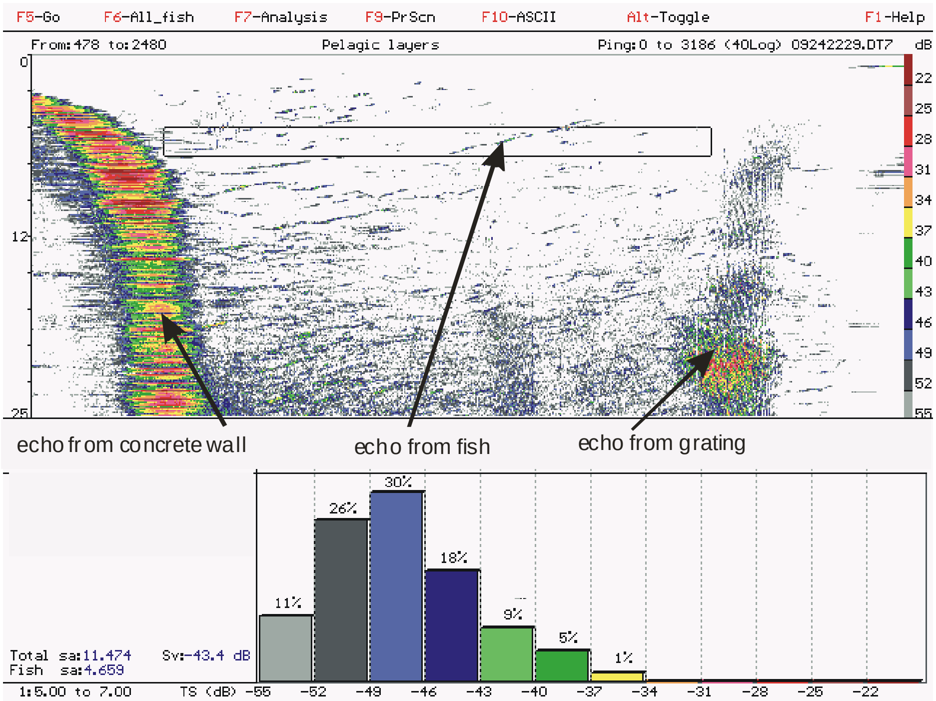

Fig.6 Echogram from the horizontally scanning transducer at position 3 (Fig. 1). Fish size distribution comes from the rectangular area indicated on the echogram

While 20 min after switching the electric current off, the number of fish entering the area between the electrodes did not differ significantly from that when electric current was on (10 and 11 fish accordingly), one and half hour later the number of fish stabilized at a level nearly 30 times higher, that is 283 fish.

Since the sampling volume of stationary observations was very small (only the distance of about 2 m long, from 5 to 7 m from the transducer face, was free of disturbances) a scanning acoustic system was applied with the acoustic beam changing slowly its position by more than 90 degree, starting from parallel to the foot-bridge. This allowed to increase the effective distance from transducer to nearly 50 m, and thus greatly expanded the sampling volume. The corresponding echogram with the analysis of fish acoustical sizes (histogram in dB) is presented in Fig. 6. Many fish tracks can be seen between the two limiting borders (the concrete wall on one side and grating on the other). The lower percentage of larger fish as compared to Fig 5, when the electric current was switched off, shows that larger fish are more strongly affected by the electric current than the small ones, as known from the electro-fishing literature (Cowx & Lamarque 1990). The mobile survey of the whole reservoir performed along the four transects as shown in Fig. 7 revealed strongly uneven fish distribution (Fig. 8).

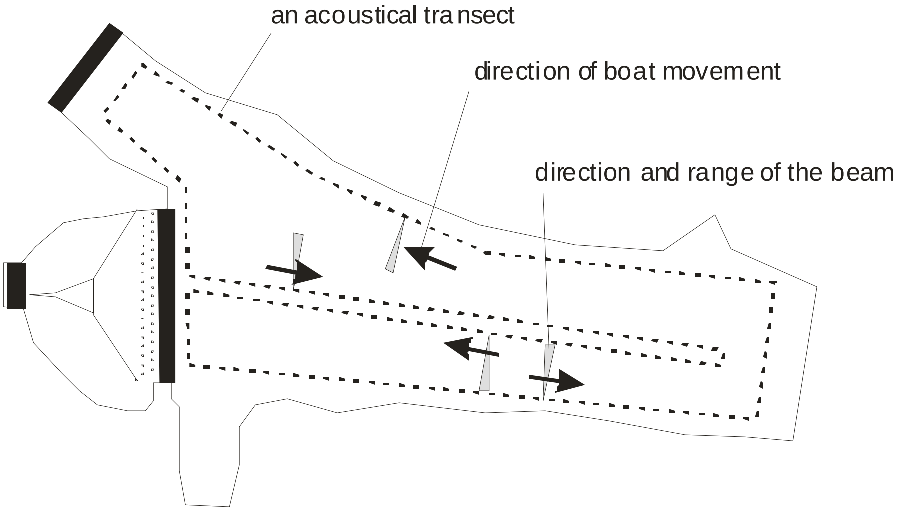

Fig.7 Transects of the acoustical survey on the Krzywaniec reservoir with the direction of swimming and of the beam indicated

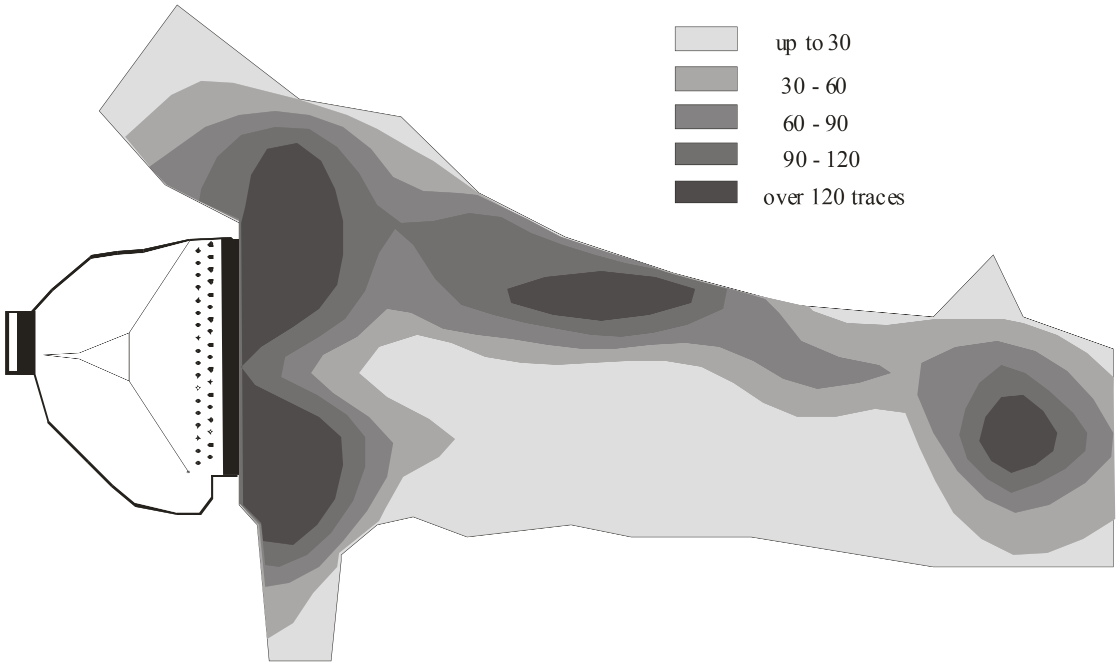

Fig.8 Fish density distribution in the Krzywaniec reservoir at night estimated from the mobile horizontal survey as indicated in Fig. 7

The left bank was practically devoted of fish, while maximal concentrations were observed in the vicinity of the barrier and along the right bank of the reservoir. The high abundance of fish covering the right bank can be easily explained by presence of abundant emerged macrophytes, in contrary to the empty opposite side of the reservoir. However, the high fish concentrations along the barrier may have at least two sources. It could be the result of the barrier, effectively stopping fish movements down the reservoir, and squeezing them in a smaller area, or fish could have been attracted by the lights illuminating the foot bridge. Since measurements were performed only during the night, it is impossible to exclude the second possibility.

The application of hydroacoustical monitoring allowed us to verify the effectiveness of a new prototype of electric barrier. These results are preliminary, but they look very optimistic. When the electric current was on, only negligible number of fish (about 3%) was entering the area between the electrodes. Although the reservoir above the barrier was abundant in fish, the electric barrier effectively limited their migration towards the dam.

AKNOWLEDGEMENTS

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