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# The effect of underwater noise emitted by motor boats on fish behaviour

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*The aim of the study was to determine susceptibility and avoidance behaviour of some freshwater fish exposed to underwater noise emitted by motor boats, most of all by the fishing boats with a Mariner motor (200 HP). The experimental station to study fish responses was located in Lake Narie. Pikeperches, breams and carps were placed in a net cage and exposed to noise emitted by an underwater loudspeaker, noise duration and its characteristics being pre-established. Fish behaviour was registered on a video tape and stored in form of files related to selected sequences. Pikeperch and bream did not show significant behavioural changes compared to the control periods. Carp, on the other hand, showed a noticeable and spontantaneous reaction, consisting of a 6-fold increase of the swimming speed. Adaptation period to noise of maximal volume was about 20 sec. It can be expected that in the conditions of the Vistula Lagoon, the minimal fish reaction will take place at a distance of about 150 m, while escape reaction should occur at 20 to 50 m. It is proposed to limit the speed of motor boats over fish spawning grounds and migration routes.*

## 1. Problem.

Acoustic disturbances of the freshwater ecosystems and their surroundings tend to increase. It has been assumed that there is a causative connection between the decrease of some fish resources and the increasing underwater emission of noise. Studies were conducted in the recent years to determine the level and spectrum characteristics of noise emitted by hydrofoil boats and a variety of motor boats used in the Vistula Lagoon. Fishing boats with an outboard motor Merkury-Mariner (200 HP) proved to emit the highest levels of underwater noise.

There were also some experiments carried out in the last years on the reaction of pikeperch, bream and pike to underwater noise emitted by a stationary boat with a Tohadsu (40 HP) motor running. Later on, underwater loudspeaker was used to emit noise recorded on a tape. This method made it possible to eliminate side-effects on fish of the hydrostatic pressure, water current, moving underwater objects, and water siltation.

The aim of this study was to determine threshold levels of fish susceptibility and avoidance reaction to noise emitted underwater by motor boats. A few fish species were selected, and an attempt made to preliminary determine possible results of intensive navigation on live aquatic resources, as well as to propose methods and means of limiting its harmful effects.

## 2. Study methods and conditions

Registered noise made by motor boats was played underwater using a system composed of a cassette player, an amplifier, and an underwater loudspeaker. An attempt was made to maintain the signal at the output from the measuring amplifier at the same level as the signal recorded in the field conditions. In order to check whether the underwater loudspeaker copied in an appropriate way the underwater noise emitted by fishery boats, measurements were carried out inside the fish cage of noise intensity and distribution. The underwater loudspeaker was made in the Institute of Telecommunication and Acoustics of the Polytechnical University in Wrocław. Nominal power of the Ist version was 100 W at average level of +36 dB re 1m 1Pa, and transmission band 100-10000 Hz. When this loudspeaker broke down, version II was used, having average level of +38dB re 1m 1Pa and transmission band 20-10000 Hz.

The station used to study fish behaviour in an acoustic field was located in a shed placed over poles set in Lake Narie. Fish were placed in a cage net and - after an adaptation period - exposed to noise emitted by the underwater loudspeaker, duration and characteristics of the noise being pre-determined. Fish behaviour was registered with a

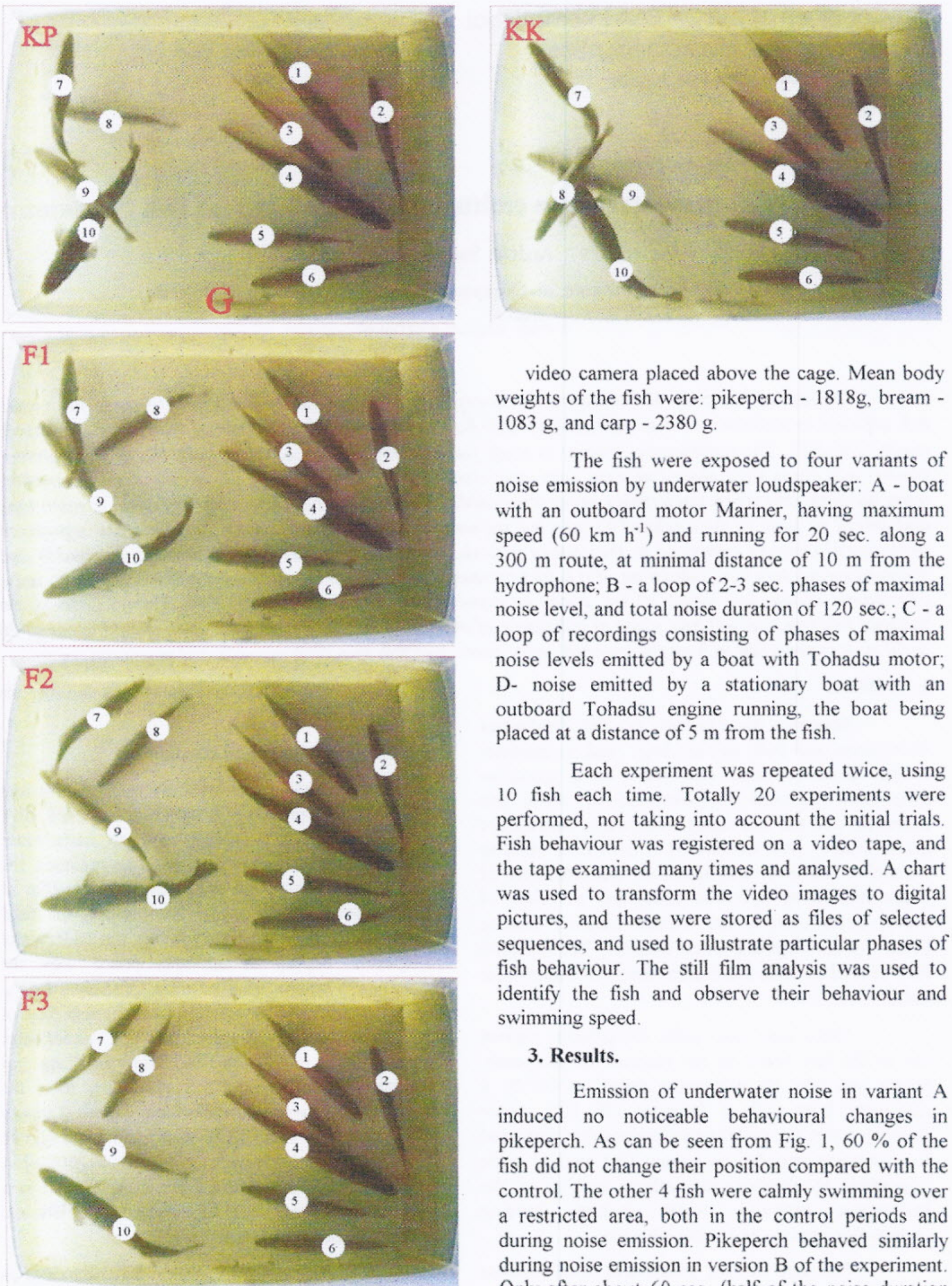



*Fig. 1. Responses of pikeperch to recorded underwater noise emitted by boat with an outboard motor Mariner. Variant A. (KP and KK - control before and after the experiment, F1, F2, F3- consecutive phases, 8 - fish identification number, G - location of the loudspeaker).*

video camera placed above the cage. Mean body weights of the fish were: pikeperch - 1818g, bream - 1083 g, and carp - 2380 g.

The fish were exposed to four variants of noise emission by underwater loudspeaker: A - boat with an outboard motor Mariner, having maximum speed (60 km $h^{-1}$) and running for 20 sec. along a 300 m route, at minimal distance of 10 m from the hydrophone; B - a loop of 2-3 sec. phases of maximal noise level, and total noise duration of 120 sec.; C - a loop of recordings consisting of phases of maximal noise levels emitted by a boat with Tohadsu motor; D- noise emitted by a stationary boat with an outboard Tohadsu engine running, the boat being placed at a distance of 5 m from the fish.

Each experiment was repeated twice, using 10 fish each time. Totally 20 experiments were performed, not taking into account the initial trials. Fish behaviour was registered on a video tape, and the tape examined many times and analysed. A chart was used to transform the video images to digital pictures, and these were stored as files of selected sequences, and used to illustrate particular phases of fish behaviour. The still film analysis was used to identify the fish and observe their behaviour and swimming speed.

### 3. Results.

Emission of underwater noise in variant A induced no noticeable behavioural changes in pikeperch. As can be seen from Fig. 1, 60 % of the fish did not change their position compared with the control. The other 4 fish were calmly swimming over a restricted area, both in the control periods and during noise emission. Pikeperch behaved similarly during noise emission in version B of the experiment. Only after about 60 sec. (half of the noise duration time) pikeperch began to show some distress symptoms, evidenced by increased breathing rate and pectoral fin movements. Also bream showed only more rapid fin and breathing movements during the peak (variant A) of noise emission.

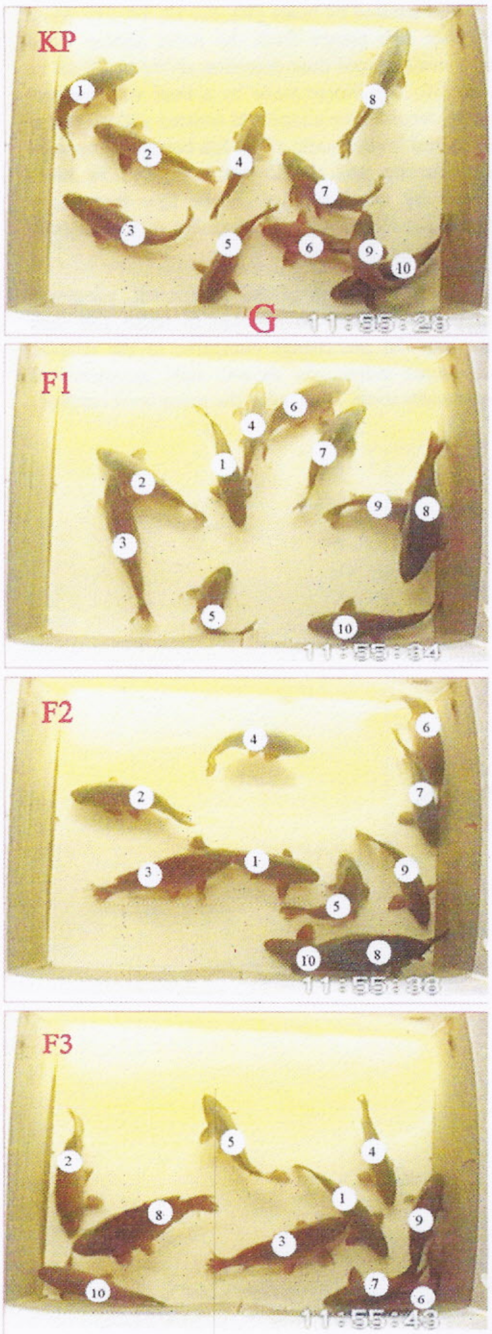
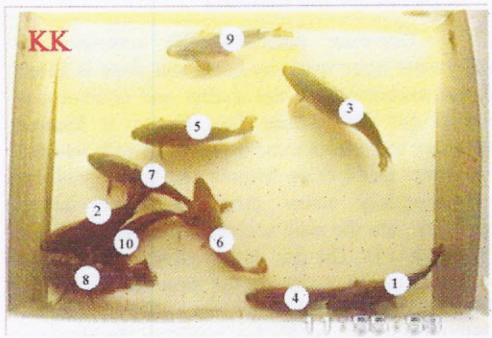



*Fig. 2. Responses of carp to recorded underwater noise emitted by boat with an outboard motor mariner. Variant A. (KP and KK - control before and after the experiment, F1, F2, F3 - consecutive phases, 8 - fish identification number, G - location of the loudspeaker).*




Notwithstanding this, the fish did not move much. During the experiment in variant D, the fish cage became silted; this was caused by Tohadsu engine running. Comparison of the results obtained in variants A and B, and C and D reveals that the responses of pikeperch and bream to underwater noise emitted directly by a motor boat were caused most of all by the current of muddy water made by the engine.

In variant A of the experiment, when the noise at first increased and then decreased, carp showed an instantaneous and spontaneous reaction (Fig. 2). It was manifested most of all by increased swimming speed. Changes of swimming speed of 10 carps exposed to the emission of underwater noise which was recorded during boat movements, are presented in part A of Fig. 3. Carp response consisted first of an increase, and then a decrease of the swimming speed, proportionally to noise level changes caused by boat moving to and away from the hydrophone. Swimming speed of carp, determined as the distance covered in 1 sec. in relation to body length, increase 5.5-fold on the average (from 0.06 to 0.33 L $sec.^{-1}$) compared to the control period.

Carp responses were also very noticeable and spontantaneous in variant B of the experiment. Differences in fish behaviour were related to the fact that the underwater noise was emitted at the highest level throughout the experiment. A period of certain adaptation to higher noise, determined as the swimming speed of 0.12 L $sec.^{-1}$, was attained by carp in about 20 sec. Maximal mean swimming speed increased 6-fold in this variant, from 0.06 to 0.36 $L.sec.^{-1}$ Comparison of carp responses evidenced by an increase of the swimming speed in variant A (boat moving along a route) and variant B (loop) is presented in Fig. 3. It shows that maximal swimming speed of the fish was similar in both variants of the experiment.

## 4. Discussion and summary

Literature describing fish responses to underwater noise made by boats and ships is based almost exclusively on the studies and observations carried out with marine fish. Hence, it became necessary to perform some experiments with selected freshwater fish species. Motors and boat vibrations, and especially screw propellers which induce cavitation, are the main sources of underwater noise [5, 8, 14, 15]. The fish detect sounds via sensoric spot cells of the otoliths in the inner ear [7, 9, 20]. Environmental conditions, in this background noise, and physical state of the fish influence the response intensity in form of escape reaction observed in fish exposed to underwater noise emitted by boats [10, 11, 12, 14, 21]. Most probably, fish escape from the noise source when noise levels exceed their detection ability by 30 dB or more [16, 17]. Noise made by a boat with mariner engine, recorded on a tape and emitted underwater at the highest level, should affect fish behaviour because its frequency was the lowest compared to noise emitted by other motors. These low frequencies correspond to the highest sensitivity of the majority of fish species [1, 3, 6].

In variant A of the experiment, pikeperch and bream showed no reaction to noise and their behaviour did not change compared to the control. Only some individuals showed mild symptoms of restlessness some 7 sec. after the noise level reached

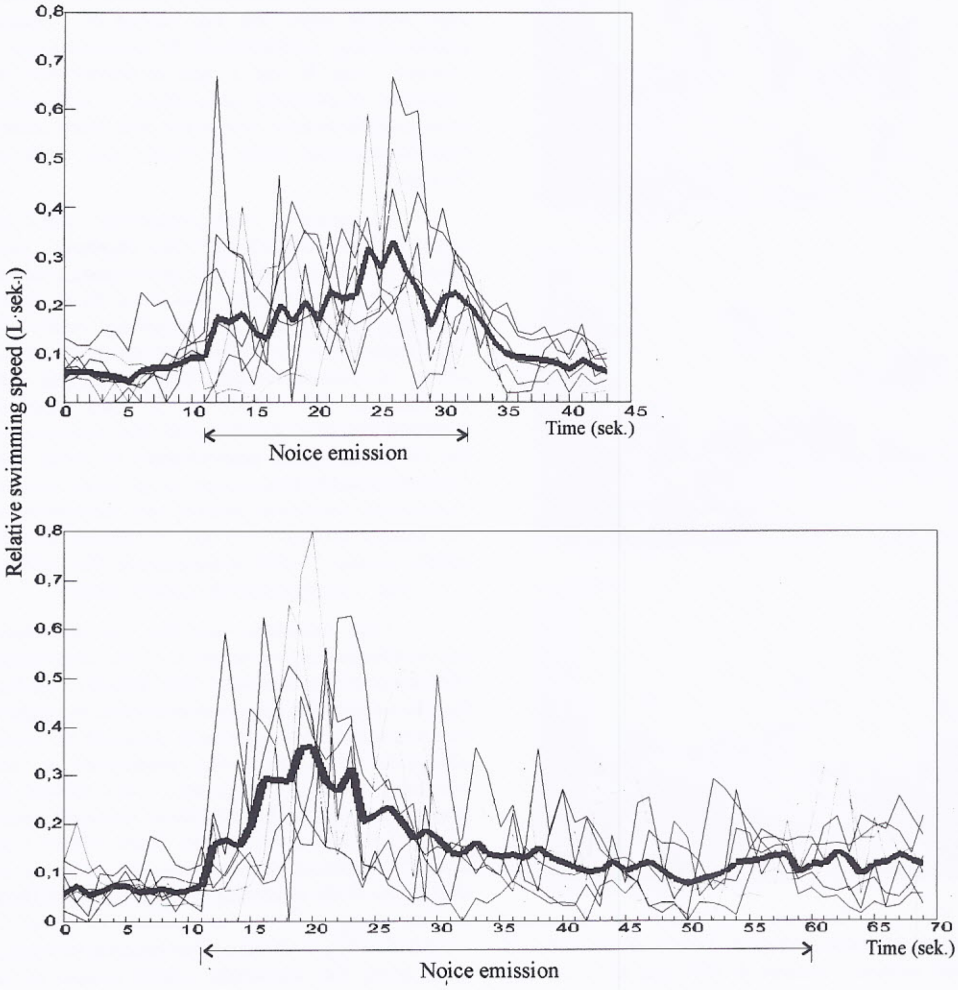



*Fig. 3. Comparison of the effect of emitting recorded underwater noise from a boat with a Mariner motor in variant A (boat running) and variant B (noise loops) on carp behaviour. Relative swimming speed of the fish was determined as the distance made during 1 sec. in relation to fish body length (L).*

the peak. These symptoms consisted of more intensive movements of the fins and increased breathing rate. In variant B (noise loop), part of the fish showed slight distress symptoms and changed their position in the cage.

In the experiments with carp, the loudspeaker was a little more powerful and had lower signal frequency range. Carp responses were very strong and spontantanous in both variants (A and B) of the experiment. This was evidenced by a 6-fold increase of the swimming speed. Analysis of carp behaviour in variant A (boat moving along a route) of the experiment (Fig. 3A) reveals that carps increased their swimming speed already from the beginning of noise emission at a distance of some 150 m. The cause for stronger and more spontantanous reaction of carp than of pikeperch and bream might have been the difference in fish susceptibility to sounds, difference in the loudspeaker characteristics, or both these factors.

The experiment focused on big and mature fish because much smaller fish were used in the previous experiments (e.g. pikeperch aged 0+), and these fish showed no response whatsoever to the acoustic field in the cage. The air bladder of fish functions as an amplifier of high sound frequencies, at a rate proportional to the diameter of a spatial equivalent of bladder volume [2, 18, 19]. According to Mitson, in the case of two times bigger cod, number of fish showing escape reaction increased twice [13].

Ability of fish to adapt to rapidly increasing noise levels is a yet another problem. Experiments revealed that the period of probable tiredness and partial adaptation of carps to maximal noise levels was about 20 sec. in variant B (Fig. 3). Usually acoustic stimulus first scares the fish, so that they escape to deeper waters, but they adapt fairly rapidly and then do not react to the subsequent noise. Fish response to sound is the more noticeable the higher the amplitude of acoustic pressure [10, 11, 12].

Navigation vessels usually move along strictly established routes. The effect of noise emitted by these vessels on fish reproduction and development should be relatively lower than of fishing boats which move around with no spatial limits, often over the entire area of a water body. Ways of sound propagation in water and level of the ambient noise should also be taken into account. Motor boats used in natural conditions affect fish responses as they make underwater noise, increase hydrostatic pressure, and induce strong water currents carrying mud and suspended matter. The effect of the latter may be stronger than of the noise itself. Assuming that threshold of sound detection by fish in the Vistula Lagoon could be close to the level of ambient noise, minimal reaction should take place at a distance of 150 m from the noise source, and escape reaction at a distance of 20 to 50 m.

Notwithstanding little data available, in order to protect live resources of fresh waters it would be advisable to limit the permissible speed of fishing motor boats outside the established navigation routes, especially close to the fish spawning grounds and migration routes. Diner and Masse [4] found that when ship speed was reduced by 24 % (from 8.5 to 6.5 knots), the distance at which fish showed a response decreased by 50 %, from 300 to 150 m. The need to limit power of the motors used by fishermen and speed of the fishing boats results also from the fact that these vessels usually exceed noise standards required by work safety regulations for the fishermen.

There is a need to continue studies on the responses of fish exposed to noise emitted by fishing motor boats. Their aim should be to explain the effect of noise level and frequency on the behaviour of particular fish species and sizes. To achieve this, the experimental station should be enlarged and the methods improved so as to ensure a variety of sound signals emitted to water as regards their level and frequencies.

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