DAY/NIGHT EFFECTS OF PASSING BOAT ON FISH DISTRIBUTION IN THE SHALLOW MALTA RESERVOIR

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Hydroacoustical measurements of fish population in the shallow Malta reservoir (mean depth <3 m) were performed in September and October 2008 using mobile horizontal beam. During the different time of day and night the same transects were covered in two directions, from the dam towards the upper part of the reservoir and back. During the day the number of fish registered on the returned way was lower than on the way forward in 83% of cases, and during the night in 67% of cases, however these differences were not statistically significant. Observation of fish at different distances from the boat have shown small avoidance reaction, especially for the small fish, that was similar during the day and at night, thus suggesting that mainly noise was responsible for the fish avoidance. Nevertheless, in shallow waters boat avoidance by fishes is of much less importance than in marine environment.

INTRODUCTION

Hydroacoustics is commonly used for stock assessments at sea. Over the past few decades, it has become increasingly important also to the assessment of open water fish populations in lakes and reservoirs. However, fish avoidance behavior could bias the results of acoustic stock assessments. There is a number of papers that focused on fish avoidance in the marine environment [1, 2, 3, 4, 5, 6], and they all have shown that avoidance could be a serious problem. Fish swimming away from the approaching boat, either horizontally or vertically, are exposing less reflective parts of the body to the sonar beam, and thus lower their TS. It is expected that in inland waters fish avoidance can cause even larger problem. Acoustic surveys in freshwaters are carried out by much smaller and less noisy boats than at sea, but on the other hand the distances are also much shorter, especially in shallow waters. Only a few authors have dealt with avoidance in freshwater environment [7, 8, 9], and the results are not unequivocal. Most avoidance behavior was found with small fish at distances less than 10 m. In Czech reservoirs no significant indications of fish avoidance were found [9]. However, in clear oligotrophic waters fish did react to the passing boat [9, 10], indicating that visual clues play an important role in avoidance behavior.

The aim of the present paper was to investigate whether in shallow Malta reservoir (mean depth less than 3 m), presence of small boat did influence the fish distribution and biomass estimates or not.

1. MATERIALS AND METHODS

The experimental work was conducted in September and October 2008 in Malta Reservoir (total area 64 ha, volume 2x10^6 m^3, mean depth 2.8 m, maximum depth 5.5 m), located in the city of Poznań (western Poland). This is a very shallow hypereutrophic reservoir [11]. During summer chlorophyll a concentrations fluctuated between 7.5 – 58 $\mu g dm^{-3}$, mean Ptotal was around 0.2 $mg dm^{-3}$, and Ntotal 0.6 $mg dm^{-3}$. The transparency measured by Secchi disc was below 1 m. Fish community was dominated by roach (*Rutilus rutilus*) about 70% of the population. Other species included perch (*Perca fluviatilis*), bream (*Abramis brama*), and among predators: pikeperch (*Stizostedion lucioperca*), pike (*Esox lucius*) and wels (*Silurus glanis*). The water temperature and dissolved oxygen content were measured in a central part of the reservoir at 1 m intervals from surface to bottom using the OXI 196 (WTW). Due to shallowness of the reservoir, water was well mixed and the thermocline was absent through the year.

Hydroacoustic measurements were conducted from the 5 m long boat "Echo" with 40 HP engine mounted outboard, sailing at the constant speed of 8 $km \cdot h^{-1}$. Parallel transects were run first in one direction and than immediately a second run in the reversed direction (Fig. 1), to check if passing boat affects fish distribution and the biomass estimate.

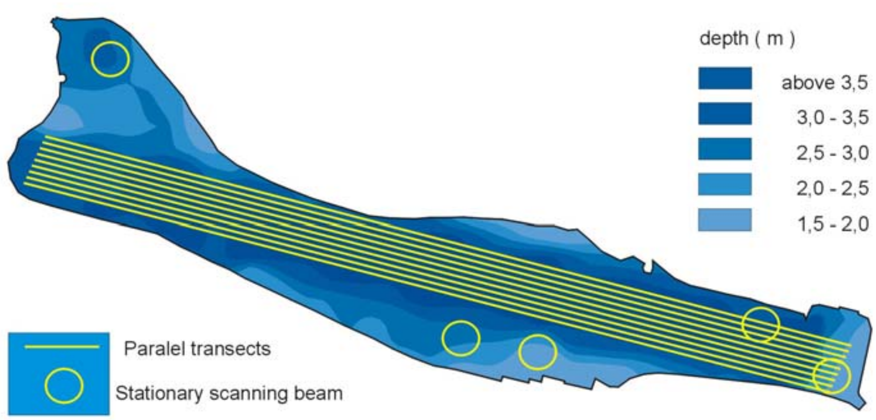


Fig.1. The contour of the Malta reservoir with bathymetry, survey transects and places of stationary measurements

The total length of transects was about 8.4 km, which gives the coverage coefficient, defined as the ratio between the total transects length and the square root from the area under study around 10 according to Aglen [12]. This is enough to expect coefficient of variation for biomass estimate to be well below 10% [13]. Apart from survey along the transects, a stationary measurements were performed in several points to estimate fish density without visual and hearing stimulus which could affect fish distribution during mobile survey. To increase sampling volume the transducer was rotated for 360 degrees around the vertical axis. The scheme of the construction used is presented in Fig. 2.

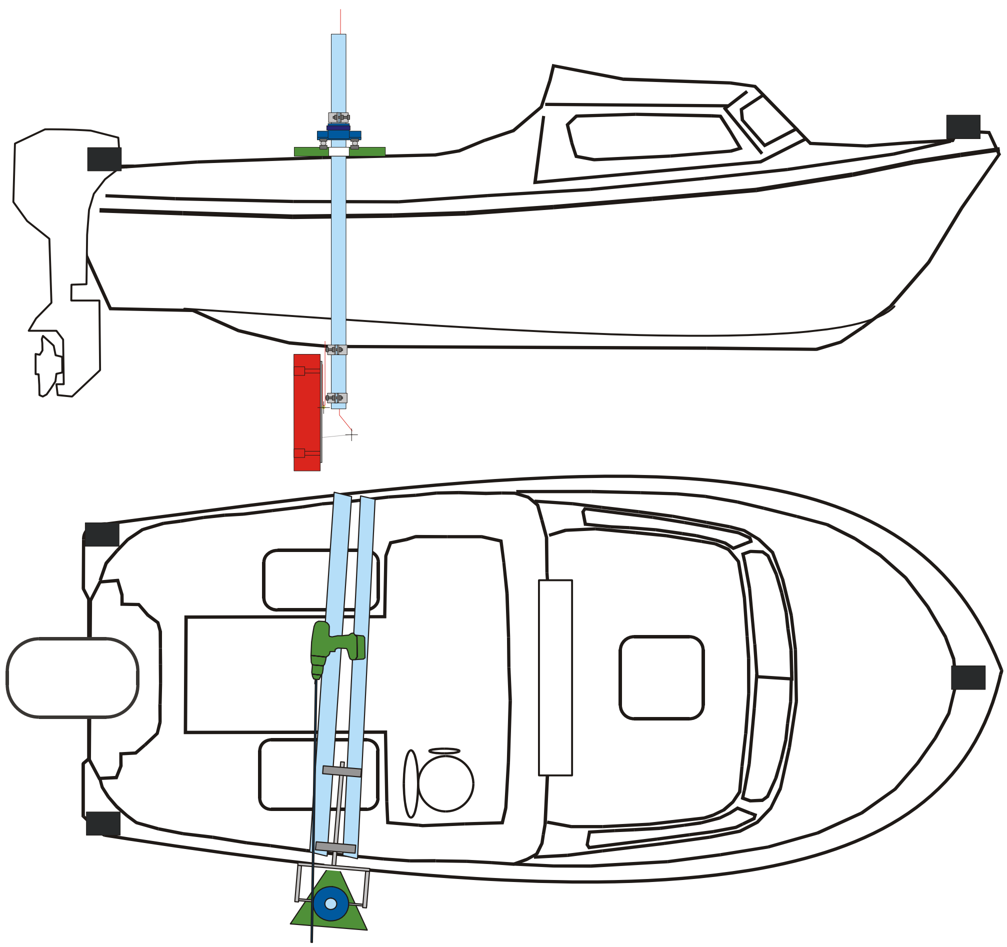


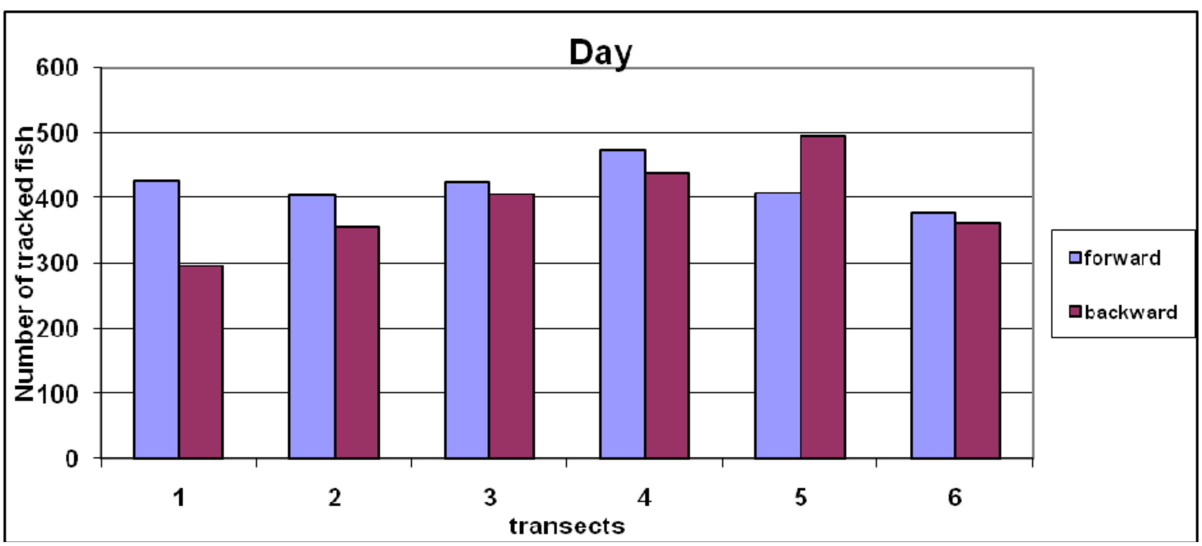
Fig.2. The scheme of transducer mounting and rotation

The geographical positions of the soundings were recorded by the GPS connected to the sounders. Hydroacoustic surveys were conducted at night, during complete darkness, and during the day, when fish could see the approaching boat. The Simrad EY500, split beam echo sounder with frequency 120 kHz and elliptical transducer (opening angles 4 and 10 degrees at -3dB) were used. The transducer was aimed horizontally (2 degrees from the surface, beaming perpendicularly to the direction of the boat) and was fixed on the side of the boat on a special frame at the depth of 0.5 m. The pulse duration was set to medium (0.3 ms), the ping repetition rate to 5 Hz, and the TS and Sv thresholds to –50 dB and –56 dB respectively. Simrad post-processing software EP500 and Sonar 5-Pro software version 5.9.6 [14] were used. Target strength frequency distributions were received by the automatic track analysis of Sonar 5. Tracking was based on single echo detections defined by 0.7-1.3 relative pulse width, a one-way beam compensation of 3 dB, and a maximum phase deviation of 0.3. To build a track the following criteria were set: at least 2 echoes for the same target, separated by a maximum one missing ping within a 0.3 gating range. From each track, the average TS from successive echoes was calculated in linear domain.

In order to identify the species and size structure of the fish, benthic gill net catches were carried out using the CEN standard [15]. Gillnetting was performed both the nights before and after the echo sounding. The nets were set before sunset and raised after dawn, for 12 hours periods, to include individual nocturnal migrations, and maximise the catches of the fish. After being removed from the nets, the fish were identified to species, weighed (to the nearest gram) and measured (total length, TL, to within one mm).

2. RESULTS AND DISCUSSION

During the day the number of tracked fish was about 4 times lower than at night. However, this was rather reflecting spatial fish distribution, which changes diurnally, and surely can not be attributed to fish avoidance during the day. Nevertheless, the first impression was that the boat was frightening the fish since during the day in 5 transects out of 6 (i.e. in 86% of cases) the number of fish registered on the way back was lower than when crossing the transect for the first time, and during the night it was lower in 4 out of 6 transects (i.e. in 67% of cases, Fig. 3).



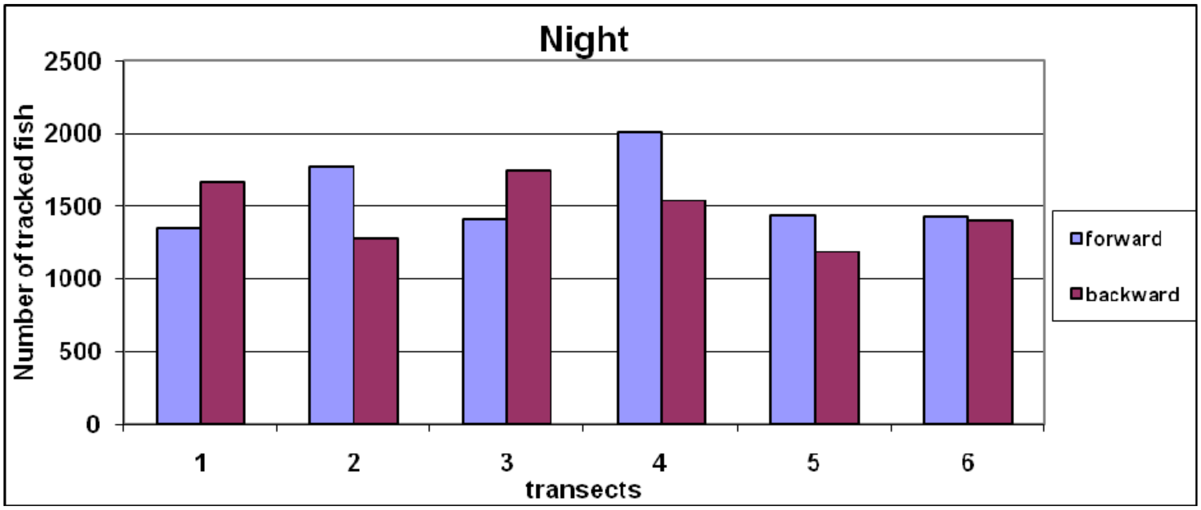


Fig.3. Number of tracked fish along the transect forward and back during the day and at night.

However, 6 transects is not enough to make statistically sound conclusions. Therefore we decided to divide each transect into 16 segments and made comparisons between them. The Fig. 4 presents points as number of fish registered on a given transect on the way forward and back, and the straight line is y=x.

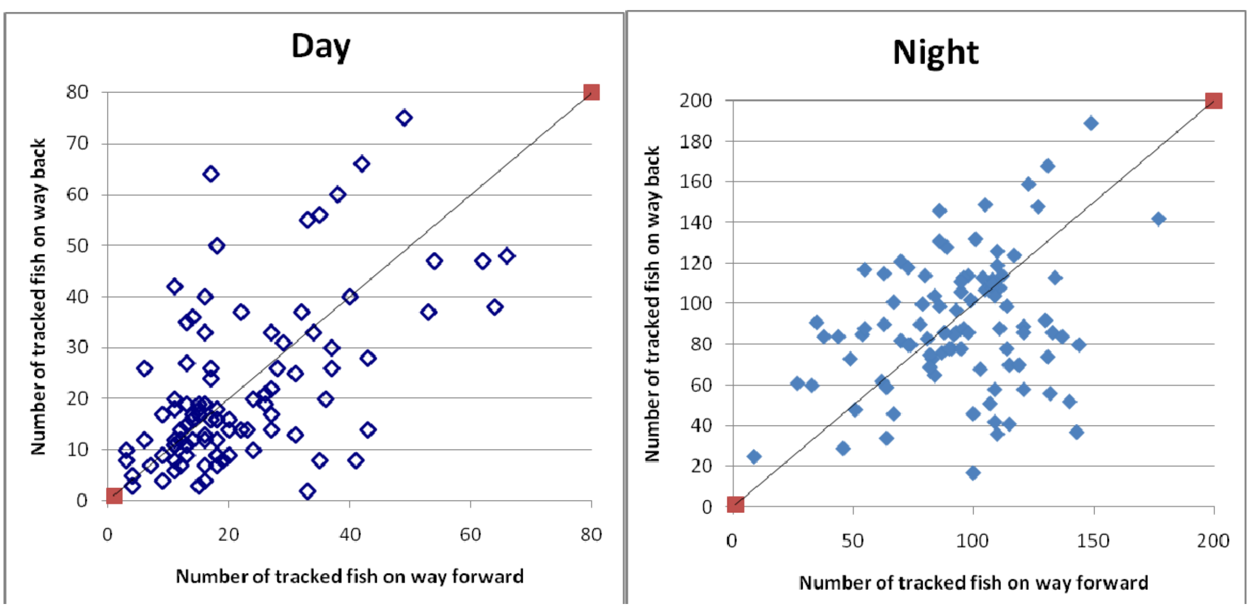


Fig.4. Points represent the numer of fish tracked in each segment,
while the solid line is a curve x=y

If the number of fish registered on the way forward and back was the same, all the points would lie on the curve x=y. If either direction, forward or backward would have any preference of being higher or lower, the points would concentrate on one side of the curve, below or above.

As can be seen from the Fig 4 this is not the case, no trend of constantly being lower for the transect back can be discernible. Considering small segments makes higher fluctuations than when analyzing the whole transects, and this small trend observed for the whole transects has disappeared when analyzing segments. In case of Malta reservoir, the transparency was rather low (Secchi disc< 1m), and it can be the reason why differences were not statistically significant. In fact the number of observed fish on all the transects was very stable and coefficient of variation did not exceed 5%. Our results are consistent with Drastic and Kubecka [9] who did not observe fish avoidance neither in shallow lake Balaton, no in Czech reservoirs, which similarly like Malta had very low transparency of water. By contrast, they did observe fish avoidance in very clear waters of oligotrophic lake Wallersee.

Fish avoidance from approaching boat may result from different sources of stimulation such as visual cues, anti-predator behavior, or noise. Visual cues play a role only in sufficiently light conditions, that is during the day, and especially in clear waters. Visual cues cause an increase in minimum approach distance towards a predator [16] with much stronger anti-predator behavior in small fish than in the big ones. Drastic and Kubečka have shown that also in case of a boat, small fish were avoiding survey boat to much greater extend than the big fish. Also in Malta reservoir (Table 1) it was very clear that both during the day and night in the shortest 5 m distance from the boat mean length of the fish was nearly twice larger than further away from the boat (calculated to cm according to the relationship by Frouzova et al. [17]. At even larger distances it was increasing again probably due to the beam covering areas closer to the bottom where usually large fish concentrate. The Fig. 5 shows that indeed fish lengths showed increasing trend with distance.

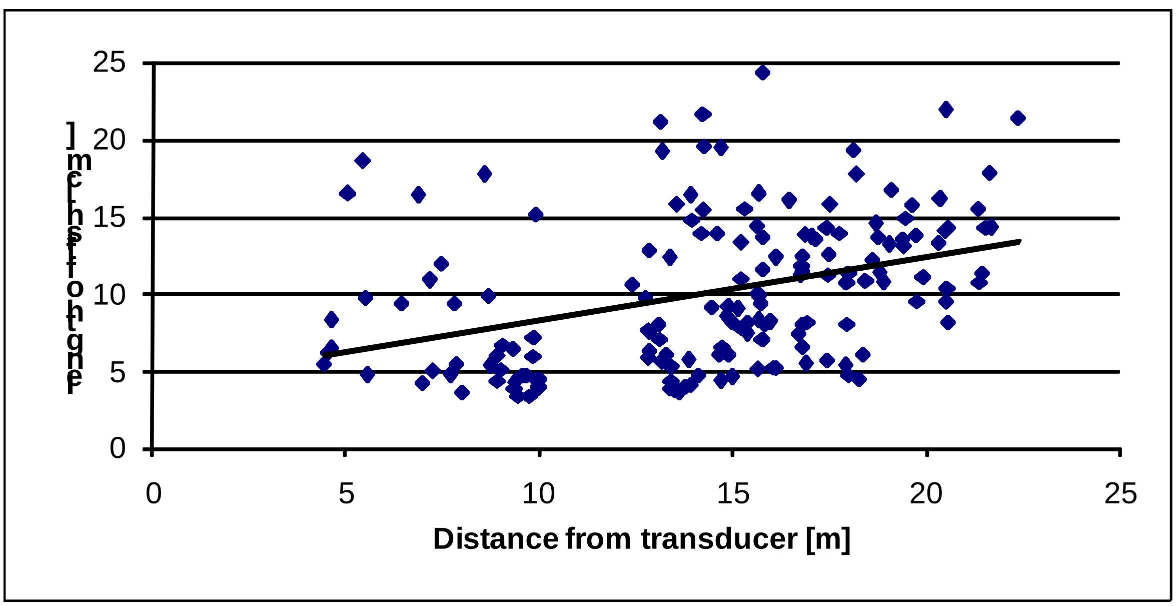


Fig.5. Length of fish on one of the transects as a function of the distance from the boat

Tab.1. Fish parameters during the day and night on one of the transects in different distances from the boat

distance	Number of fish D/N	Mean length D/N [cm]	Max length D/N [cm]	Biomass [$kgha^{-1}$]	Density fish$(1000m^3)^{-1}$
below 5m	21/6	10/11	19/17	10/16	5/8
between 5 and 10	93/34	7/6	18/22	25/21	12/16
between 10 and 15	147/59	10/10	18/55	42/90	13/16
between 15 and 20	189/67	11/13	24/62	30/141	9/14
above 20	36/25	15/13	22/43	25/113	5/27

Our results confirm conclusion that in eutrophic waters where visibility is low, visual cues are not very important.

The noise of the boat can cause the avoidance behavior as well. Sound detection capabilities of fish are characterized by wide spread of the sensitivity and the frequency range of hearing among species. Some fish such as a carp (*Cyprinus carpio*) are considered to be “hearing specialists”, because they are particularly sensitive to sounds over a wide frequency range, from 460 to 1500 Hz [18]. However, the range of hearing frequencies of freshwater species is hardly studied. The results for perch (*Perca fluviatilis*) have shown that perch readily responds to infrasound frequencies from 300 Hz down to 0.3 Hz [19], that is within a range of spectrum of the noise produced by the boat engine. Our results received at night are similar to those during the day suggesting that it was the noise that was most probably responsible for the observed avoidance. Drastic & Kubečka [9] did not observe night avoidance. It can not be excluded, that since appearance of moto-boats in these reservoirs is quite common phenomenon, the fish got used to, and did not react to it. The other possibility is that the noise was lower than sound sensitivity threshold for dominating fish populations. Unfortunately neither the noise emitted by the boat was measured, no the value of threshold for the species present in studied lakes was known. We also did not observe clear differences between the mean fish densities estimated with mobile and stationary surveys. Thus, both literature data and our own results suggest that fish avoidance in shallow waters surveyed by small boats seem to be much less important than in marine environment, where larger and more noisy boats are used.

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