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Detecting changes in fish distribution by fixed-location horizontally-directed echosounder

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Fixed-location horizontally-directed echosounder was used in a deep stratifying eutrophic lake to study fish behavioural reaction in response to counterfeit information on risk to predation. It has been shown that after the treatment fish aggregated and moved inshore. The change in fish distribution was clear only immediately after the treatment, fading away few hours later.

1. Introduction.

Most hydroacoustic data on fish distribution in marine and freshwater habitats are based on vertically-oriented-beam surveys (MacLennan & Simmonds 1992). The same is true in regards to hydroacoustic data on diel changes in distribution of pelagic and littoral fish species, also typical cyprinids, that are known to shift between littoral and offshore habitats in their effort to compromise between the need to feed on rich offshore 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 (Gliwicz & Jachner 1992). Such vertical survey was also applied in our recent field study on the effect of the counterfeit information on the risk to predation (alarm substance from the skin of cyprinids' commercial catches) on fish distribution along the littoral-offshore transect in a stratifying eutrophic lake (Gliwicz 1992, Gliwicz & Jachner 1993, Gliwicz et al. 1998]. The diel change in the distribution of the dominant target fish, roach *Rutilus rutilus* L., a typical littoral-bound species, was not clearly displayed in traditional vertical survey, and this was the reason why we also tried to use the horizontal beaming in a similar way to that suggested by Kubecka [1996]. Such approach, starting from early seventies has been largely aimed at counting migratory salmonids [Mesiar et al. 1990, Staig & Johnston 1995, Ransom et al. 1998]. Recently it has been used in studies of fish behaviour in lakes and rivers [Kubecka & Duncan 1998, Kubečka & Wittingerova 1998, Comeau & Boisclair 1998].

We expected three advantages of horizontal-beaming from a stationary transducer. First, the data would not be affected by a known phenomenon of fish escape from the moving boat (Olsen et al. 1983). Second, this would allow to get data for the near-the-surface, top water strata (Gaudreau & Boisclair 1998). Third, this would lead to increasing sampling volume by making data along the whole length of the beam available up to 80 m (at 11^0 beam width and transducer at 2 m depth), instead of merely 10 m length at the vertical beam, in which fish could be counted only from the depth of 2 m to the depth of 12 m (maximum depth of roach occurrence).

The aim of the present work was to test whether the changes in fish behaviour caused by the odour of predator (cyprinid skin preparation) could be detected hydroacoustically. The study was part of a larger project CIPA-CT 93-0118 „Controlling the behaviour of planktivorous fish with counterfeit information on risk to predation" granted to Z. M. Gliwicz.

2. Materials and methods.

A single beam SIMRAD EY-200P echosounder with a 200 kHz, 11° beam width transducer was used. The transducer was fixed on a 4.0x0.8 m metal frame with two buoys at the surface and a weight attached to its bottom ridge, the frame anchored from its top ridge by three fixing lines, two in the front - sideways and one in the back. The transducer, fastened horizontally at 2 m depth, was facing offshore.

Echosounding was done using a pulse duration of 1.0 ms, ping rate of 3/sec, a receiver gain 5, and a time varied gain (TVG) function of 40logR. Calibration of target strength was made using a standard copper sphere (TS=-44.1 dB). Received signals were recorded using a tape recorder (SONY TC - D5M) and after digitizing in the laboratory they were analysed by means of a HADAS program.

The behaviour of fish was monitored over a period of 24 hour on 17 days in July and August 1996 (Table I), covering few days before the treatment, the day of the treatment and few days after the treatment.

Table I. Timetable of treatments and distribution of the total 48 hours of hydroacoustic recording.

Treat-ment day	Treatment time	Acoustic data from	to	Hours of record
5.07	19. - 20.30	1. 07	7. 07	8
16. 07	21. - 22 00	14. 07	20. 07	14
30. 07	16. 15 - 17	29. 07	1. 08	14
9. 08	16.15 - 17	7. 08	11. 08	12

Out of the four treatments, only two secured readable acoustical data from the horizontal beaming that could be used for analysis (30 July and 9 August). The night data could not be analysed due to very strong at 200 kHz signal from *Chaoborus flavicans* Meigen larvae, which completely masked the signals from fish.

The sampling time differed from 5 to 45 min. In order to find minimal time required for representative samples, the dependence between variability of fish density data and the number of pings was analysed. It has been found that variability of fish density was inversely proportional to the sampling volume and the sampling time (the sample's size, Fig. 1). The fluctuation of fish density was strong up to about 2000 pings, thus the records shorter than 10 min were disregarded.

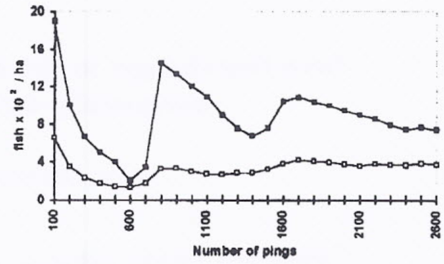

Fig. 1 Single fish (open squares) and total fish (filled squares) densities shown as integrated data for subsequently increasing number of pings, each subsequent point increased by 100 pings.

3. Results

From the integration of all the data available (one to five replicates for each hour point), it is clear that single fish density diminishes in early morning to increase again during the evening (Fig. 2.)

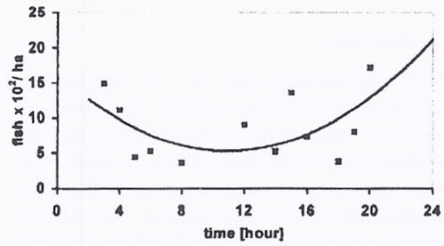

Fig. 2. Diurnal changes in mean density of single fish. Each point is the mean from all the dates for which the data are available, from one to five replicates for different hours, solid line being a best-fit trend.

This is in accordance with other observations on diel changes in roach distribution - fish staying in a safety of littoral during the day and surging offshore under the cover of night [Gliwicz & Jachner 1992]. From the recordings taken at dusk and dawn (Fig. 3) the rate of change in fish distribution can be determined. The best fit curve is not linear and the rate of movement is higher in the evening than during the morning.

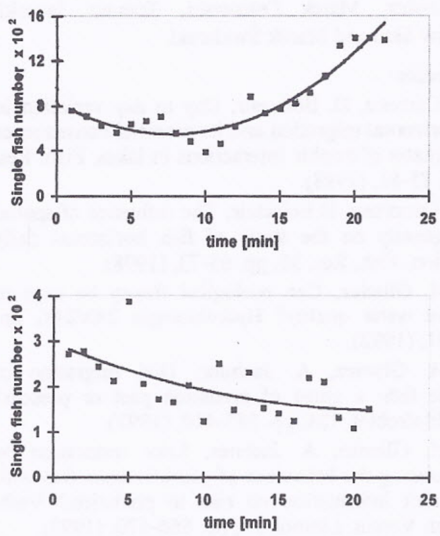

Fig. 3. The dawn (top) and the dusk (bottom) sequence of single fish number change on 7 August, two days before subsequent treatment. Each point is the mean for 200 pings (66 seconds of recording time).

One of possible fish responses to increased risk to predation is gathering into aggregations. Comparing the contribution of single fish to total fish density immediately before and immediately after the treatment (Fig. 4) one can see the dramatic change from more than 50% to only 4%. The change is very distinct, but short-lasting. From other observations it is evident that fish disperse again few hours later.

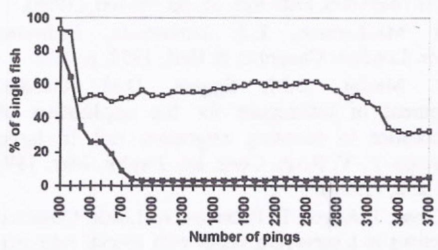

Fig. 4. The contribution of single fish to total fish density immediately before (open squares) and immediately after (filled squares) the treatment on 30 July shown as integrated data for subsequently increasing number of pings, each subsequent point increased by 100 pings

Contrary to 30 July (Fig. 4.) the change on 9 August was not as evident, the data being shaded by an accidental large fish aggregation passing through the beam. Comparing the % of single fish at 20.00 hour for a couple of days (Table II) however, one can see that on the day of treatment this value was significantly lower than during the other days.

Table II. Fish densities and percent of single fish in the total number of fish on all five dates the 20.00 hour's data were available including the data of the treatment day (9 August).

Day	Single fish density	% of single fish	Total fish density
29 July	2030	77	2647
7 August	845	85	996
8 August	1068	94	1140
9 August	3473	57	6131
10 August	1179	83	1416

It seems that effect of the treatment can be also seen in total fish distribution along the echosounder beam (Fig. 5).

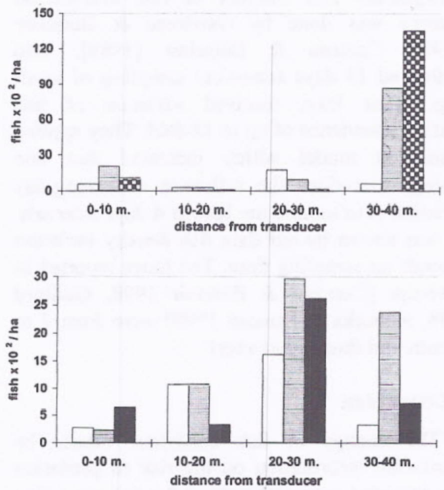

Fig.5. Total fish density along the echosounder beam at different distances from the transducer, immediately before (un-shaded), immediately after (light-shaded) and one (top) or three hours (bottom) after (dark shaded) treatment, on 30 July (top) and 9 August (bottom). Treatment start time on both dates, 16.15.

Immediately after the treatment fish density becomes higher at different distances from the transducer, most drastic change seen from 20 to 40 m. This suggest that frightened fish moves towards the shore, where transducer is situated. The possible inshore movement is further suggested by the bottom panel of Fig. 4, where fish density is shown longer time elapsed after the treatment.

4. Discussion

Our data show that fixed-location horizontally directed echosounder offers a good tool for studying changes in fish distribution in near-the-surface water strata of a deep lake, a tool as good as when used in a shallow lake. It seems that data properly reflect the main feature of fish behaviour such as diurnal horizontal migrations. Due to temporal and spatial resolution offered by hydroacoustics it is possible to receive description of fish distribution and their migration patterns with accuracy not achievable by other methods. The recorded fish densities, although fluctuating, were within a range of values estimated for habitats of similar trophic state, but different in origin, such as Czech reservoirs [Kubecka & Wittingerova 1998]. For a proper estimation of the fish abundance in lakes like Ublik Mały, an appropriate sampling strategy should be developed, taking into account its natural variability. A step in this direction, i. e. investi-gations on homogeneity and stability of fish distribution patterns was done by Gaudreau & Boisclair [1998]. Comeau & Boisclair [1988], who performed 15 days acoustical sampling of small oligotrophic lake, received variation of fish relative abundance of up to 12-fold. They applied simulation model which indicated that one strategy to reduce the influence of among-day variation is to sample the lake at 4 days intervals. As was shown by our data fish density variation depends on sampling time. The times reported in literature [Comeau & Bosclair 1998, Guillard 1998, Kubecka & Duncan 1998] were from 3 to 15 min and thus rather short.

5. Conclusion

The change in fish behaviour caused by counterfeit information on the risk to predation was recorded very distinctly. After the spreading of the alarm substance fish gathered into aggregations and moved inshore, where they could hide among vegetation. The ability of detecting gentle change in fish distribution along inshore-, offshore-transect, as well as change in the degree of aggregating, could suggest that horizontal beaming may be widely used as a method to study diel changes in fish distribution and fish reaction to the increased risk to predation by aquatic piscivores and waterfowl.

6. Acknowledgements

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