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Evaluation of the PhD Thesis

"Fish detection with modern sonar systems"

by mgr. Michal Tuser (School of Doctoral Studies in Biological Sciences, University of South Bohemia in České Budějovice Faculty of Science)

Modern sonar systems represent techniques that are fast, accurate and are non-intrusive, so they are more and more frequently used worldwide to examine the aquatic ecosystems over a broad range of spatial and temporal scales. In fact, they are the only ones that allow a remote continuous and synoptic observation of the individuals in their own habitats. The last years have continued to bring innovative developments both in the acoustic technology and in signal processing, widening their applications in many areas of both marine and freshwater ecosystems. The basic problem to be resolved by fisheries acoustics is the estimation of fish stocks. In spite of more than 50 years of hydroacoustic applications in marine and freshwater environments it is still not a trivial task, mainly due to the uncertainties close to the boundaries.

In this context the PhD thesis of Michal Tuser represent an important contribution to the present knowledge. His dissertation is focused on improving the methodology to detect fish and to estimate its true abundance with modern sonar systems.

The thesis are divided into three parts. First part is related to the correction of fish biomass estimates in water bodies which are characterized by the steep bottom profile. This part of work is continuation of author's B. Sci. Degree in ecology titled "The dead zone in acoustic detection of fish near the bottom of reservoirs, in Czech". This first part consists of two papers already published in high quality scientific journals. The authors have demonstrated in them:

1. that the formulas used so far to estimate dead zone are not applicable in case of highly sloped bottoms, and they proposed a new formula.

2. that undetected fish in the acoustic dead zone can seriously bias density assessment. From their measurements it follows that depending on the habitat, 36 to 75% of the gillnet catch by number was present in the acoustic dead zone, representing 5–51% of the biomass.
3. they proposed an original method to correct the bias in acoustic biomass estimates due to dead zone by concurrent sampling with benthic gillnets

The second part deals with the orientation of fish, which is crucial for proper fish biomass estimation in shallow waters, where horizontal acoustic beaming is applied. One of the biggest issues in the application of horizontal acoustics is the unknown orientation of the fish relative to the transducer beam axis. With vertically-aimed transducers, the fish are often detected in dorsal aspect or close to it. However, when the beam is aimed horizontally, the fish aspect angle can be side, head or tail. The difference in target strength between the two extremes (side and head/tail) typically ranges between 20 and 30 dB. Thus, without knowledge of fish orientation relative to the transducer it is practically impossible to obtain a reliable distribution of fish sizes. To overcome this problem it is widely assumed that fish are oriented randomly relative to the acoustic axis, and that the probability of detecting a fish in any aspect is exactly the same. In practice, the assumption of randomness of the fish aspect has never been tested by field measurements. The aim of the second part of mgr. Tuser's thesis was to test this hypothesis in lacustrine and riverine zone of the Rimov Reservoir. This part of thesis is continuation of his Master Thesis: "Fish orientation along the longitudinal profile of the Římov reservoir" and consists of one published paper. According to results received,

1. fish orientation in canyon-shaped reservoir is different between the lacustrine and riverine zones.
2. in the lacustrine environments of the reservoir, fish appear to move in random directions and the assumption of random orientation was confirmed.
3. in the riverine zone the fish directions are represented predominantly by side-aspects to the acoustic beam and movements parallel to the main flow. Thus, the assumption of random fish orientation used in acoustic surveys for biomass estimation is not valid in the tributary area and may lead to TS-overestimated size and biomass in these zones.

The third part is technically the most advanced and provides new information on precision and accuracy in gaining biological information about fish by using multi-beam sonar – DIDSON. This part of thesis is presented in a form of unpublished manuscript. Authors performed an experiment in the field to ascertain the dependences of fish detection and their length estimates using DIDSON on fish size, spatial orientation and range from the transducer. The measurements were performed on six fish from the family Cyprinidae, namely two bream Abramis brama (L.), three roach Rutilus rutilus (L.) and one common carp Cyprinus carpio carpio L., ranging from 10 to 60 cm in total length and weighing from 9 g up to 3.5 kg. As shown by the results from experiment, the ability to detect of any fish posed no problem when the fish were sideways to the transducer in any position from the center to edges of the beam array. However, the estimate of the fish length diminished to the edges of the beam array. When fish body aspect was altered, the detection probability and observed length of the fish dramatically declined with diminishing fish size and increasing distance from the transducer. Additionally, an effect of acoustic shadowing was observed, which could cause a drastic shortening of the observed length. In conclusion authors state that the current DIDSON with its capabilities and functionalities for both data handling and processing

1. cannot be quantitatively used for detection and sizing of fish smaller than 20 cm from variable aspects.
2. there is a need to improve signal-to-noise ratio or the resolution of the systems.

The three parts of the thesis clearly show scientific development of the candidate, who started from the easiest and most common vertical echosounding, through more advanced and difficult horizontal applications, finally to the most advanced and sophisticated acoustical cameras. And at each level of complexity he managed to solve the problem he was given in an effective and elegant way.

In conclusion: the thesis consist of four publications, three of them already published in very good, widely recognized international journals and the last one submitted for publication. Publishing of the results in high quality journals is the best proof of the importance of the undertaken studies and their high scientific value, already evaluated by the reviewers. The scientific achievements of the candidate are really impressive, he is co-author in 13 publications, all in highly impacted scientific journals, participant of 4 projects and numerous national and international conferences with oral presentations. I am fully convinced that presented PhD Thesis together with the scientific achievements of the candidate indicate that

he is talented researcher in the field of environmental sciences and definitely deserves the degree of Doctor of Philosophy.

None work is ideal, so I would like to add some detailed comments which do not change my overall very high opinion about the thesis:

1. The unpublished manuscript clearly needs language verification, as at present there are some sentences not possible to understand

2. Page 2
   It is written "Unfortunately, most conventional sonars (single-, dual- or split-beam) cannot determine fish size…", which is not correct since splitbeam systems can estimate fish size in dB
3. Page 5
   It is "As the conversion of acoustic target strength is immensely dependent on fish orientation in the sonar beam..", should be "As the acoustic target strength and consequently its conversion into fish length in cm is immensely dependent on fish orientation in the sonar beam.."
4. I do not like expression "standard acoustic experiment" in paper 4. In acoustics we have standard spheres and CEN standard (still under evaluation), I did not hear about any other standards

5. The equation on variance of product in paper 2 (page 52 of thesis) seems to be incorrect, see Leo Goodman (1960). ***"On the Exact Variance of Products"*** in *Journal of the American Statistical Association*, December, 1960, pp. 708-713.

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EVALUATION PhD THESIS MICHAL TUSER

As accepted reviewer of the PhD thesis "Fish detection with modern sonar systems" worked out by Michal Tuser, I state that this piece of work is definitely contributing to the field of freshwater fisheries science. Novel and innovative hydroacoustic applications are needed to enhance our knowledge about (acoustic) fish stock assessment methods by means of both limits and options. The candidate proved to be familiar with field work, post-processing and analysis of data, and to keep scientific standards. This comprises the use of "traditional" echosounders as well as "state-of-the-art" imaging sonars. The PhD should be granted.

Since there is no doubt that the candidate is able to use sonar systems in theory and practice, I would like to focus the discussion during the defense on some certain aspects.

Related question Paper I:

1. The acoustic dead zone on sloping bottoms is caused by the side-lobe effect. Sometimes a fish can be seen in a way like you show the FLO in Paper I, Fig. 5. Have you any idea if the TS of such detected fish are valid? Additionally, do you have any idea about the minimum size of fishes that can be detected in this way with respect to the slope? Probably I will present an echogram from Eder reservoir here.

Related questions Paper II:

1. I think that Biesbosch is a very special ecosystem. Do you have any idea if your results are transferable to other lakes and reservoir types in Europe, especially if you consider that reservoirs are definitely "more structured" than Biesbosch?
2. "The proportion of biomass obscured in the dead zone" is 1-12% for the study presented here. If you consider that biomass is almost a strongly varying factor during the seasons and years, do you think that the results should be considered in standard biomass surveys?
3. Do you have any idea if we are able to classify reservoir and lake types by their fish community to outline if your correction method should be applied or not by means of a standard procedure?

The orientation of fishes in the acoustic beam is a crucial part of (mobile) horizontal surveys as kind of "king discipline" in hydroacoustic science. The bias in biomass estimations can be enormous when the fish aspect is unconsidered or misinterpreted. Paper III gives a good idea about the complexity of this topic. I see this as a start-up for more investigations which are definitely needed.

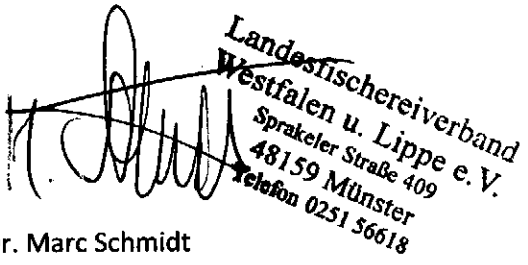
Related questions Paper III:

1. The study was carried out during five days in September. I guess that inflow and water level were more or less constant during this time. Higher inflow rates can cause a current even in a reservoir system especially in the tributary. Do you think that the orientation of fishes (even in the lacustrine zone) can be affected by this, e. g. during a period of flooding?
2. Your results clearly show how variable the horizontal aspect can be and which factors are influencing it. With respect to the investigated fish community, would you expect differences between a more lacustrine community and a community recruited from riverine ecosystems?

The use of imaging sonars has steadily increased during the last five years. Although most scientists and hydroacousticians definitely see the advantages of the DIDSON compared to other acoustic systems, it is needed to discuss the application of such systems in a critical way. Since the candidate proved to investigate and outline detection and measurement limits, I would like to discuss the results due to automatic detection and tracking possibilities, counting, and species identification purposes.

Related questions Paper IV:

1. Concerning the precision of fish lengths measurements your findings are coherent to our experiences. However, even the TS-TL relationships in horizontal split-beam applications (deconvolution) are an approach. Based on your widespread experience with both technologies, how do you evaluate this in the context of "acoustic accuracy"?
2. Your work is a stationary application. In a mobile hor/ver DIDSON application fish echoes become "snowflakes". If you drive the boat slowly enough you may be able to detect fish more precise at any aspect. Do you think that mobile horizontal DIDSON surveys can assist our demands with respect to fish density and biomass estimates in shallow waters and riverine environments?
3. You have tested three cyprinids. Nevertheless, the three species have different habitus. Have you observed any conspicuous features during you experiment which will provide species identification purposes in fixed horizontal application?



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