COMPARISON OF ACOUSTICAL ESTIMATES OF FISH ABUNDANCE FOR DIFFERENT COVERAGE AND SURVEY DESIGN

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The aim of this paper is to investigate the influence of the degree of coverage, survey design, and method of calculation on fish abundance estimation results. Measurements were performed in deep, mesotrophic lake, containing fish community dominated by vendace (Coregonus albula L.). Two types of survey design were applied: the regular parallel transects with constant distance between them and the triangular (zig-zag) transects. It has been shown that at high enough degree of coverage both designs give equivalent estimates of fish abundance and similar fish distribution, however at lower coverage the parallel transects are preferable. With increasing degree of coverage the fish abundance increases as well until some asymptotic value, which is reached at degree of coverage equal to 0.8. The three different methods of estimating total stock have been applied: arithmetic mean, weighted mean, and kriging. The estimates of fish abundance received by the first two methods were very similar, while the third one was significantly lower.

INTRODUCTION

The Water Framework Directive requires that all European countries monitor aquatic ecosystems and ensure their good ecological status till 2015 [1]. The WFD stresses the importance of biological indicators and among parameters to be measured indicates fish abundance. However at present reliable methods that are appropriate for monitoring fish abundance do not exist. It seems that hydroacoustics offers the most promising tool in this respect, at least for deep lakes, however it needs further development and standardization. Hydroacoustical methods have been used extensively at sea, where they became a standard [2, 3, 4], while in freshwaters the traditional fisheries methods are much more frequent. These methods are very tedious, time- and work-consuming, and applying them for monitoring all the water bodies would be very costly. The hydroacoustic methods by contrast are time- and cost effective, once the equipment is available. However applying them in freshwaters is much more difficult than at sea, due to higher variability of the freshwater ecosystems. Especially in shallow waters the disturbances due to short distance to the surface and bottom may completely prevent their use. The current practices in acoustic survey design and analysis procedures carried out are very variable and the comparison of different case studies is often impossible. Acoustic surveys are usually performed in large volumes of water. Due to limited time available to conduct such survey, only a small proportion of this volume is observed acoustically. It is assumed that acoustic measurements provide samples that are representative for the total water body, however precision of the results depends on transect spacing or so called degree of coverage. According to Aglen [5] it is defined as a ratio between the total length of the cruise track and the square root of the surface of the studied area. Coefficient of variation for the fish abundance depends on this degree of coverage and the type of fish distribution. Since fish distribution in a lake is neither regular, nor random, the only way to determine the coverage necessary for the required precision is to develop it empirically by *in situ* investigations. The results of Aglen were received for marine populations, whose distribution is usually more patchy than in a lake. For inland waters such investigations were not reported. Another important problem to be solved is the survey design. Two types of design are the most frequently used: the triangular (zig-zag) transects, especially popular in shallow waters, as they allow to avoid dangerous near shore areas, and the parallel transects (either randomly or regularly spaced). After an acoustic survey has been conducted, the routine analysis of the recorded data gives us as an output the fish density values for each Elementary Sampling Distance Unit (ESDU). The next step is to determine on the basis of the measured samples the total abundance in the surveyed area. This again can be done in a different way. The simplest one is to calculate the arithmetic mean for all the ESDU and multiply it by the surveyed area. The second way is to use the weighted mean, which takes into account the uneven fish distribution. It is often found that fish tend to concentrate in one localities and are scarce in others. Over the past decade there has been substantial progress in applying geostatistics to the analysis of acoustic surveys [6, 7]. Kriging is a powerful interpolation technique that is now accepted as a reliable way to construct contour maps of fish density distributions and it has been applied as a third method.

The aim of this paper is to investigate the influence of the degree of coverage, survey design, and method of calculation on fish abundance estimation results in lake Pluszne, a typical deep coregonide lake.

1. THE STUDY SITE, MATERIALS AND METHODS

The study was conducted in October 2007 in the largest (600 ha) and deepest (51 m) basin of Lake Pluszne (total area of 903 ha, mean depth 15 m), located in the northeastern Poland. This is a mesotrophic lake with vendace (*Coregonus albula* L.), as a dominating species. Vendace is very important both: commercially, because of its good taste, and ecologically, because of its role in lake eutrophication processes. On one hand vendace is often considered as an indicator of the healthy state of the lake, but on the other, being planktivore, it eliminate zooplankton from the lake, thus worsening its quality. Therefore monitoring of fish stock, to keep it at the right level, is required for both fisheries management, and ecosystem quality monitoring.

Hydroacoustical measurements were conducted 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. The SIMRAD EY500, split beam echo sounder was used with frequency

120 kHz and the round transducer with opening angle of 7^{o} at –3 dB points. The pulse duration was set to medium (0.3 ms), repetition rate to "as fast as possible" 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 integration method was applied. The Elementary Sampling Distance Unite was chosen to be 100 m which was small enough to reveal the distribution pattern and easy for calculations of area density. At the beginning of the study the whole system was calibrated *in situ* according to the procedure described in Foote et al. [8]. In order to identify the species and size structure of fish, the control pelagic catchments were made at different depths. The fish were measured and weighed individually. Water temperature and dissolved oxygen content were determined in a deepest part of the lake at 1 m intervals between the surface and bottom using the OXI 196 (WTW).

Three different factors affecting the estimate of fish abundance were investigated: 1. the degree of coverage, i.e. the proportion of the area covered with measurements to the total area of interest, 2. triangular versus parallel transects survey design, and 3. three methods of estimating total abundance on the basis of measured samples were applied, namely the arithmetic mean, the weighted mean, and the kriging method.

<u>The degree of coverage</u>

In order to investigate the influence of the degree of coverage on the estimated distribution and abundance of fish, the measurements were performed along 14 parallel transects running perpendicularly to the main axis of the lake and separated by 200 m, and two transects along the main axes (Fig. 1). The analyses were performed for all the transects, giving the degree of coverage of 1.1, for only parallel transects, which corresponded to degree of coverage 0.82, along even parallel transects (degree of coverage 4.3), uneven parallel transects (coverage 3.8) and every third transect (coverage 2.8).

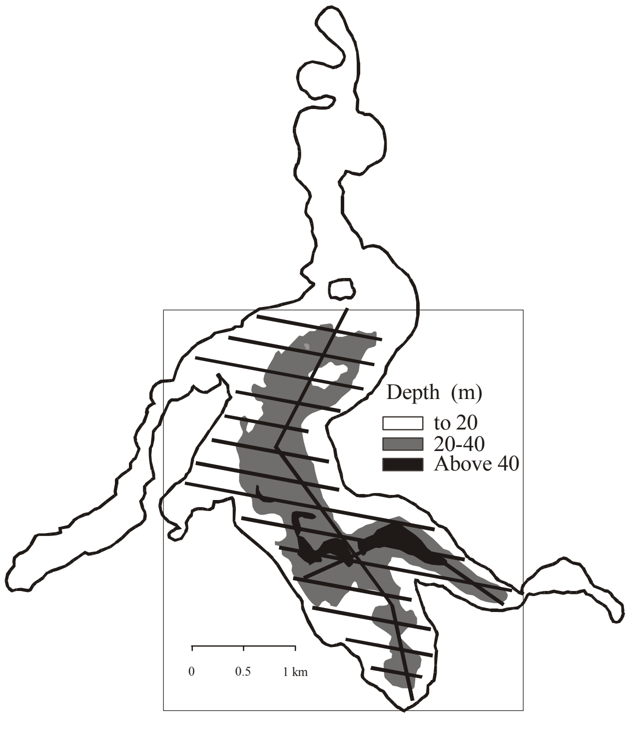

Fig.1 Bathymetric map of lake Pluszne and survey transects

Survey design

Hydroacoustical measurements were performed along the zig-zag transects with the distance between the turning points of 600-800 m, what gave the coverage of 0.7, and the results were compared with those for parallel transects that had the most similar coverage i. e. 0.82.

Method of calculation

The first method applied to calculate the total abundance of fish was just arithmetic mean for all the densities for each of ESDU's, multiplied by the area of interest. The second method was the weighted mean by transects. The mean density for each transect was calculated separately, and than weighted by the proportion of the given transect to the total survey track. Again the resulting value was multiplied by the area to get the total number of fish. The third method of determining the fish abundance was interpolation of data by kriging using data analyzing software Surfer. The detailed description of this method can be found in [6, 7]. The software was also used to make the maps of fish density spatial distribution.

2. RESULTS AND DISCUSSION

The use of acoustic techniques for studying fish populations is a recognized sampling method not only at sea but also in lake ecosystems, especially the deep and large ones [9, 10]. The densities recorded during an acoustic survey relate to the particular fish detected by the echosounder. Estimating the whole population from these samples involves some degree of uncertainty, dependent not only on the survey design, the spatial structure of the population and the inherent variability in the densities encountered, but also on the insonified proportion of the total volume. These proportions might be as small as 0.01% for a stock spread over a large area of ocean, and seldom exceed 1% for the lakes, only for the very small ones reaching values of up to 8%. In our studies we compared the distribution and total abundance of fish for coverage between 0.2 and 1.1. When analyzing the relationship between the degree of coverage and estimated total abundance of fish it is clear that at the beginning the abundance increases rapidly with increasing coverage, but than it reaches plato and changes are negligible. Fig. 2 shows that in case of lake Pluszne fish abundance at degree of coverage 0.8 does not differ practically from that at coverage 1.1.

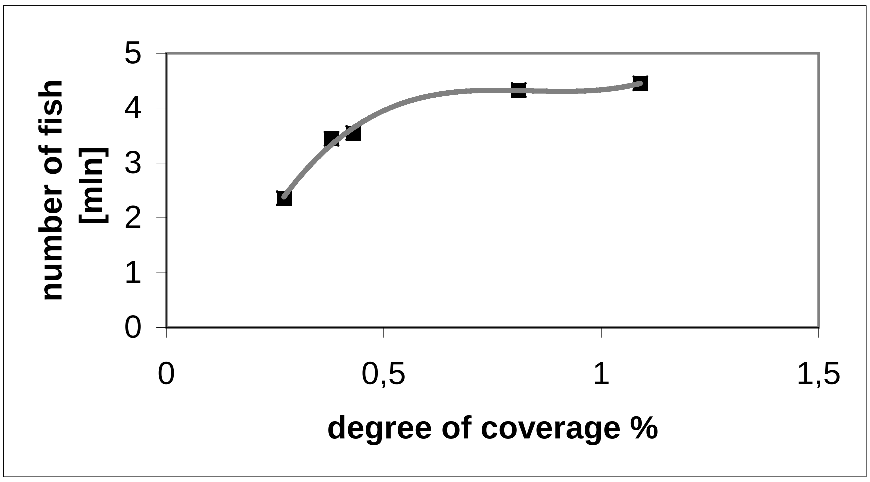

Fig.2 Abundance of fish estimated acoustically in lake Pluszne in relation to the degree of coverage

Also the spatial distribution at this coverage picks up the most characteristic structures of fish occurrence (Fig. 3).

Comparison of two different survey designs with the similar degree of coverage (Fig. 3) shows that they are equivalent. At the triangular transects with coverage 0.7 estimated total abundance was very close to abundance estimated at the parallel once with degree of coverage 0.8. Also the spatial fish distribution did not differ a lot. Since the zigzag transects have some advantages over the parallel ones, as they optimize the time used for measurements, and minimize time spent close to the shore, where can be dangerous, especially at night, due to shallows and obstacles on the bottom, it seems that they can be used efficiently whenever preferred for any reasons to the parallel transects.

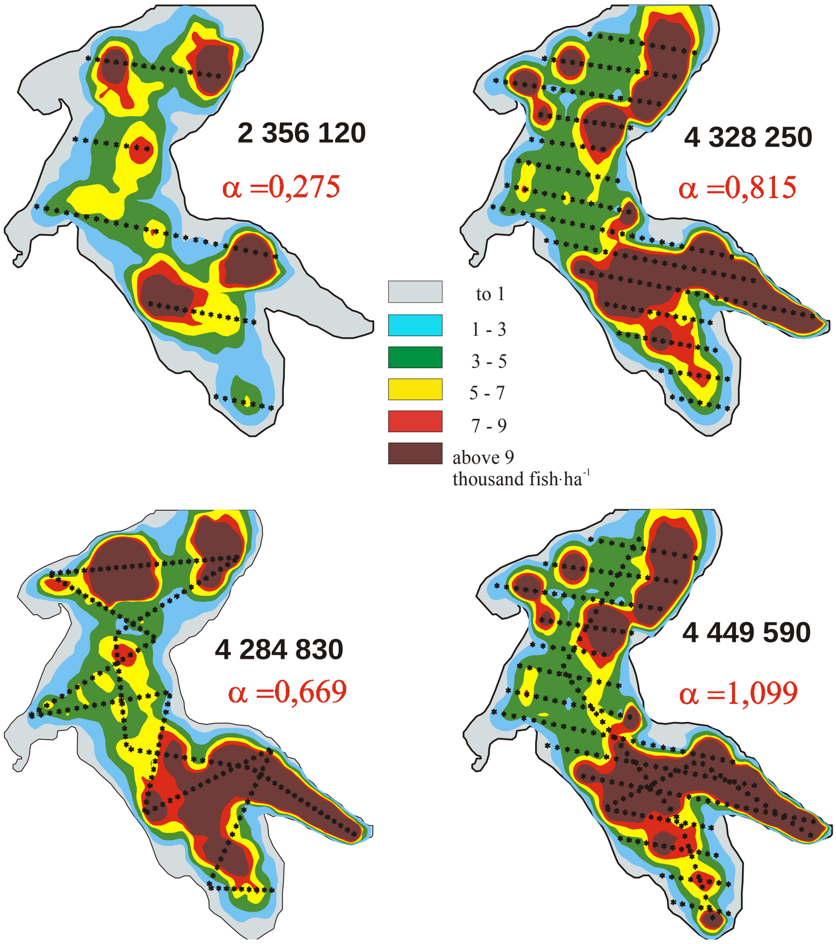

Fig.3 Total number of fish and its distribution in the Lake Pluszne at different degree of coverage α and survey design

The results for estimated fish abundance received at different survey designs and calculated with different methods are summarized in Table 1. While the arithmetic mean and weighted mean give very similar values, the abundance estimated with kriging is systematically smaller than the other two, independently on the degree of coverage. Unfortunately the program SURFER does not give the information on variance (it just calculates the total abundance of fish), so the comparison for statistical significance of differences is not possible.

Tab.1 Fish density [fishha $^{-1}$] in the Lake Pluszne estimated acoustically with different methods and survey designes

Typ of survey	Coverage	Fish density kriging	Fish density average	SD	N	Fish density weighted	SD	N
paralel	1.10	7 416	10 284	9 588	269	9 592	6 349	19
paralel	0.82	7 214	9 196	9 280	200	8 095	4 229	14
paralel	0.43	5 915	9 366	9 554	106	8 268	4 911	7
paralel	0.38	5 739	9 004	9 008	94	7 992	3 816	7
paralel	0.28	3 927	6 570	6 278	68	6 147	2 336	5
zygzag	0.7	7 141	10 090	10 609	192	9 575	7 238	12

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