HYDROACOUSTIC ASSESSMENT OF LAKE QUALITY WITHIN THE "DEWELOPMENT" PROJECT

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Deterioration of water quality and quantity is a world-wide problem. To prevent global water crisis, the European Water Framework Directive (WFD) requires that all European countries monitor aquatic ecosystems and ensure their good ecological status by 2015. Traditional methods of assessing water quality were mainly based on physico-chemical parameters of water, while WFD stresses importance of biological indicators and requires ecosystem approach within the whole water basin. With modern hydroacoustic equipment one can get not only detailed information on fish abundance, individual sizes, behavior, spatial and temporal distribution patterns, but also information on height, abundance and distribution of underwater vegetation and characteristics of bottom substrate. The acoustic measurements of fish and macrophytes were performed in 4 lakes of the river WEL catchment using Simrad split beam echosounder EK60, 70 kHz. Several acoustic metrics such as fish abundance, bubbles abundance and max vegetation depth were used as acoustic indicators of lake quality and compared with classification systems based on other quality indicators. The results have shown that hydroacoustics is a promising tool for monitoring and mapping an ecosystem.

INTRODUCTION

According to UNESCO experts declines in water quality and quantity are currently two of the most critical factors limiting sustainable development. The new European Water Framework Directive (WFD) requires that European countries perform regular monitoring of all surface waters and achieve their good ecological status by 2015. Monitoring procedures for biological elements of aquatic ecosystems, such as fish, phytoplankton, macro-invertebrates, macrophytes, etc. are not yet fully developed in none of the European countries. There were several EU projects that aimed at developing classification systems based on biological indicators and setting monitoring standards, to mention a few like REBECCA, STAR, ECOFRAME, EFI+, WISER. The DeWELopment project (www.dewelopment.eu) is one of them and is funded from the Polish-Norwegian Research Fund. It aims at conducting a complete and integrated, Water Framework Directive 2000/60/EU compliant assessment of the ecological status of all the surface water bodies within the river WEL catchment. It is based on many already accepted or being under development methods of quality assessment and includes also hydroacoustics. Novel hydroacoustic methods offer a new, potentially very effective remote sensing tool for monitoring of aquatic ecosystems. Echo sounding techniques can supply not only the basic information on fish abundance, individual sizes, spatial and temporal distribution patterns, but also on bottom sediments characteristics and macrophytes coverage, i.e. information on fish habitat. In opposite to traditional fishery methods, hydroacoustics provides synoptic, high resolution, area-based data, easy for mapping using GIS. The aim of the present paper was to show preliminary results of acoustic investigations within the DeWELopment project and compare them wit results of other assessment methods.

1. MATERIALS AND METHODS

In the river Wel catchment there are 10 lakes, but only the four deepest ones: Dąbrowa Wielka, Lidzbarskie, Kiełpińskie and Rumian were studied acoustically. Simrad split beam echosounder EK60, 70 kHz, with a ES70-11 transducer with opening angle 11 degrees was used. The pulse length was 0.256 ms, repetition rate 5 times per sec, and TS threshold was set to -60 dB to account for even the very small fish. Measurements of fish were performed at night, one hour after sunset, along the predefined parallel or zig-zag transects. To ensure uncertainty estimation, the coverage defined as the ratio between the all transects length and the square root from the lake area was pretty high, between 10 and 30 (Fig. 1).

Dedicated macrophytes measurements were performed in Lake Dabrowa in 3 small areas, in Lakes Kiełpinskie and Rumian along the zigzag track in the near shore area , and in Lake Lidzbarskie only max vegetation depth was determined from the recordings dedicated to fish survey. Measurements of macrophytes were performed during the day from the small boat approaching the shore as close as possible and swimming away until no macrophytes were detected on the bottom. All hydroacoustic data were analysed using Sonar 5 software [1]. The echosounder was calibrated using the Lobe calibration program.

The water temperature and dissolved oxygen content were measured in the deepest part of each lake at 1m intervals from the surface to the bottom using the OXI 196 (WTW).

Several acoustical metrics were considered as indicators of the ecosystem quality: fish abundance, bubbles abundance, max vegetation depth. Lakes ordered in their quality from the best to the worst based on these metrics were compared with other assessment methods such as chlorophyll *a* concentration, % of microcistis in phytoplankton and integrated macrophyte index [2].

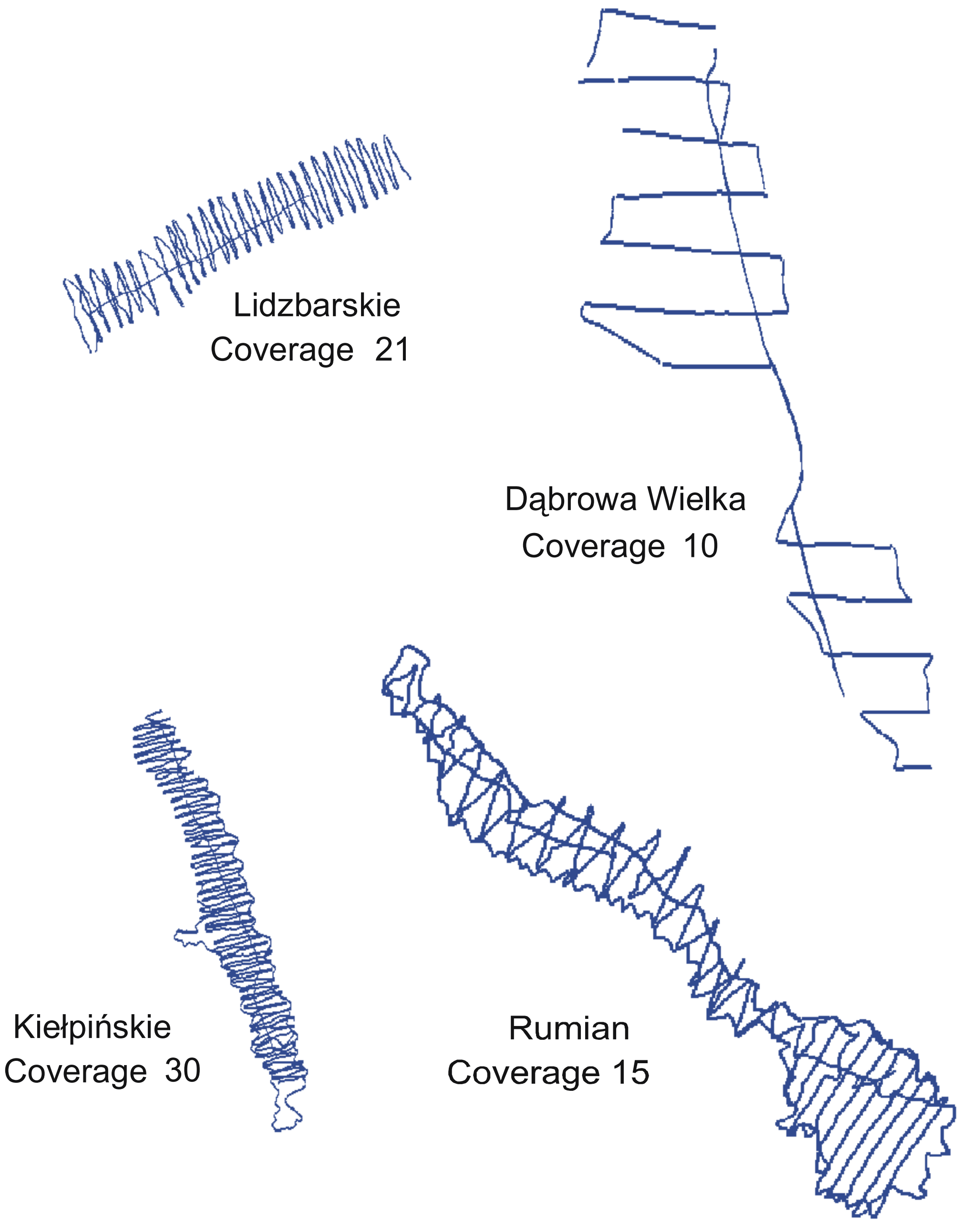

Fig.1. Hydroacoustic transects with coverage defined as the ratio between the total transects length and the square root from the lake surface

2. RESULTS AND DISCUSSION

The results of temperature and dissolved oxygen measurements have shown that in 3 out of 4 lakes there was no oxygen below the thermocline (Fig. 2).

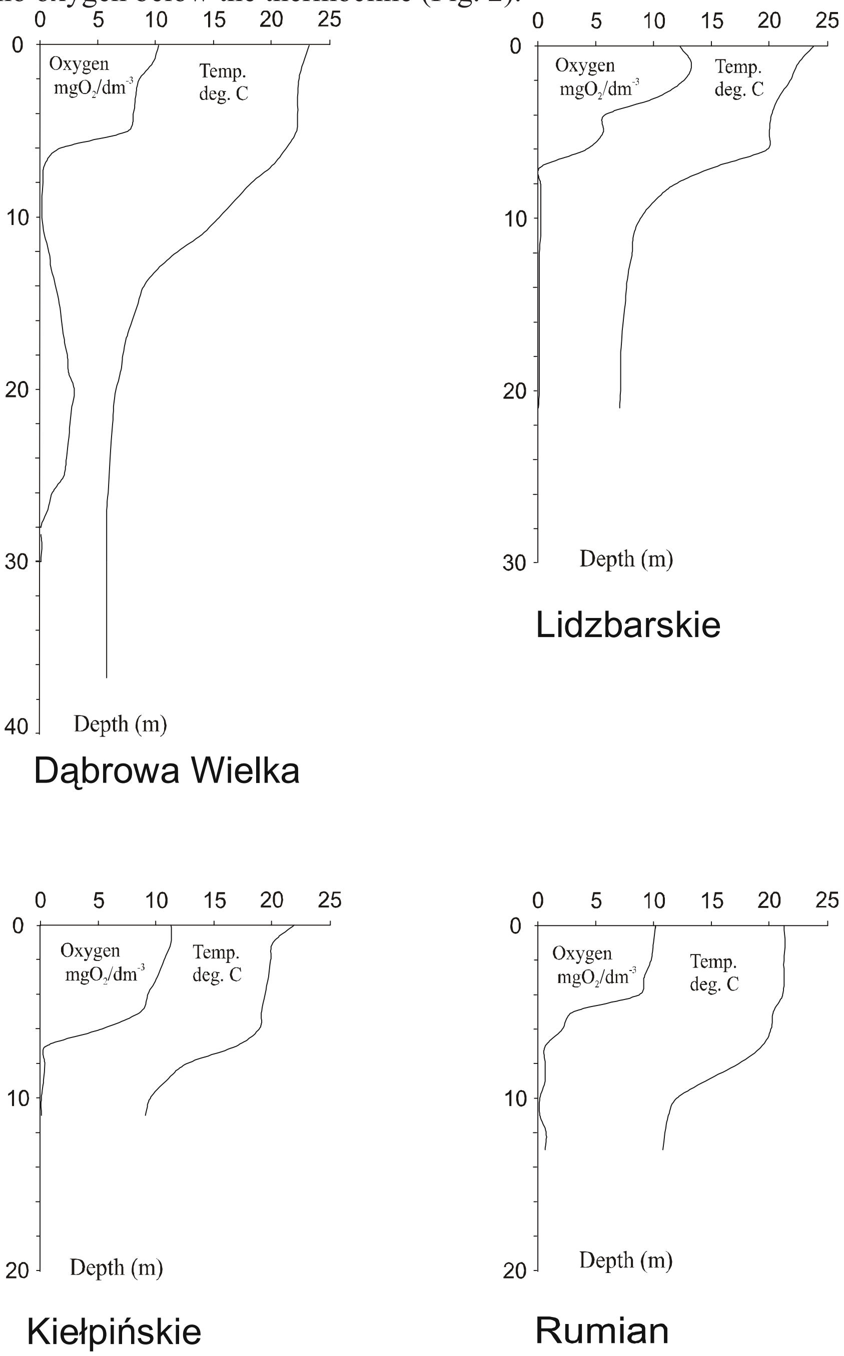

Fig.2. Temperature and dissolved oxygen profiles in studied lakes

As the consequence there were no fish there, instead there were gas bubbles coming out of the bottom due to decay of organic matter. The bubbles were very well distinguishable during the stationary measurements, but difficult to separate from fish during mobile survey (Fig. 3).

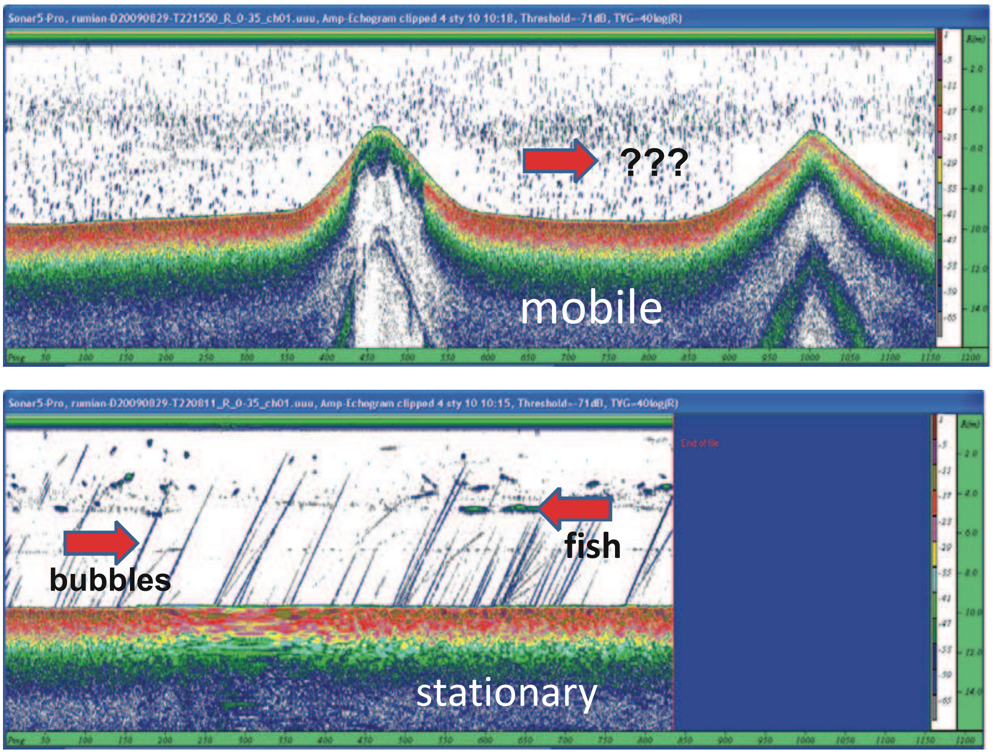

Fig..3 Example echograms with bubbles during stationary and mobile survey

Vertical distribution of the targets indicated, that in the upper layer (above the thermocline) all sizes targets were evenly distributed, while in the lower layer (below the thermocline), mainly smaller targets were present (Fig. 4). Since there was no oxygen below the thermocline it has been assumed that all targets below the thermocline are bubbles, while above the thermocline there is a sum of both: bubbles and fish. The calculations of fish and bubbles abundances were done taking into account these assumptions (Table 1). There is an extended literature [3, 4, 5, 6] showing that with increasing eutrophication level fish abundance also increases until some level, after which it drops again. Three of studied lakes most probably were already on this descending side, since we observed increase of bubbles with decreasing number of fish. Without doubt the bubbles were caused by anoxic conditions at the bottom (and not by its geology) since they were present only in these parts of the lakes where depth exceeded the thermocline depth.

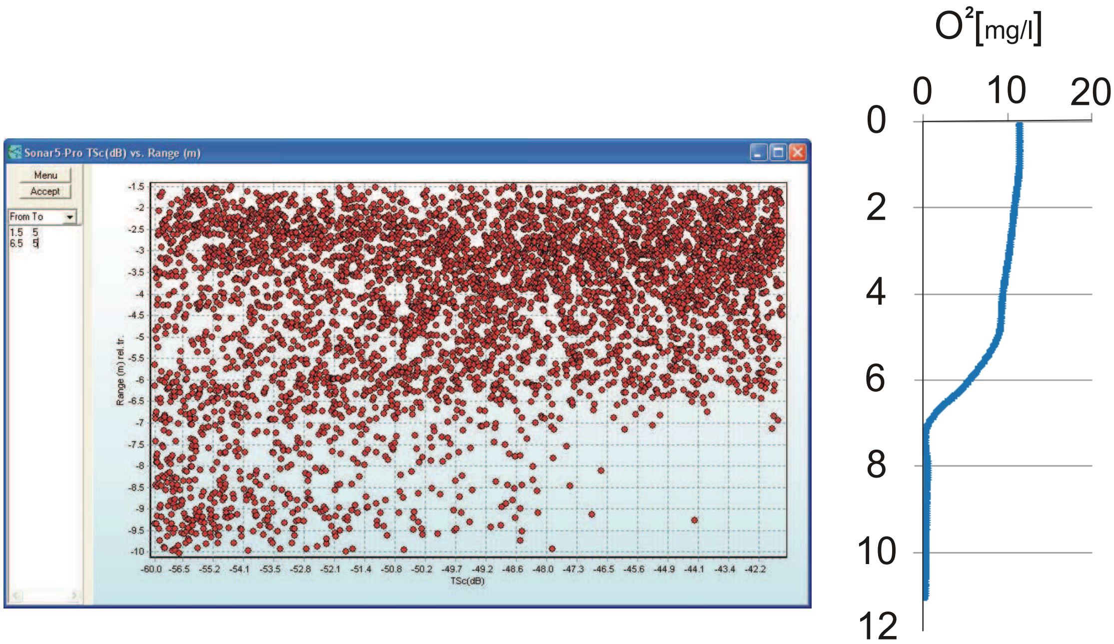

Fig.4. Depth distribution of single echo detections (SED) in lake Kiełpińskie

In lake Dabrowa Wielka the hydrological situation was slightly better (may be because the measurements were done two weeks earlier), there was some oxygen left below the thermocline, and there were clear traces of vendace, which inhabits hypolimnion of the deep lakes. So in the lake Dąbrowa Wielka there was a separation of vendace below the thermocline and other fish species, mainly cyprinids, above the thermocline (Fig. 5).

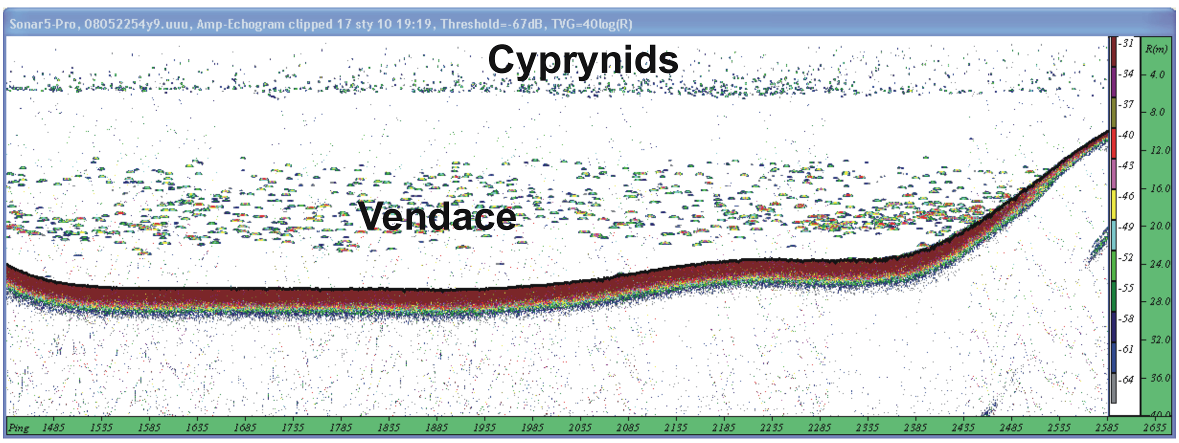

Fig.5. Example of echogram from Dąbrowa Wielka with cyprinid fish above the thermocline and vendace below the thermocline

Tab.1. Acoustical parameters used as indicators of lake quality

Lake	Fish/ha	Bubbles/ha	Max vegetation depth	Average macrophyte range
Dabrowa Wielka	11 474	0	8.3 m	6.4 m
Kiełpińskie	25 800	849	7.5 m	6.5 m
Rumian	16 900	3 100	7.6 m	6.4 m
Lidzbarskie	7 500	3 380	3.5 m	3.5 m

All macrophytes records were analyzed using Sonar 5. This software provides not only the visualization of plant heights structure, but also a number of very important parameters concerning vegetation, such as areal and volume coverage, an average and max height, depth etc. Example of results for one transect is shown in Fig. 6.

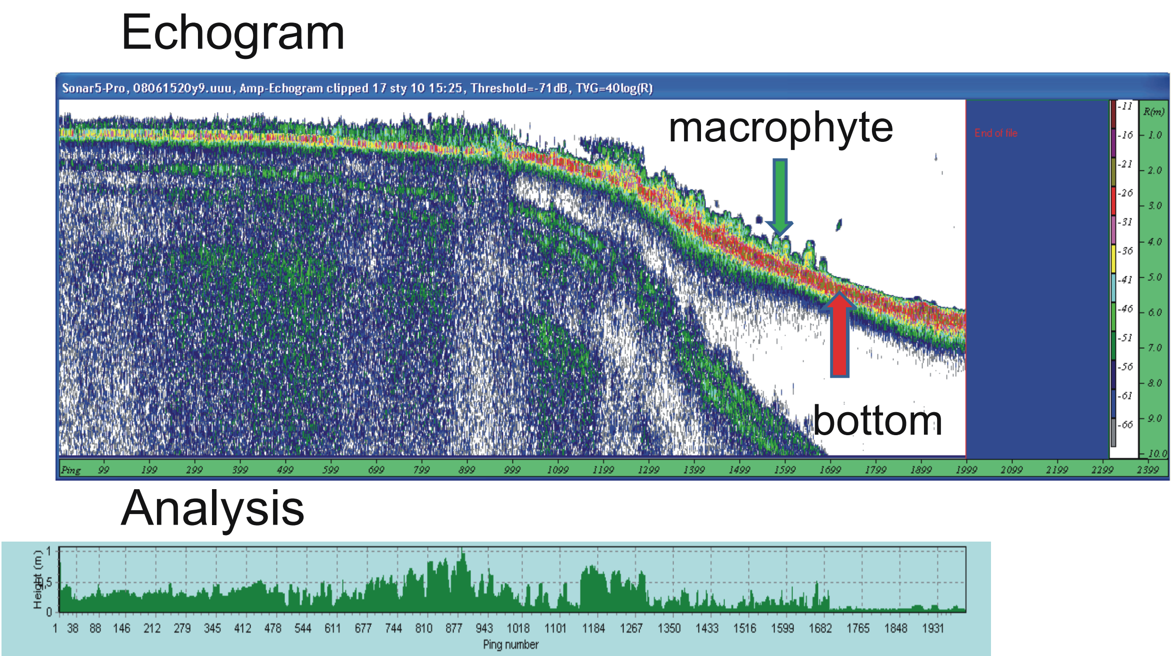

Fig.6. An example of echogram from macrophyte transect with sample of data analysis for lake Kiełpińskie

Mean root depth = 3.31 m
Mean bottom depth = 4.16 m
Mean Bioheight = 0.52 m
Max Bioheight = 3.49 m
Area investigated = 5613.53 m^2
Bioarea = 2199,39 m^2
% Area inhabited (PAI) = 39.18
Volume investigated = 30843.56 m^3
Biovolume =1228.60 m^3

%volume inhabited (PVI)	= 3.98
Mean Sv	= -19 dB
Mean Sa	= 1107.34 m^2/ha
Max plant depth	= 7.5 m

From these parameters probably some metrics can be developed, which have classification power for lake quality, but because we had comparable data only for two lakes, this could not be done with the data available. Nevertheless, even information on maximum vegetation depth is an important indicator of the water quality. The plant presence and their size distribution in relation to depth can prove very useful for the macrophyte people independently of their classification power (Fig. 7). The use of acoustics for the assessment of submerged vegetation is rapidly developing last years [7, 8, 9, 10, 11].

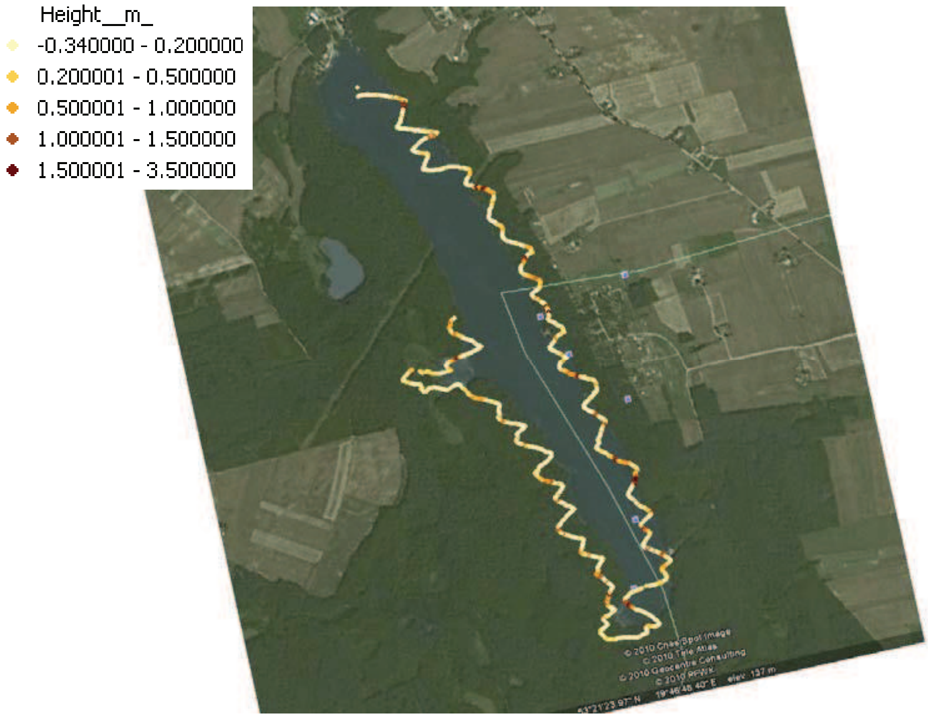

Fig.7. Macrophyte height according to the legend plotted on the GIS map of lake Kiełpińskie

Apart from acoustics other complex investigations were performed. They included phytoplankton concentration and structure, chlorophyll a, macro-invertebrates, fish, macrophytes and general physico-chemical parameters. All of these indicators will be used to order the lakes from the best quality to the worst. The data are still under the analysis. As can be seen from data presented in Table 2, only integrated macrophyte index and acoustics gave identical results. It is worth noting that these two methods were based on spatial information from the whole lake area, while others were based on point measurements.

Tab.2. Comparison of the ordering of the lakes from the best to the worst as classified by different methods of assessing quality

Chlorophyll *a* *μg/l*	% Microcistics in phytoplankton	Macrophytes Integrated Index	Hydroacoustics (all 3 indicators)
Kiełpińskie	Kiełpińskie	Dąbrowa	Dąbrowa
Dąbrowa	Lidzbarskie	Kiełpińskie	Kiełpińskie
Rumian	Dąbrowa	Rumian	Rumian
Lidzbarskie	Rumian	Lidzbarskie	Lidzbarskie

Before hydroacoustical methods can be used for monitoring of ecological status of an ecosystem, the adequate metrics must be formulated and their reference values in the context of lake typologies must be set-down. Also standardization of procedures for acoustic survey as well as standardization of parameters for data acquisition and analysis are required.

ACKNOWLEDGEMENTS

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