

A hydro-acoustics approach of accessing macrophyte biomass data

Hidro-akustično pridobivanje podatkov o biomasi makrofitov

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Abstract: Hydro-acoustic methods are commonly used to estimate the abundance and distribution pattern of fish in aquatic environments, while studies on the assessment of the biomass of submerged macrophytes in the littoral zones are still rare. In the present study we provide first results showing that indeed this method is a useful tool to estimate the aquatic plant stands in lakes. The aim of the recent presentation is to show an initial data evaluation by graphs describing hydro-acoustic signals at three distinct layers in a small shallow lake: the solid sediment, the fine or muddy sediment, and the 'plant canopy' of submerse macrophytes. The most difficulties of data processing and assessment of biomass were for hydro-acoustic records close to the water surface where the echo-signal is interfered by reflectance. Methodological details and progress in evaluating hydro-acoustic records will be discussed.

Key words: aquatic macrophytes, biomass, hydro-acoustics

Izvleček: Hidro-akustične metode se navadno uporabljajo za oceno pogostosti in zastopanosti rib v vodnem okolju, medtem ko so tovrstne raziskave biomase makrofitov v litoralu razmeroma redke. Raziskava podaja rezultate, ki kažejo na uporabnost metode za oceno sestojev makrofitov v jezerih. Namen raziskave je prikazati začetno vrednotenje podatkov hidro-akustičnih signalov na treh različnih plasteh majhnega plitvega jezera: trdnih usedlin, finih oziroma rahlih usedlin in sestojev potopljenih makrofitov. Največja težava pri obdelavi podatkov in oceni biomase so bili signali v bližini vodne površine, ki so interferirali z odbojem. V prispevku je podan metodološki pristop in potek ocenitve hidro-akustičnih signalov.

Ključne besede: vodni makrofiti, biomasa, hidro-akustika

Introduction

Assessing aquatic plant stands in freshwater and marine systems might become of even more interest as macrophyte belts are known to be important to inhabit young fish, as they play an important role to share nutrient sources with planktonic primary producers by alternative stable states and are hence of decisive importance for a good ecological status of an aquatic ecosystem (Scheffer 2002). Beside the need of more quantitative information about macrophytes, studies about macrophyte records are still rare compared with other aquatic assemblages as e.g.

studies of fish or plankton. One reason could be the effort used for recording macrophyte data. The state of art of assessing and processing biomass information of aquatic plants is based traditionally on harvesting methods, or on field surveys focusing on visual plant mass estimates. The effort of estimating standing crop of macrophytes becomes even higher in case that recording can be done only by divers. Different from that approach is the application of hydro-acoustics. This method that is usually applied to fish-relevant research and commonly used in practice (Brandt 1996, Rakowitz et al. 2009), has also been used for macrophyte research for

over two decades in some water bodies, with sufficient success in freshwater and marine science (e.g. Komatsu et al. 2002), too. Some trials on macrophytes were done with dual frequency echo sounder (Dumfart and Pall 2003, Jäger et al. 2004), and some other trials detected biomass in an experimental set-up by means of horizontal echo sounding (Hohausová et al. 2008). Trials with the same low-cost instrument we were using have also been applied by the Portland State University (USA; Litz 2007). A widely applicable method for estimating macrophyte biomass, however, is missing.

Echo sounding reveals only numerical information on depth. The advantage of the method, however, is, that many systems can store the original signal and can hence provide high resolution measurements by trials on both, temporal and spatial scales. Aside from calculating information on fish types, little effort has been put into differentiating a typical macrophyte signal, and a simplification of data processing and dis-

play of results is also needed. The aim of the study is to show graphically first results of quantitative recording of macrophyte stands by using a low-sophistication standard sonar equipment. This method allows to detect macrophyte stands and to calculate water plant-filled volumes leading to a semi-automatic assessment of biomass.

Materials and methods

Our approach is based on low-sophistication standard sonar equipment normally used in fishery. The sonar generates a standard echogram with 256 bit resolution, which will be used for detection of ground, sediment and macrophyte height. This signal can be used for automatic height detection of macrophyte stands. The respective water volume covering the plants refers to a semiautomatic biomass estimate.

LMS-480M Sonarviewer (Lowrance Inc.) was used in our research which is standard sonar

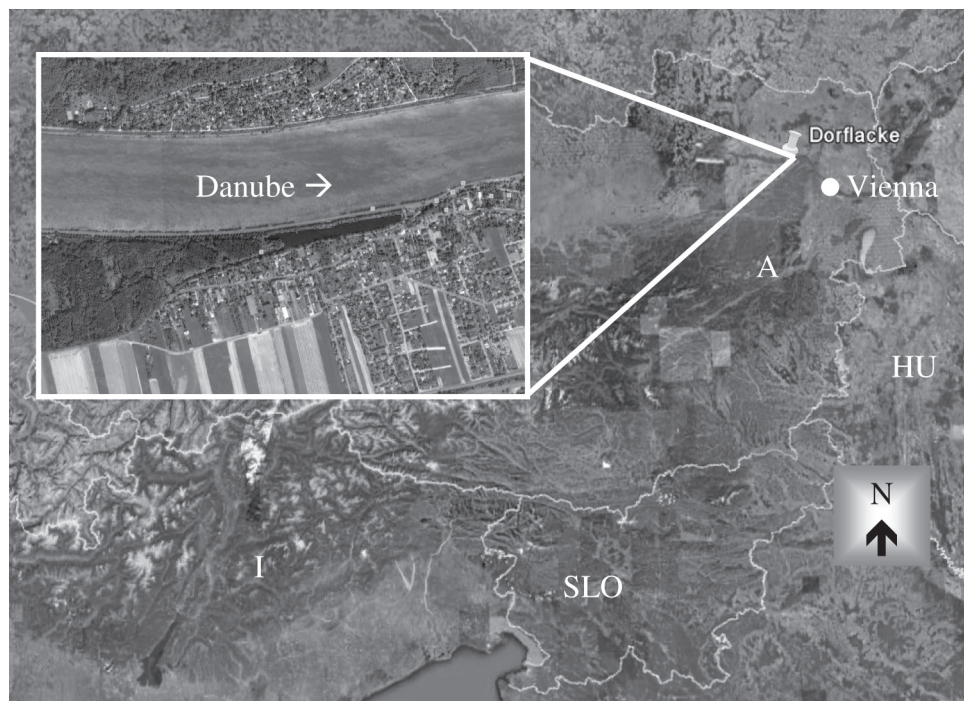


Figure 1: Survey site "Dorflacke", a part of former side channels of the Danube River.

Slika 1: Preiskovano območje "Dorflacke", del stare stranske struge reke Donave.

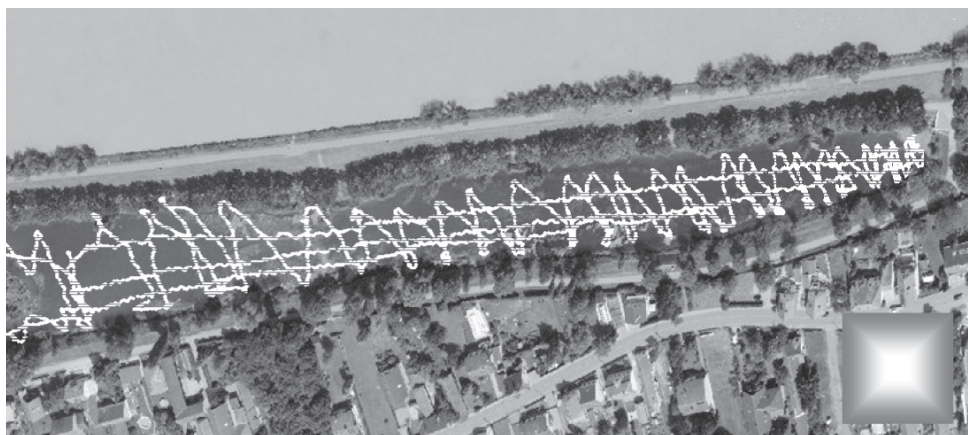


Figure 2: Track of hydro-acoustic run.

Slika 2: Potek hidro-akustičnega pregleda dna.

and usually used for detecting fish. This instrument features single frequency (50/200 kHz depending on the detected depth) with 500 watts of RMS power and displays depth from approximately 50 cm to 400 m with a resolution of 5 cm on its 5" diagonal high resolution, 256-bit monochrome display. The high speed skimmer transducer has a built-in temperature sensor. The instrument is equipped with a 12 channel WAAS/EGNOS compatible GPS receiver and provides accuracy up to 3 meters. The sonar has a built-in SDRAM card slot and stores the original sonar data for further processing in an internal raw data format. This internal data format was reverse engineered by means of Matlab version 7.4. This program was used for reading and processing the raw data and further post processing and visualisation. Google Earth (Google Inc.) and ArcGIS 9.3 (ESRI) are used for defining the shore line of the water body under survey. When using our equipment in areas under nature protection the instrument is used from a conventional rubber boat propelled by an electric outboard motor.

Data processing for the calculation of macrophyte biomass yield is described in detail in Janauer and Wychera (2000). According to an empirical data set, the biomass yield was calculated by the significant relationship between the volume of the plant stands and the plant material harvested from patches of defined area of usually 0.25 to 0.5 m². This relationship was tested for

macrophyte assemblages at different height in the respective water layer. Further a yield index for specific macrophyte dominance pattern was developed (Janauer et Wychera 2000, Kohlbauer 2008). Such calibration data set and biomass calculations are not shown in the recent study for Dorflacke. We focused here on the graphical presentation of hydro-acoustic measurements.

The hydro-acoustics run was performed in zigzag pattern once during summer, on June 30, 2010. The track is shown in Fig. 1. Where plants reached the surface the transducer was lifted for a short moment to avoid getting entangled in plant stems. This procedure did not interfere with either the reception of the acoustic signal nor with the GPS reading.

Study Area

Dorflacke is a relict part of the lower reach of the small river 'Kleine Tulln', which merged with Danube River side channels before the construction of the Greifenstein run-of-river hydro-electric power plant. Today this water body is located in parallel to the longitudinal levee of the power plant reservoir. The Dorflacke receives most of its water from the groundwater and seepage from the reservoir (Fig. 2). Its length and width is about 500 and 40 m, respectively. The maximum depth is 5.5 m.

Results

Results of data processing of hydro-acoustic records in shallow Dorflacke are presented by graphical illustration shown in Figs. 3 and 4. Our measurements comprise a data set of 65 transversal transects and 3 longitudinal runs on the summer trial. The results of the summer macrophyte situation are exemplified here by a single transversal transect (Fig. 3). This figure shows a typical echogram obtaining three zones of different acoustic properties. The lowest line delineates the zone of the bottom layer at the ground and refers to solid sediment at the bottom of the lake. The area between the ground and the middle line indicates the zone of muddy sediment (fine sediment). The upper line refers to the 'underwater canopy of macrophytes'. The area between the lines of fine sediment and of the canopy relates to water layers inhabiting macrophyte biomass. The dotted grey line in Fig. 3 might indicate the top layer where hydro-

acoustic data do not provide reliable information on macrophyte biomass as explained in detail in the discussion. This shallow depth is electronically attenuated and hence indicated a recorded signal which is invalid describing a hydro-acoustic pattern.

The morphometry of the water basin of Dorflacke is shown in Fig. 4. This contour map is automatically generated by the sonar diagram and can be linked to transect information exemplified in Fig. 4. The map shows that even a shallow water body can vary by spatial heterogeneity. Even if most area is indicated by a depth of two meters only, some limited areas refer to a water depth deeper than 4-5 m. Further, this high resolution measurement shows that a littoral zone shallower than 1 m is more common at the south shore line than compared to the northern part.

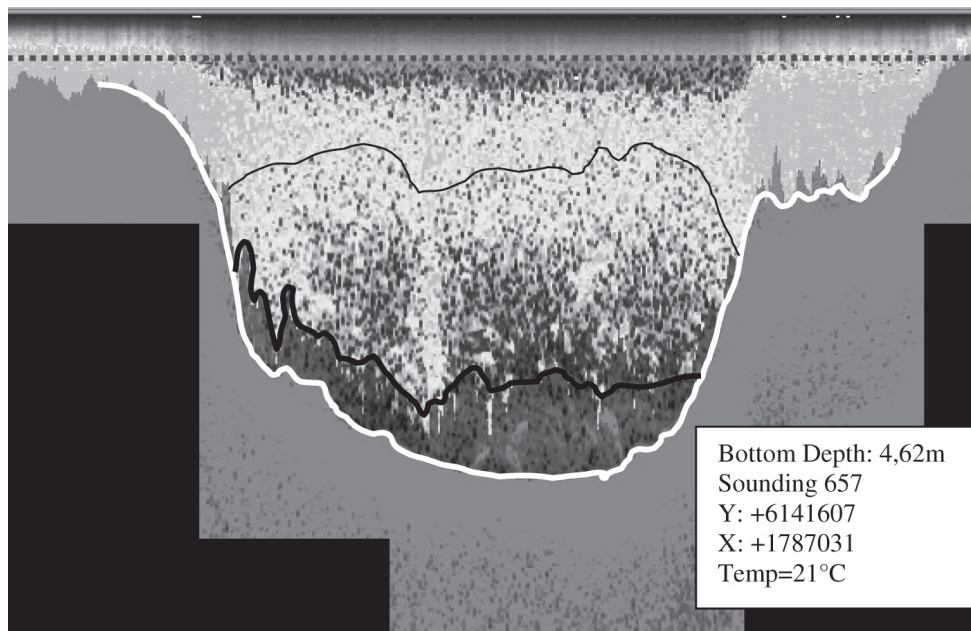


Figure 3: Echogram of a transect, with ground line of solid sediment (white), sediment line of fine/muddy sediment (bold black), smoothed macrophyte line of plant canopy (thin black) and dotted grey line minimum depth of detection.

Slika 3: Ehogram transektu z mejo trdne usedline (belo), mejo fine / rahle usedline (odebeljeno-črno), izravnano mejo makrofitske vegetacije (tanka-bela) in minimalno mejo detekcije (pikčasta siva črta).

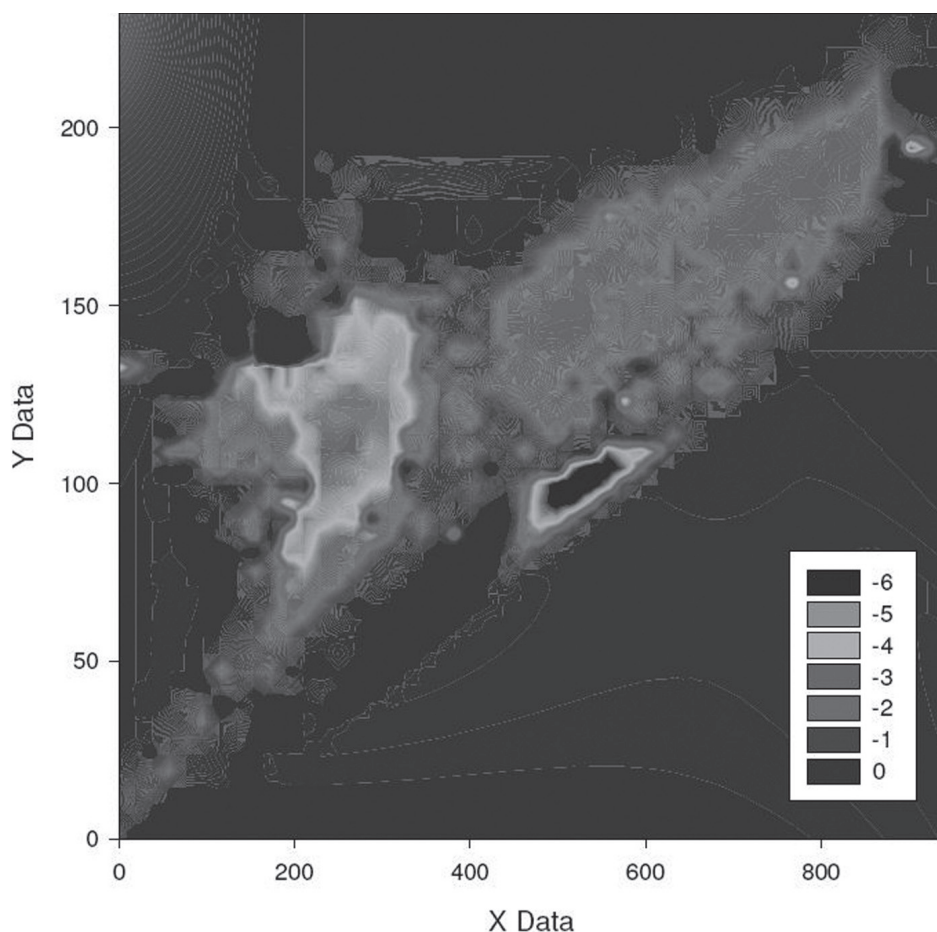


Figure 4: Depth contour map of Dorflacke, colour coded. For better visualisation the y-axis has been stretched, banks are in white, some artefacts located outside the water body are due to mathematical interpolation. Both axes indicate the spatial distance in m.

Slika 4: Globinske črte proste vode v vodnem telesu Dorflacke (različno obarvano). Zaradi boljše preglednosti je merilo na y osi povečano, bregovi pa so belo obarvani. Artefakti zunaj vodnega telesa so posledica matematične interpolacije.

Discussion

The results by our hydro-acoustic measurements sound promising as both, the water depth and the water plant canopy, were recorded with excellent accuracy. Based on this information a 3-D-model of the plant mass will be calculated for Dorflacke in a further study relating to an estimation of total macrophyte biomass.

The analysis of the acoustic data shown in

this study allowed an automatic separation and detection of three distinct 'surfaces' as regards filtering and edge detection of the echo sounding signal of solid sediment, the fine and/or muddy sediment, and the 'plant canopy' indicating the height of the aquatic plant stands. The graphical presentation refers to a calculation of triangulated irregular networks which allow a three dimensional description required for estimating macrophyte biomass yield in water bodies.

A semiautomatic evaluation was carried out following the procedure described by Kohlbauer (2008), in a process of validating our approach. A problem in automatically assessing the total volume of plant stands is due a low reliability of data at the near surface layer. In the uppermost strata of the water body, usually at a range of less than 50 cm, the acoustic signal is interfered by the reflectance of the water surface. As this shallow layer at water surface provides an invalid hydro-acoustic signal, plant stands reaching all the way up to the water surface are not accurately recorded in these parts of the water body by standard data processing. Therefore data need to be corrected manually in an additional post processing step. The areas can be digitized by means of GIS and marked as 'macrophytes-to-surface' along the survey track or can be simply estimated by recording the perimeter of these areas by means of normal GPS.

In case of calculating biomass of submerse macrophytes, aside the hydro-acoustic data the information about the macrophyte composition along transects is needed. Therefore, a hydro-acoustic run might be accompanied by a botanical survey of the macrophyte beds in the field. Processing the data in the lab, the signal of hydro-acoustics needs to be linked to the specific species composition at the respective measured area. In an earlier study by Janauer and Wichera (2000), a calibration data set for more than 20 macrophyte yield patterns is developed to provide specific yield indices. Such index refers to the ratio of the macrophyte biomass and the

water volume covered by the submerse plants for each macrophyte taxon. In a next step of data processing, the recent hydro-acoustic data of Dorflacke presented in this study, will linked to this calibration index calculating finally the species-specific biomass.

Conclusion

Our results show first promising results as graphical mapping provide in principle reliable data for macrophyte canopy and contour plots for water basin morphometry.

In a next step a user-friendly access will be developed for digitizing the shoreline, and for a convenient user interface enabling post-processing the plant stand volumes, as well as the calculation of biomass will be developed. The automatic differentiation of the different readings of solid and muddy sediment, and of the macrophytes by means of Kalman filter as well as an automated detection of 'macrophytes-to-surface' areas will be included.

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References

- Brandt S.B., 1996. Acoustic assessment of fish abundance and distribution. In: Murphy B.R., Willis D.W. (Eds.) *Fisheries Techniques*, 2nd edition, Am. Fish. Soc., 385-432.
- Dumfarth E., Pall, K., 2003. Die Erfassung der Unterwasservegetation mittels DGPS, Echsonde und Tauchkartierung. ICRA & Systema, Salzburg, www.icra.at/images/folder_makrophyten.pdf 2003
- Hohausová, H., J. Kubecka, J., Frouzová J., Husák, S., Balk, H., 2008. Experimental Biomass Assessment of Three Species of Freshwater Aquatic Plants by Horizontal Acoustics, *Journal Aquatic Plant Manage.* 46, 82-88.
- Jäger, P., Pall, K., Dumfarth, E., 2004. A method of mapping macrophytes in large lakes with regard to the requirements of the Water Framework Directive. *Limnologica*, 34, 140-146.
- Janauer, G.A., Wichera, U., 2000. Biodiversity, succession and the functional role of macrophytes in the New Danube (Vienne, Austria). *Archive of Hydrobiology*, 135, 61-74.

- Kohlbauer, R., 2008. Saisonale Biomasseentwicklung von Makrophyten und deren Bezug zur Phytoplanktonentwicklung in den Gewässern der Lobau. MSc-Thesis, Vienna, 171 pp.
- Komatsu, T., Mikami, A., Sultana, S., Ishada, K., Hiraishi, T., Tatsukawa, K., 2003. Hydro-acoustic methods as a practical tool for cartography of seagrass beds. *Otsuchi Marine Science*, 28, 72-79.
- Lotz, J., 2007. Coral Fish Shoal Detection from Acoustic Echograms. Portland State University, NEAR-LAB, (<http://nearlab.ecc.pdx.edu/news.html>).
- Rakowitz, G., Kubecka, J., Fesl, C., Keckeis, H., 2009. Intercalibration of hydroacoustic and mark-recapture methods for assessing the spawning population size of a threatened fish species. *Journal of Fish Biology*, 75, 1356–1370.
- Scheffer, M., 2002. Ecology of shallow lakes. In: *Population and community series*, 22. Kluwer Academic Publisher. The Netherlands. pp 357.