Project: A system for the sustainable management of Lithuanian marine resources using novel surveillance, modelling tools and ecosystem approach

Technical Report No. 1

Surveillance of marine resources using multi-frequency hydroacoustics

Project indicators:
1. Multi-frequency hydroacoustics system purchased, installed and calibrated
2. Developed algorithm to differentiate fish, mysids and zooplankton

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ABBREVIATIONS

FRT – fish removal threshold (dB). The upper echogram threshold applied in TS domain (with 40logR TVG function) in order to filter out stronger backscattering than certain FRT.

MFHA – multi-frequency hydroacoustics

s_v – volume backscattering coefficient (integrated acoustic backscattering energy over insonified water volume; m^{-1}).

S_v – volume backscattering strength (logarithmic equivalent of s_v; $S_v = 10 \log (s_v)$ (dB re m^{-1}).

TS – target strength (dB re 1 m^2), the ability of a given target (e.g. fish) to reflect acoustic signals.

TVG – time varied gain. Its purpose is to compensate the range dependence of the echo.

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INTRODUCTION

Currently hydroacoustic methods are widely used for pelagic fish assessments (Simmonds and MacLennan, 2005). Traditionally, collection of fisheries acoustic data is optimized for one single frequency. However, it has been shown that using multi-frequency hydroacoustic (MFHA) technique is possible to detect and distinguish zooplankton and larger crustaceans from other organism groups (e.g. fish) in the water (different sources, for review see Simmonds and MacLennan, 2005). The methodology for the identification of different groups of marine organisms using MFHA has undergone rapid development recently. Method using frequency response signature is one of new techniques facilitating classification of marine organism (Korneliussen and Ona, 2003). In order to use multi-frequency acoustic data for marine organism classification and identification, it must be collected simultaneously with at least with three frequencies. The multi-frequency hydroacoustic system may consist of combination of single-frequency systems with the possibility to run them synchronized.

Mysids (*Mysidacea*) are group of crustaceans common in many freshwater and marine environments. Mysids are omnivores, but also feed effectively on zooplankton. In the Baltic Sea together with clupeid fish they are most important zooplanktivores (Rudstam et al. 1986). Due to high content of polyunsaturated acids (Arts and Johannsson, 2003) mysids believed to be an important part of pelagic fish diet during autumn and winter when other food sources are limited (Aneer, 1980; Szypula, 1985; Posey and Hines, 1991; Raid and Lankov, 1995; Lankov and Kukk, 2002). Because of that they have potential to decrease overwintering mortality of fish (Snyder and Hennessey, 2003). Holliday et al. (1989) further proposed that a mixed diet was crucial for a good weight at age in older herring (c.f. Ogonowski, 2010). Mysisds are known to perform nocturnal diel vertical migrations, which constitute important benthic-pelagic link by making energy which would normally by locked in sediment available to the pelagic food-web (Ogonowski, 2010).

During first project stage multi-frequency hydroacoustic equipment system was purchased, installed, tested and calibrated. During the second stage an algorithm for differentiation of fish and mysids (zooplankton) acoustic targets was developed. Acoustic and biological data for the project were collected at the Lithuanian coastal areas (up to max 30 m depth) and the Exclusive Economic Zone.

First project stage

Purchase

Preparations for the purchase of the multi-frequency hydroacoustic system began with literature studies dealing with this mater. The theoretical and practical aspects of fisheries hydroacoaustic were well described by Simmonds and MacLennan (2005). The extensive descriptions of recommendations for the multi-frequency acoustic system were presented by Korneliussen et al. (2008), which served as a background for the development of technical specifications (see Annex I) for the system planed to purchase.

A survey of the scientific fisheries hydroacoustic equipment market was performed in order to find and identify the potential producers and suppliers of the equipment. There were no official dealers and/or distributors of such equipment located in Lithuania. Therefore, producers (or representatives for Europe in case of overseas producers) of the equipment were contacted directly.

Following suppliers/producers of the hydroacoustic equipment were contacted:

BioSonics, Inc.
4027 Leary Way NW
Seattle, WA 98107
U.S.A.
Tel: +1 206 782-2211
Fax: +1 206 782-2244
E-mail: emunday@biosonicsinc.com
Web page: www.biosonicsinc.com

Furuno Danmark A/S
Hammerholmen 44-48
DK-2650 Hvidovre
Denmark
Phone: +45 36 77 45 00
Fax: +45 36 77 45 01
E-mail: furuno@furuno.dk; salg@furuno.dk
Web page: www.furuno.dk

Hydroacoustic Technology, Inc.
715 NE Northlake Way
Seattle, WA 98105
U.S.A.
Phone: +1 206 633 3383
Fax: +1 206 633 5912
E-mail: support@HTIsonar.com
Web page: www.htisonar.com

Simrad Kongsberg Maritime AS
P.O.Box 111
Strandpromenaden 50
3191 Horten
Norway
Tel: +47 3303 4000
Fax: +47 3304 2987
E-mail: fish_research@simrad.com
Web page: www.simrad.com

Official purchase documents were prepared in accordance to the official laws and rules of the Republic of Lithuania. On 2008-12-28 started the simplified purchase procedure using inquiry “The purchase of hydroacoustic system for pelagic studies for the Klaipėda

University, financed by the Norwegian Financial Mechanism and the Republic of Lithuania". The invitations to participate in the simplified official purchase using inquiry were sent for the above mentioned potential suppliers. Only one supplier - Simrad Kongsberg Maritime AS officially expressed interest and asked for the official purchase documentation. Simrad Kongsberg Maritime AS presented tender with muti-frequency hydraocoustic system to the Open Purchase Jury of Klaipeda University. Their tenders met the requirements of the technical specifications of the official purchase, and this was documented in the technical expertise of the tender.

In the "Contract for Supply of Goods" of the first version of purchase documents was included 18% VAT. From 1 January 2009 officially was introduced new, 19% VAT rate, which resulted in long-lasting communication and adjustment of documents with Central Project Management Agency and Ministry of Finance. Finally VAT was withdrawn from the contract. The supplier was selected and the purchase contract of the hydroacoustic system was signed with Konsberg Maritime AS, Subsea Division – Simrad was signed on 2009-07-09. Time-span of "The purchase of hydroacoustic system for pelagic studies for the Klaipėda University, financed by the Norwegian Financial Mechanism and the Republic of Lithuania" is presented in Table 1.

Table 1. Time-span of "The purchase of hydroacoustic system for pelagic studies for the Klaipėda University, financed by the Norwegian Financial Mechanism and the Republic of Lithuania"

Time-span	**Activity**
October 2008	Literature studies on MF acoustics
October 2008	Survey of the scientific fisheries hydroacoustic equipment market
November – December 2008	Selection of the potential suppliers/producers
December 2008	Preparation of the purchase documentation
28 December 2008	Sending the invitations to potential suppliers, i.e. official start of the simplified purchase procedure using inquiry
February – June 2009	Adjustment of documents and communications with Central Project Management Agency and Ministry of Finance
February 2009	Evaluation of the tender's technical conditions
09 July 2009	Signing of the purchase contract
27 July 2009	Delivery of the MF hydroacoustic systems to CORPI, KU

Soldering and setting up of the multi-frequency hydroacoustic system

Installation

A basic diagram of the multi-frequency hydroacoustic system is presented in Figure 1. System installation started with selecting the platform to mount transducers of three frequencies, and hydrophone of catch monitoring system. The information on possible solutions was collected and evaluated. The towed body concept was selected as the most suitable platform among the others, first of all because it was not bound to one vessel and can be used from different ships. A new simplified purchase procedure using inquiry procedure was initiated for the acquisition of the towed body. The selected engineering company designed and produced the towed body. Second installation stage covered mounting of the transducers on the towed body, setting up all equipment units, and soldering of the connection plugs for the transducers and power supply. It is common practice that the system parts with electric cables to be installed on board of the ship are delivered form factory with uninstalled connector plugs.

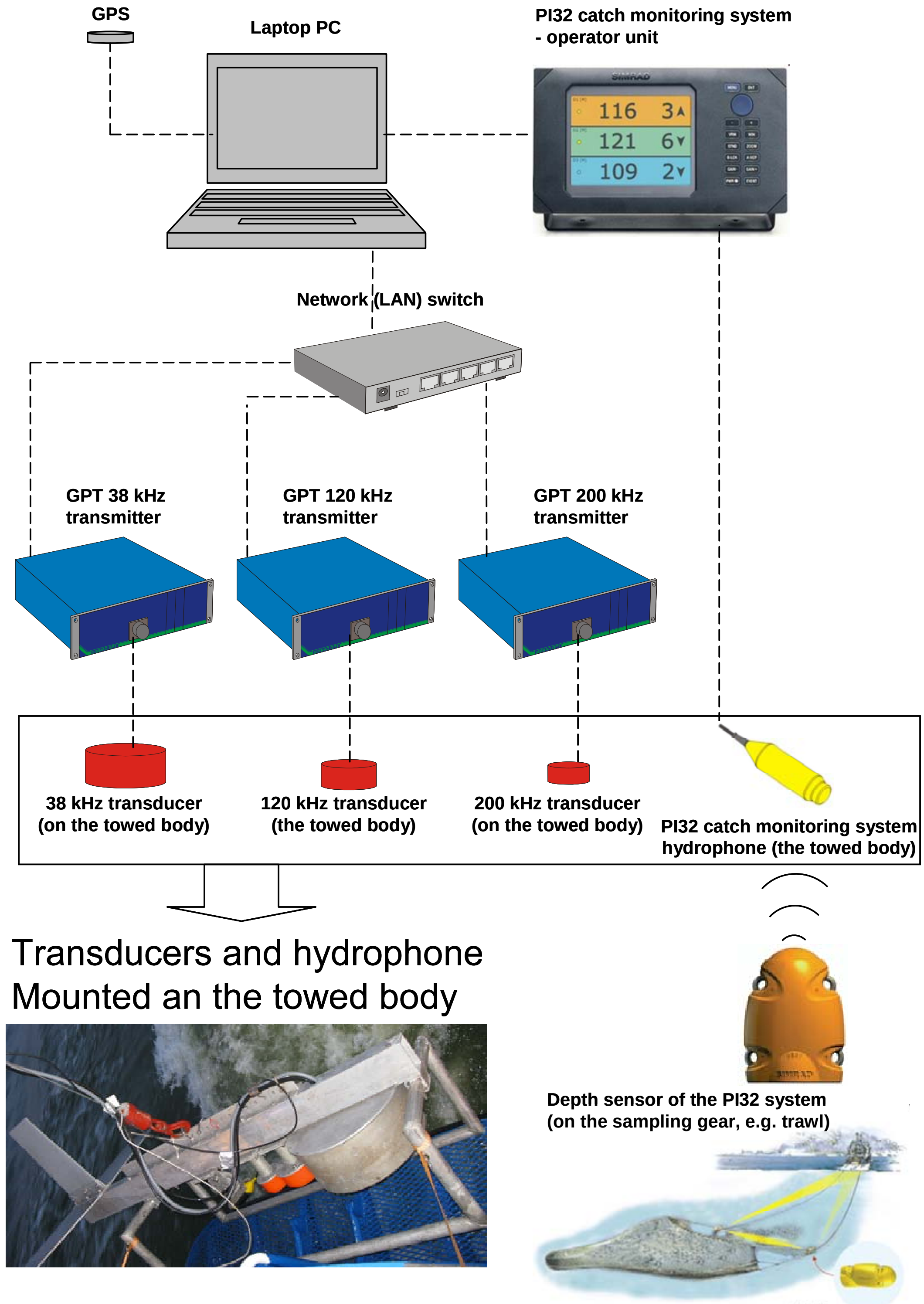


Figure 1. Basic diagram of the multi-frequency hydroacoustic system for the pelagic studies

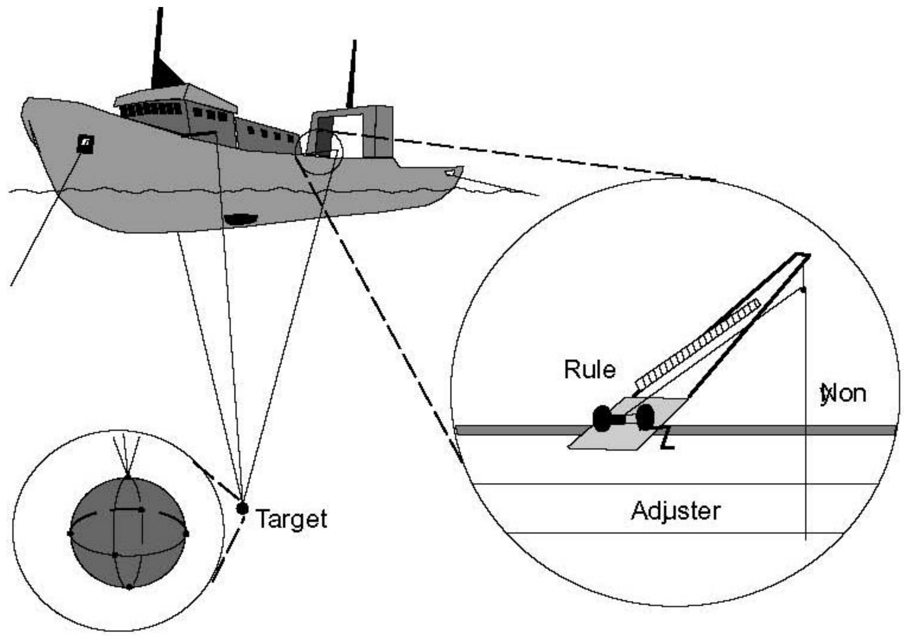


Figure 2. A basic scheme for calibration of the transducer mounted on the hull of ship (redrawn from Simmonds and MacLennan, 2005).

Testing and calibration

For acoustic surveys where accurate quantitative measurements are required it is essential that the echo sounder is correctly calibrated (Foote et al., 1987). Simrad (2008) recommends calibrating the system at least once a year, and if equipment is used in areas with different summer and winter condition at least twice a year. During calibration a reference target with known target strength is lowered into the sound beam, and the measured target strength is compared with the known target strength (Fig. 2). If it is necessary to adjust the echo sounder, this is performed automatically by the ER60 calibration software. The reference target is normally a metal sphere (Simrad, 2008). Calibration is also can be seen as thorough test of the system, as it usually reveals most of the equipment problems if any (personal communication Frank Knudsen, Simrad).

Calibration of the multi-frequency acoustic system with three transducers (38, 120 and 200 kHz) mounted on the towed body was performed in calm weather at occasion on 2009-08-10 in the open Baltic Sea with the seabed depth of 25 m, approx. 5 km Southwest of Klaipeda harbour. In order to make accurate calibration it is important to use correct water temperature, salinity and sound velocity values. Environmental conditions at the calibration site were measured using CTD sound (Sensordata AS, Bergen, Norway. Water temperature, salinity and sound velocity vertical profiles at the calibration site are shown in Figure 3.

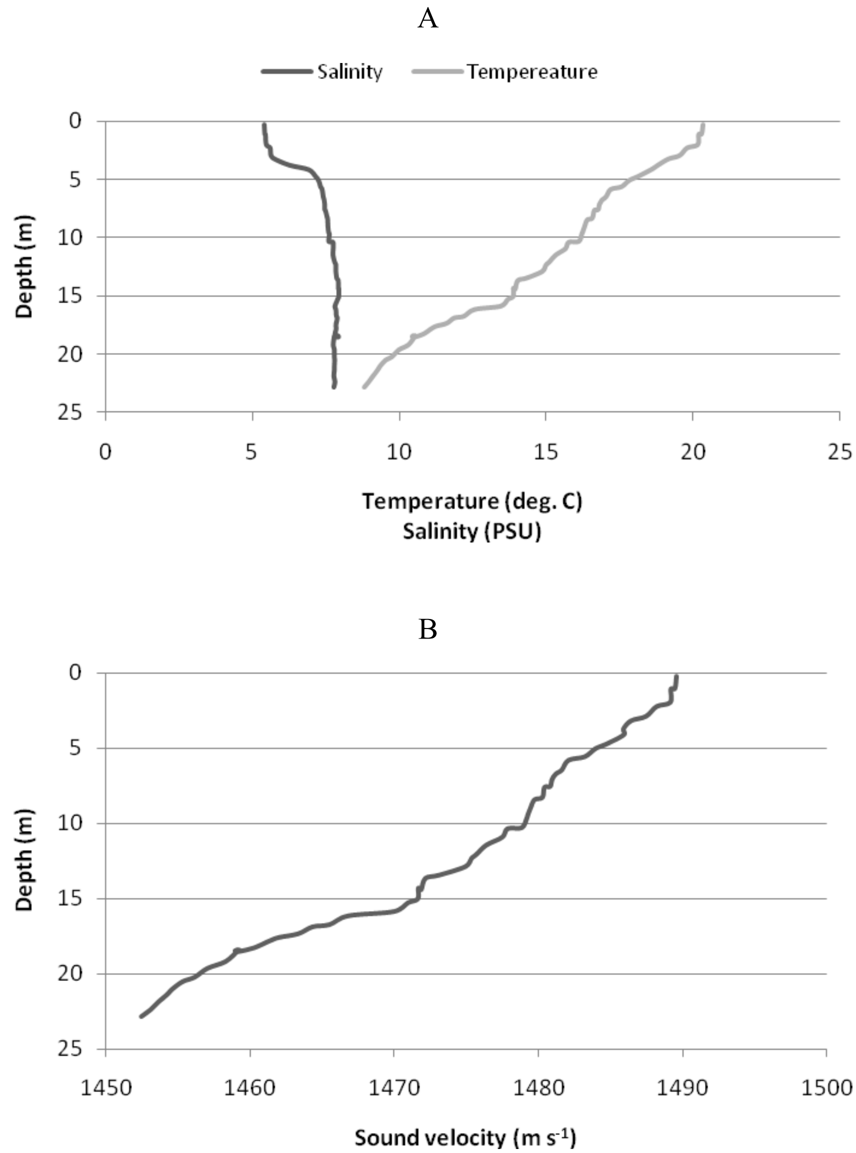


Figure 3. Water temperature, salinity (A), and sound velocity (B) vertical profiles at the calibration site 2009-08-10.

Calibration was made using the modified moving-sphere method (Foote et al., 1987), i.e. the towed-body with transducers mounted on it was tightly suspended on the side of the ship, and a sphere was moved trough acoustic beam of the transducer. Fishing rod with 0.6 mm monofilament line was used to operate the sphere. The sphere was rigged at approx. 17 m depth. The calibration was performed for each frequency separately using specific calibration spheres (see table 2). Simrad supplies copper spheres designed as reference targets for the calibration of scientific sounders. Copper is selected because it is a metal which can be made electrolytically with high purity (Simrad, 2008). The sphere diameter is different for each frequency in order to obtain target strength with minimum dependence of temperature (Foote, 1982). Each frequency system was calibrated at 256 and 512 s-6 pulse duration settings.

Table 2. Copper spheres used for different frequency calibration (Simrad, 2008). Target strength calculated for sound speed 1490 m s^{-1}.

Frequency (kHz)	Diameter (mm)	Target strength (dB)
38	60.0	-33.6
120	23.0	-40.4
200	13.7	-45.0

Calibration data was recorded by Simrad ER60 software calibration module and stored as a separate file for each frequency and pulse duration. The calibration program adjusted the parameters in the beam model to minimize the RMS error calculated on the recorded data points. The adjusted parameters, the RMS error, and the data points having maximum and minimum deviation from the model are shown in the Information view. The adjusted parameters resulting from the beam model are the parameters, which can be transferred to the echo sounder and used for the transducer during operation. Information on data deviation from the beam model indicates how well the beam model fit the recorded data. This can be used to evaluate the validity of the recorded data points. The data deviation from the beam model for a good calibration should give a RMS value less than 0.2 dB. If unwanted echoes have been observed during data collection, these should preferably be removed from the file. If, when collecting data, fish swim into the layer that includes the reference target, then these echoes should be deleted before the beam data are updated. Data with large deviation from the calculated curve are may be caused by poor acoustic conditions or by back scattering objects other than the reference target. Isolated echoes with large deviation from the calculated beam pattern can be removed, but when a large amount of the collected data diverges from the average, this indicates that the acoustic conditions have been unfavourable. When the RMS value is in between 0.2 and 0.4 dB, this indicates conditions are not perfect, but still acceptable. When the RMS value is higher than 0.4 dB the calibration is poor, and should preferably be rejected and not used for updating of the transducer parameters (Simrad, 2008).

It is difficult to find the area in the Baltic Sea near Lithuanian coast, which is completely free from fish. In the calibration site there were some fish present. In order to avoid unwanted fish echoes reference spheres were placed in the layer where fish density was lowest. The suspicious echoes possibly resulting from fish were deleted from the calibration. 38 kHz system calibration data deviation from the beam model resulted in RMS value of 0.17 and 0.19 dB at 256 and 512 ms, which indicate good calibration. 120 and 200 kHz systems gave RMS values of 0.21 and 0.30 dB and 256, and 0.29 and 0.39 dB at 512 ms respectively, indicating not perfect, but still acceptable conditions for calibration. The detail results of each frequency calibration are presented in the Annex II.

Insurance of the equipment

A simplified purchase procedure using inquiry procedure was carried out to insure MF hydroacoustic system. The insurer was selected from five potential insurance suppliers (Table 3). The insurance was bought from the "BTA draudimas" JSC. The insurance copy is presented in Annex III.

Table 3. Potential insurance companies, which were inquired in the simplified purchase procedure for insurance of the MF hydroacoustic system.

Insurance company	Contact details
"Lietuvos Draudimas" JSC	Taikos av. 66, Klaipeda, Lithuania Tel.: +370 46 404 085
"BTA draudimas" JSC	Silutes rd. 56, Klaipeda, Lithuania Tel.: +370 46 421 568
"PZU Lietuva" JSC	Liepu st. 36, Klaipeda, Lithuania Tel.: +370 46 219 933
"Seesam Lietuva" JSC	Birutes 14,, Klaipeda, Lithuania Tel.: +370 46 300 606
"If P&C Insurance AS" subsidiary in Lithuania	Lietuviniku al. 4, Klaipeda, Lithuania Tel.: +370 46 404 230

Second project stage:
Development of algorithm to differentiate fish, mysids and zooplankton

MATERIALS AND METHODS

In order to use multi-frequency acoustic data for marine organism classification and identification, it must be collected simultaneously with at least with three frequencies. The multi-frequency hydroacoustic system may consist of combination of single-frequency systems with the possibility to run them synchronized.

Multi-frequency hydroacoustic system consisting from three echo-sounders (Simrad EK60) with 38, 120 and 200 split beam transducers was used to collect all acoustic data. For detail description of MFHA system see Figure 1 and Annex I. Fish sampling was performed with pelagic midwater trawl (upper rope, theoretical opening 11×8 m, 6 mm cod end), mysids and larger zooplankton were sampled using with a Tucker trawl (trawl-mouth opening 0.25 m^2) with three separate nets (mesh size 1 mm), which could be opened and closed during trawling.

Acoustic data analyses and algorithm development were made using post/processing software Sonar5 Pro (Balk and Lindem, 2008).

RESULTS

Sonar5 contains a module of multi-frequency analysis tools, which can potentially be used to remove fish-originating echoes from acoustic data and produce modified “fish clean” echograms for further analysis. Two most appropriate tools for this type of procedures and seemingly having highest potential were tested: “Frequency response thresholding” and “Masking”.

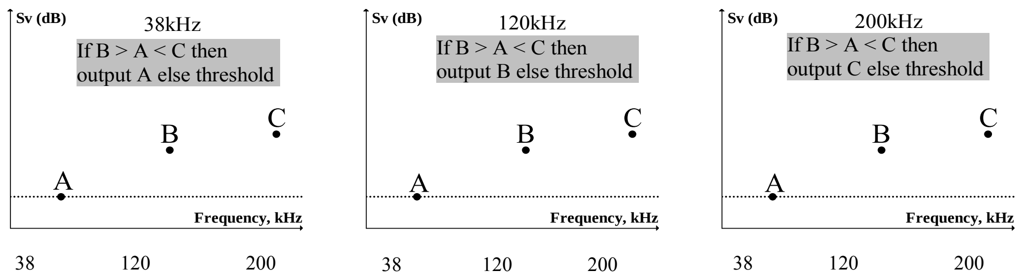


Figure 4. Schematic visualization of multi-frequency thresholding filters used to the test data set. 120 and 200 kHz data thresholded in such a way, that only data with stronger backscattering (S_v) at 38 kHz than compared to 120 and 200 kHz were allowed to pass the filters, i.e. the 38 kHz data were thresholded if its counterpart at 120 and 200 kHz was weaker.

Frequency response thresholding

The frequency response thresholding can be performed using data collected with minimum two, but preferably three acoustic frequencies. Different combinations of frequency response thresholding rules can be applied to each of 2-3 frequency sets. All of these available sets were tested.

In general, sound backscattering of zooplankton-like organisms is stronger at high and weaker at low sound frequencies, whereas many of the fish (those which possess swim-bladder) are relatively stronger acoustic targets at low frequencies. Hence, it can be assumed that all objects in the water column reflecting relatively more acoustic energy at 38 than at 120 and/or 200 kHz are not fish with a swim-bladder. Therefore, filters based on frequency response for different organism classes in the water can be designed. Using such filters acoustic targets having with higher energy (S_v) at 120 and 200 than at 38 kHz can be filtered out from 120 and 200 kHz data (Fig. 4). In the same way, the 38 kHz data can be filtered by removing echoes which are weaker backscatters at 120 and 200 kHz than compared to 38 kHz.

Data set of 38, 120 and 200 kHz which was thresholded in a way presented above is presented in Figures 5a and 5b. This set contains pronounced fish layer at 12-14 m (confirmed by midwater trawl sampling). The height and width of filter can be adjusted in different ways. The data in echograms shown in Figure 5a were filtered with 1 and 3 acoustic samples vertically (depth) and 1 and 3 ping horizontally (time; 1x1 and 3x3). Figure 5b shows data filtered with 5x5 and 7x7 windows filter size.

The highest resolution of the processed data is attained with the small frequency response thresholding filter window size (Fig. 5a). However, single fish targets were likely to be insonified by more than one ping, if they were located at the longer distance from the transducers. Strong echoes from larger fish can also take more than one vertical sample. Effective filtering can be achieved, if all acoustic backscattering that belongs to the same fish echo but appears around it is removed from the data. One way to solve this problem was by applying larger filter window (Fig. 5b).

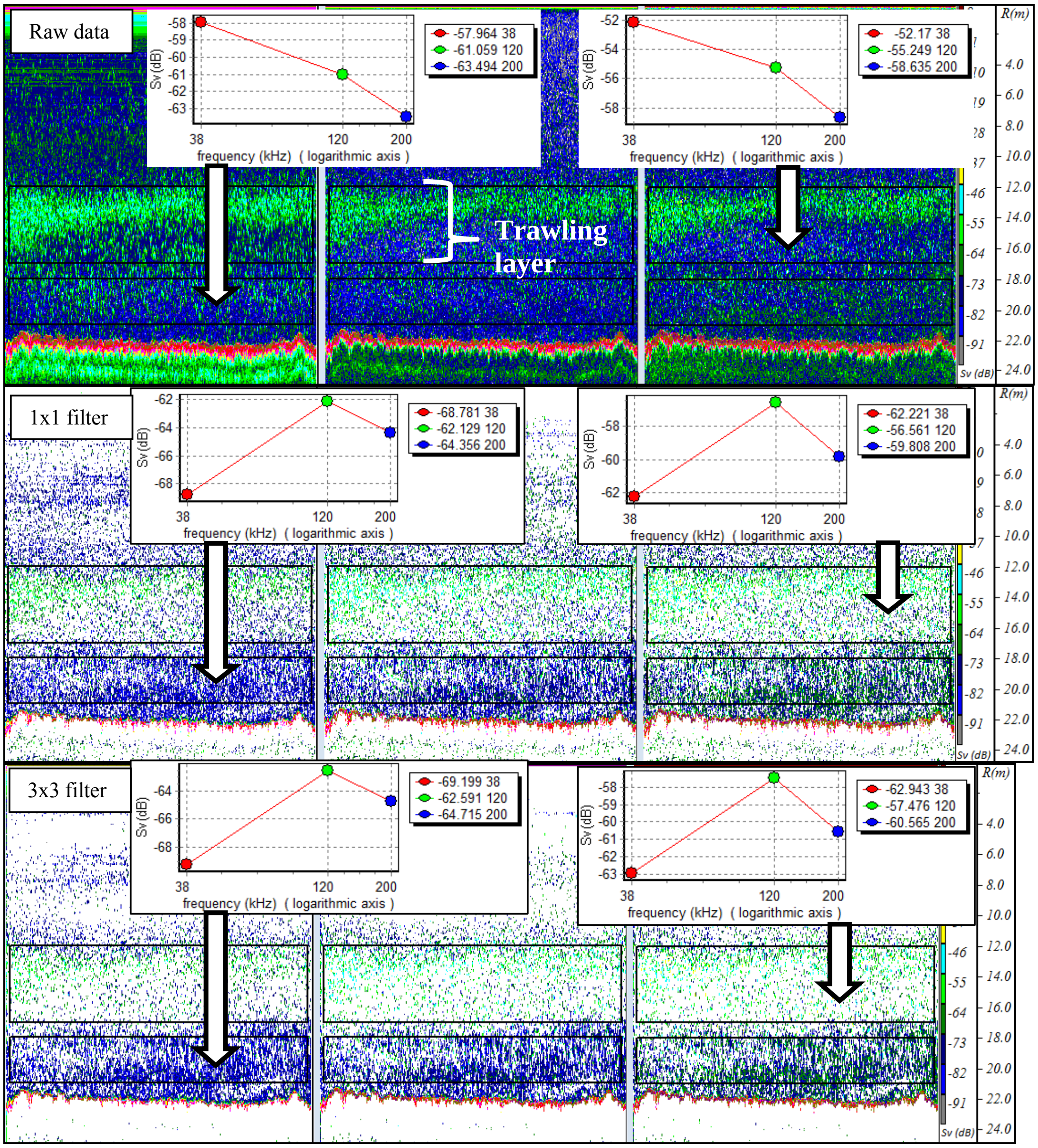


Figure 5a. Raw acoustic data with trawling layer (upper panel). Frequency response thresholding in two echogram regions with different window sizes, 1x1 – middle panel and 3x3 – lower panel. Midwater trawl catch confirmed that scattering layer at 12-14 m mainly consisted of herring and sprat (70% of catch weight). The frequency response of selected echogram regions are presented in graphs on the corresponding echograms.

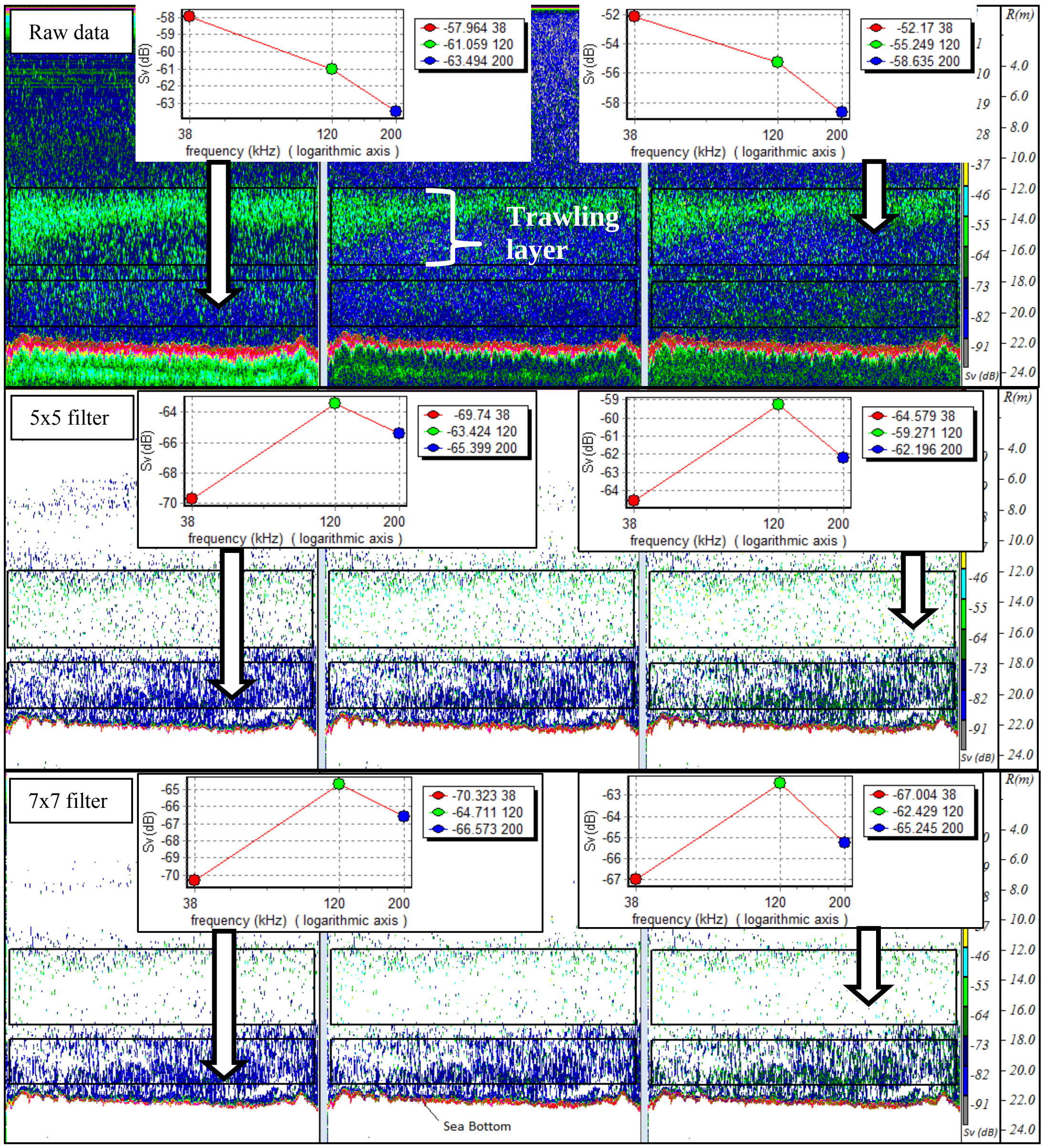


Figure 5b. Raw acoustic data with trawling layer (upper panel) Frequency response thresholding in two echogram regions with different window sizes, 5x5 – middle panel and 7x7 – lower panel. Midwater trawl catch confirmed that scattering layer at 12-14 m mainly consisted of herring and sprat (70% of catch weight). The frequency response of selected echogram regions are presented in graphs on the corresponding echograms.

Applying differently sized thresholding filter windows had little influence on the filtered data volume backscattering frequency response curve shapes (Fig. 5b). The actual S_v values at each of used frequencies were decreasing together with increased filtering window. This can indicate that by applying larger filter, more backscattering energy from echogram region close to fish was removed together with fish echo. The strong single fish echo observed at 38 kHz and ~20 m depth, were often about 4-6 pings long and 0.4 m high. Therefore, frequency response thresholding with filter size of 7 pings and 7 acoustic samples was considered as most functional for depths, which seldom exceeded 25 m.

European flounder (*Platichthys flesus*) was quite abundant in some of the midwater trawl hauls. This fish lacks swim-bladder and its frequency response curve probably have similar shape as one from zooplankton, i.e. relatively weak at low frequency and increasing at higher frequencies. Therefore, flounder echoes were probably not removed or removed not effectively using this fish filtering technique.

Masking

The Sonar5 software has built in masking tool. The underlying concept of this tool is to remove unwanted acoustic echoes from one frequency echogram and apply it as a mask to the other simultaneously recorded echogram(s) of same water volume but at another acoustic frequency(s) in order to remove masked echoes from these echograms. The set of different acoustic backscattering signal-based rules were used to filter the raw data in order to keep or remove the relevant acoustic targets, e.g. fish. Similarly masking can be used also to filter out unwanted background noise. Therefore, first it was checked if background noise filtering was necessary.

Background noise masking

It is possible to reduce the background noise in the echogram by using Sonar5 “Target – Noise separator”. As an example, the background noise was detected and removed at 200 kHz, which is considered as more effective (in relation to 38 and 120 kHz) in detecting weak (small) acoustic targets. The “noise mask” was created at 200 kHz and then applied to 38 and 120 kHz echograms (Fig. 6). In order to minimize possible zooplankton backscattering removal, automatically detected background noise threshold was used (Fig. 6b). The background noise threshold with increase of 3 and 6 dB are presented in Figures 6c and 6d.

The background noise filter can be useful when scrutinizing strong fish echoes and/or handling noisy data (e.g. containing mechanical or electrical origin noise). Small possible differences between echo energy of background noise and weak scatterers such as zooplankton resulting in low signal to noise ratios, suggested that background noise filter should be used with caution or better not used at all. After deep scrutinizing of the collected acoustic data and several data filtering tests, we decided that background noise masking was unnecessary.

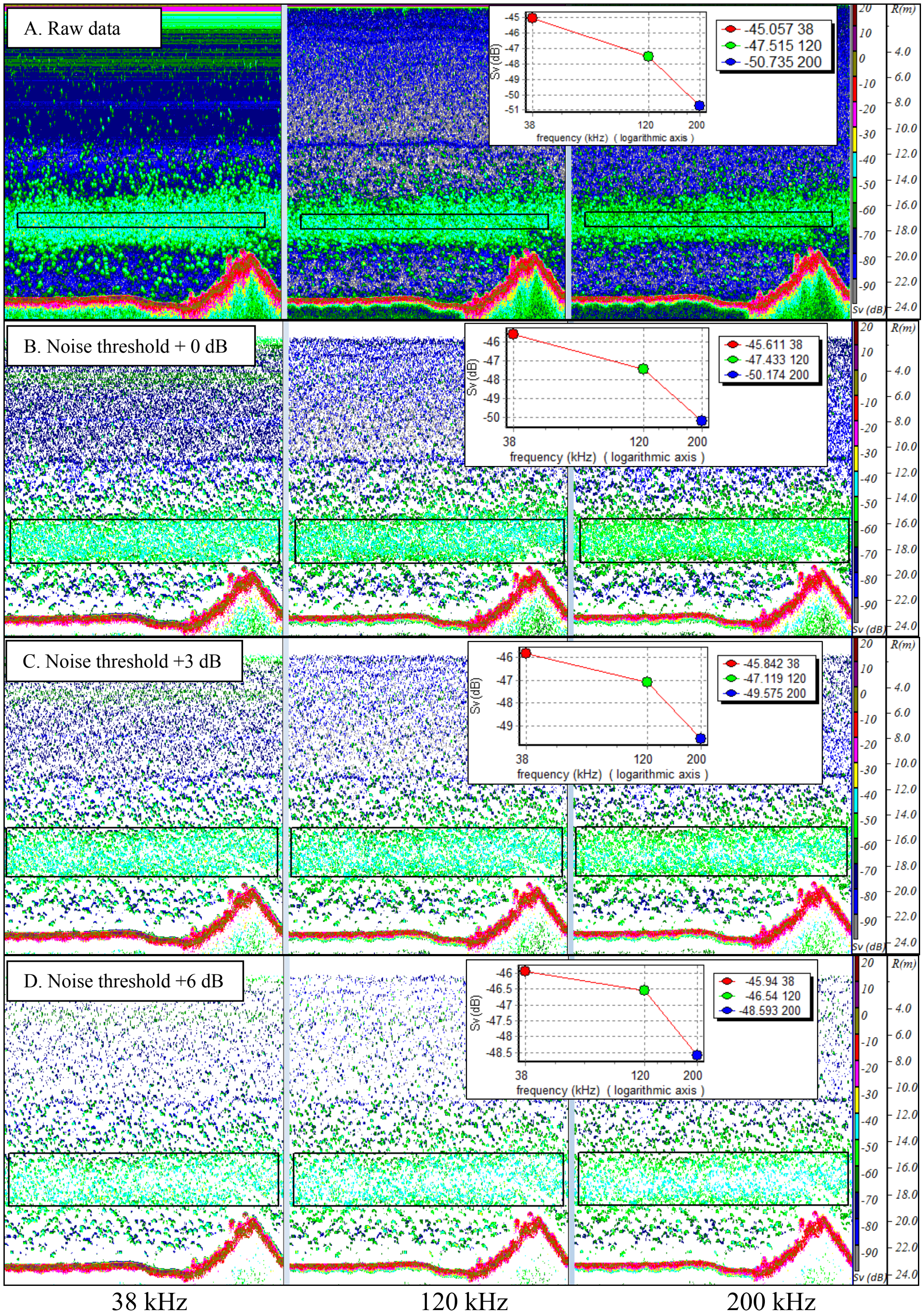


Figure 6. Background noise identified at 200 kHz and applied as a mask to data at 38 and 120 kHz. A – raw data. B – background noise mask applied. C and D – background noise threshold increased by 3 and 6dB.

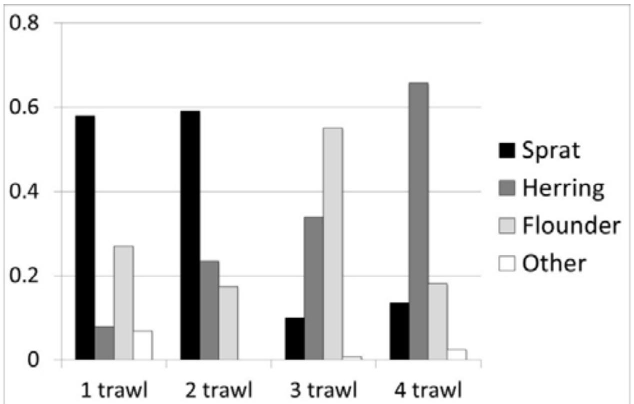


Figure 7. Fish species composition (as fraction of the total number of individuals in the catch) in midwater trawl catches.

Fish masking

Fish echoes often are "seen" slightly better at some frequencies, if multi-frequency acoustic data is available. Using Sonar5 it was possible to cut unwanted echoes in the echogram at one frequency and use the echogram as a "mask" to remove same acoustic targets from the echograms at another frequency(s). This technique assumes perfect acoustic beam overlap of all used frequencies, however practically it is almost impossible to achieve. Three important decisions have to be made before or at the start of fish masking: selection of the frequency at which unwanted fish echoes will be identified, defining unwanted echo backscattering properties ensuring that entire echo is removed.

Sprat and herring have swim-bladder and were often the most abundant fish in the water column, which was also confirmed by midwater trawling in coastal area during August 2010 survey (Fig. 7). Gas inclusion in the swim-bladder makes fish body a strong acoustic target and is accounted to reflect of 90-95% acoustical energy (Foote, 1980), especially at lower frequencies. Due to this reason, data collected with 38 kHz was used for fish echo identification.

In order to remove unwanted acoustic targets, different single echo-based parameters can be set in Sonar5 Masking tool. Some of them were considered as potential for separating fish from mysids. However, due to limited knowledge about some of the mysid and fish acousticval properties, it was difficult to design a reliable single echo detection-based filter. Furthermore, fish often were not resolved as single targets. This can occur when several fish are very close to each other or echo from a single fish is of the pure quality due some unknown reasons (e.g. noise, substantial offset from axis of the acoustical transducer beam). Since most of the fish species, observed in the midwater trawl hauls have more directive scattering (backscatter sound better) at low frequency than zooplankton, the simple thresholding of strong echoes at 38 kHz in TS domain (TVG – 40 log R) is considered as the most potential method for filtering out the and fish echo identification.

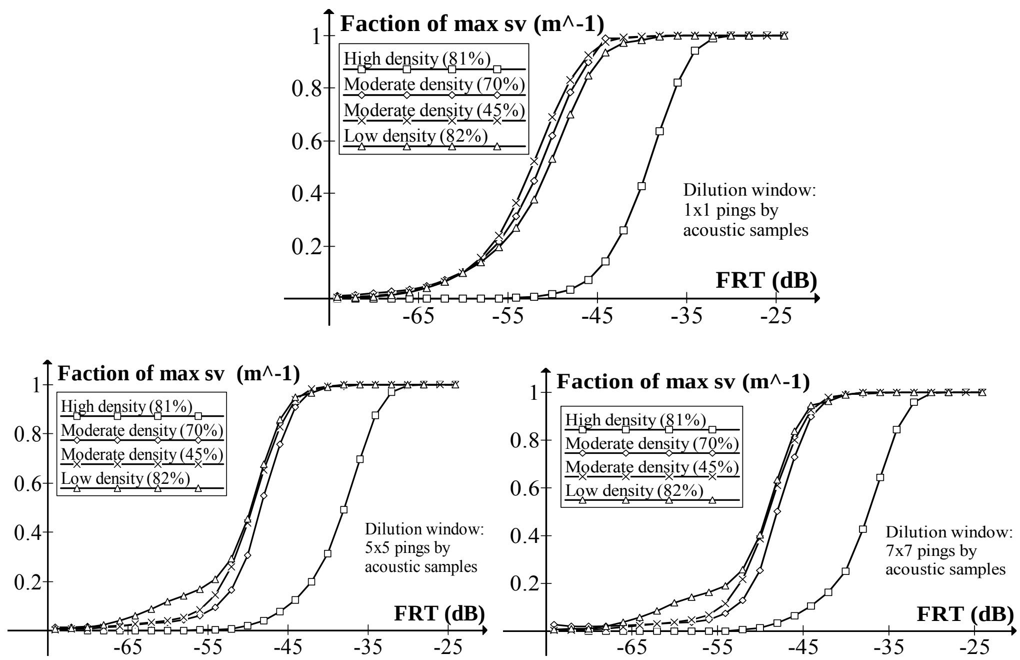


Figure 8. The acoustic volume backscattering (s_v) within the trawling layer with different Fish Removal Thresholds (FRT) applied to the data (at 38kHz). Upper panel: thresholding with 1x1 dilution window. Lower left – FRT with 5x5 dilution window, and lower right FRT with 7x7 pings by acoustic samples dilution window. Results are from areas with different fish densities: "High density" - trawl haul with relatively large fish catch (WPUE – 36.6), "Moderate density" – trawl hauls with moderate catch (WPUE – 8.9 and 12), "Low density" – few fish in the haul (WPUE – 1). Numbers in brackets indicate percentage of total mass of swim-bladdered fish in the catch.

Next step in masking procedure was to find the optimal threshold value of fish removal, at which majority of fish echoes are excluded, and most (preferably all) mysid backscattering energy is kept in remaining mask. Rudsdam et al. (2008) have measured Mysid target strength (TS) in large fresh water lake. They reported that 9 mm long *Mysis relicta* had TS of approximately -86.3 dB at 120 kHz. Mysids are probably even less directive targets at 38 kHz, and it can be expected that their TS is even lover at this frequency. Midwater trawl catches showed that sprat and herring between 8-15 cm most abundant fish in the water column. According to Didrikas and Hansson (2004) target strength on Baltic Sea herring and sprat of 8 cm is about -50 dB. Therefore, -60 dB fish exclusion threshold was considered conservative enough to identify the swim-bladder possessing fish echoes at 38 kHz in our data.

In order to select most suitable fish removal threshold (FRT), 38 kHz acoustic data collected during the midwater trawling in 2010 was scrutinized. Echogram regions corresponding to the trawled water layers were processed using different FRT and plotted against the remaining volume backscattering as a fraction of total/raw data volume backscattering (Fig. 8). Most of the fish backscattering were removed when -55 to -60 dB FRT applied together with 5x5 or 7x7 (pings x acoustic samples) dilution window (Fig.8). This resulted in almost entire removal of weaker fish echoes (see below). Figure 8 illustrates echogram with removed echoes of fish possessing swim-bladder. However, flounder echoes were most probably remaining, because they are in general have weaker energy and are difficult to identify. Due to this reason -65 dB FRT was probably more suitable than of -60 dB FRT, because it was still capable to remove swim-bladdered fish echoes (Didrikas and Hansson, 2004), but at the same time was well above of mysid target strength (Rudsdam et al., 2008). However, due to limited knowledge about flounder acoustical properties, it was difficult to conclude if -65 dB FRT at 38 kHz was sufficient to remove flounder echoes.

Strong fish echoes observed on the echogram were often surrounded by weaker scattering from same fish around it. Scattering from fish are often much stronger than one resulting from mysids, therefore it was very important to use FRT well above it, but also high enough to fully remove fish echoes from total water volume. This can be done by cutting out somewhat larger echogram region around the fish echo. One way to do this, is to use dilution window of larger size than the echo from fish before masking. The window size choice was based on the scrutinizing of single fish targets before and after fish echoes were cut out (Fig. 9). The 3 pings wide and 3 acoustic samples high (3x3) dilution window size seemed to be sufficient for fish echo removal in most cases when FRT was set to -65 dB, and 5x5 when FRT was -60 dB. However, in order to assure that no fish scattering from around strong fish echoes pass the masking, 5x5 (-65 dB FRT) and 7x7 (-60 dB FRT) dilution windows were used. Also, due to partial acoustic beam overlap at shallower depths, larger fish exclusion window was applied to 38 kHz echograms, because it was expected that it will more likely fully mask same fish target detected at 120 and 200 kHz echograms respectively.

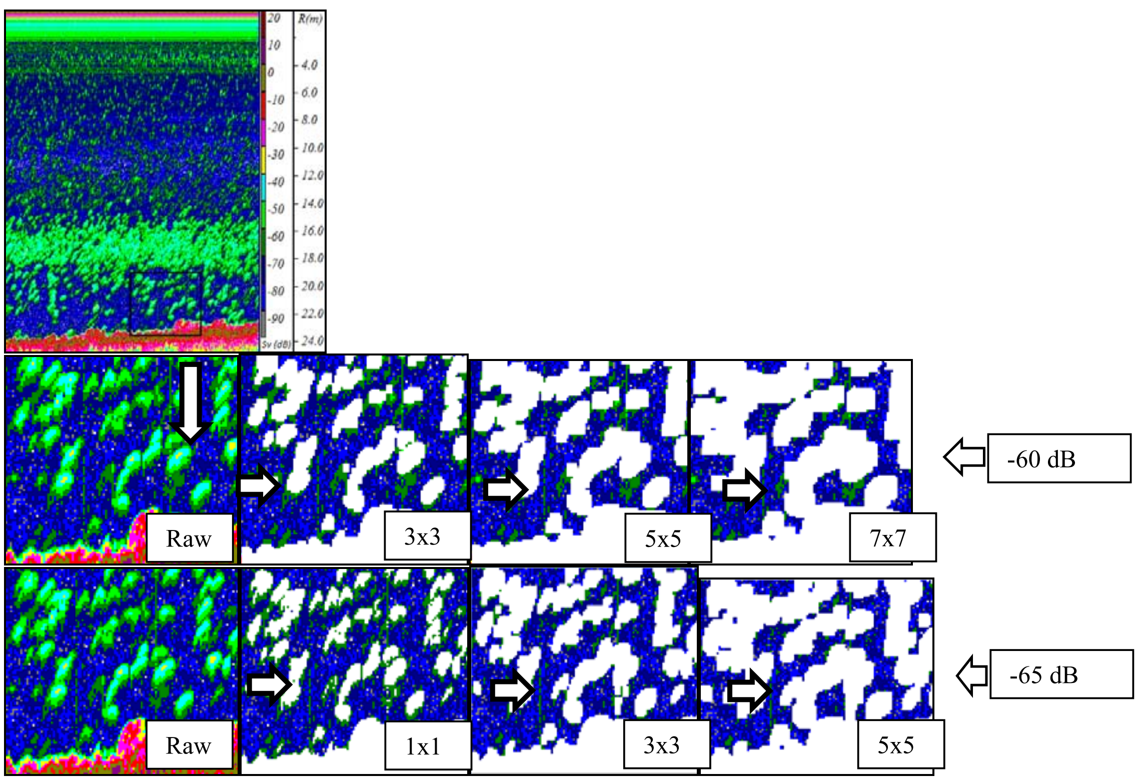
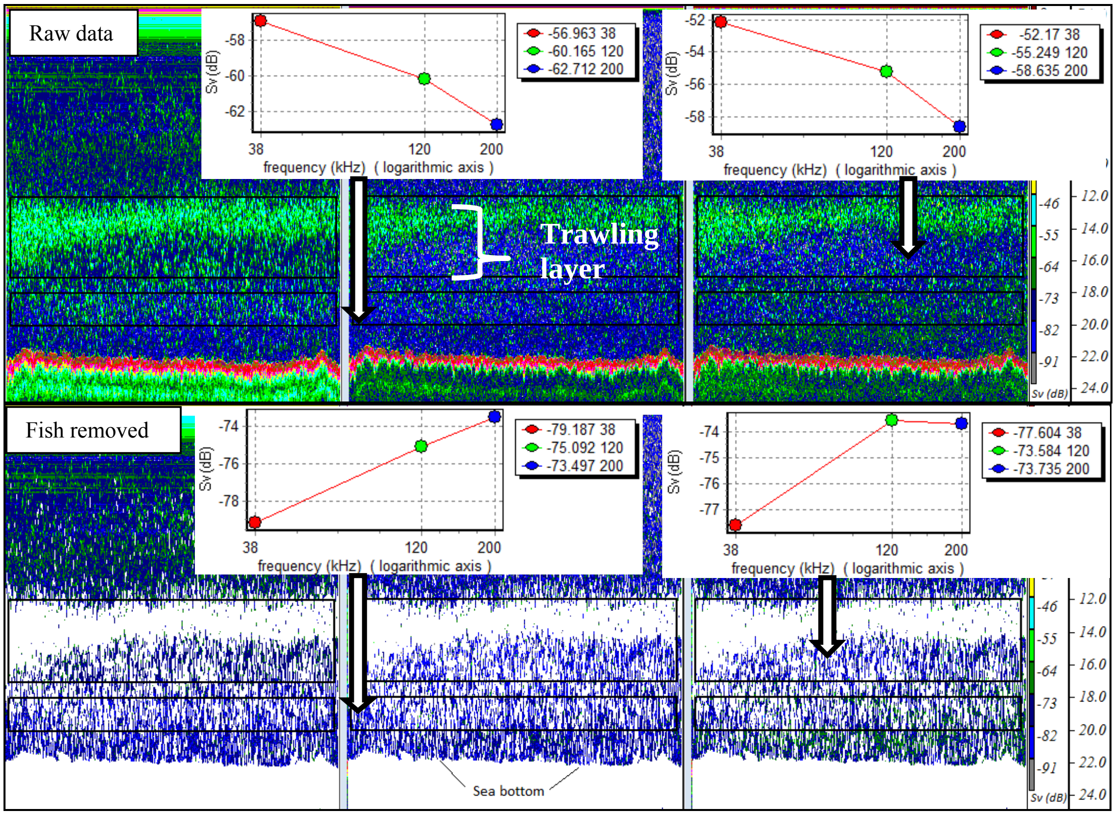


Figure 9. Example of 38 kHz echogram containing many fish echoes, which were removed using -60 and -65 fish removal threshold filtering, with different size dilution windows used to cut out echogram region around strong fish echoes.



38 kHz 120 kHz 200 kHz

Figure 10. Raw data (upper panel) and fish echo removal (lower panel; -65dB FRT + 5x5 pings to acoustic samples dilution window), and frequency response of selected echogram regions. Midwater trawling confirmed, that scattering layer at 12-14m consisted mostly of herring and sprat (70% of catch weight).

The described fish masking method can schematically be described by following steps: fish originating echoes were identified at 38 kHz data, and then the -65 dB upper threshold masking was applied in TS domain together with 5x5 pings by acoustic samples dilution window, which resulted in to a fish mask at 38 kHz. The mask was saved in S_v domain, and then applied to 120 and 200 kHz echograms.

Using masking in order to remove fish from acoustic data made possible to create “fish free” echograms and analyse backscattering of remaining weaker echoes. Acoustic data examples with confirmed presence (by biological sampling) of fish, mysids and jellyfish were used to test efficiency of this masking technique.

Herring and sprat have relatively higher backscattering at 38 kHz than compared to 120 and 200 kHz (Fig. 10). Fish masking resulted in frequency response curves with opposite slopes (Fig. 10), which indicates that masking worked reasonably well, at least removing herring and sprat echoes.

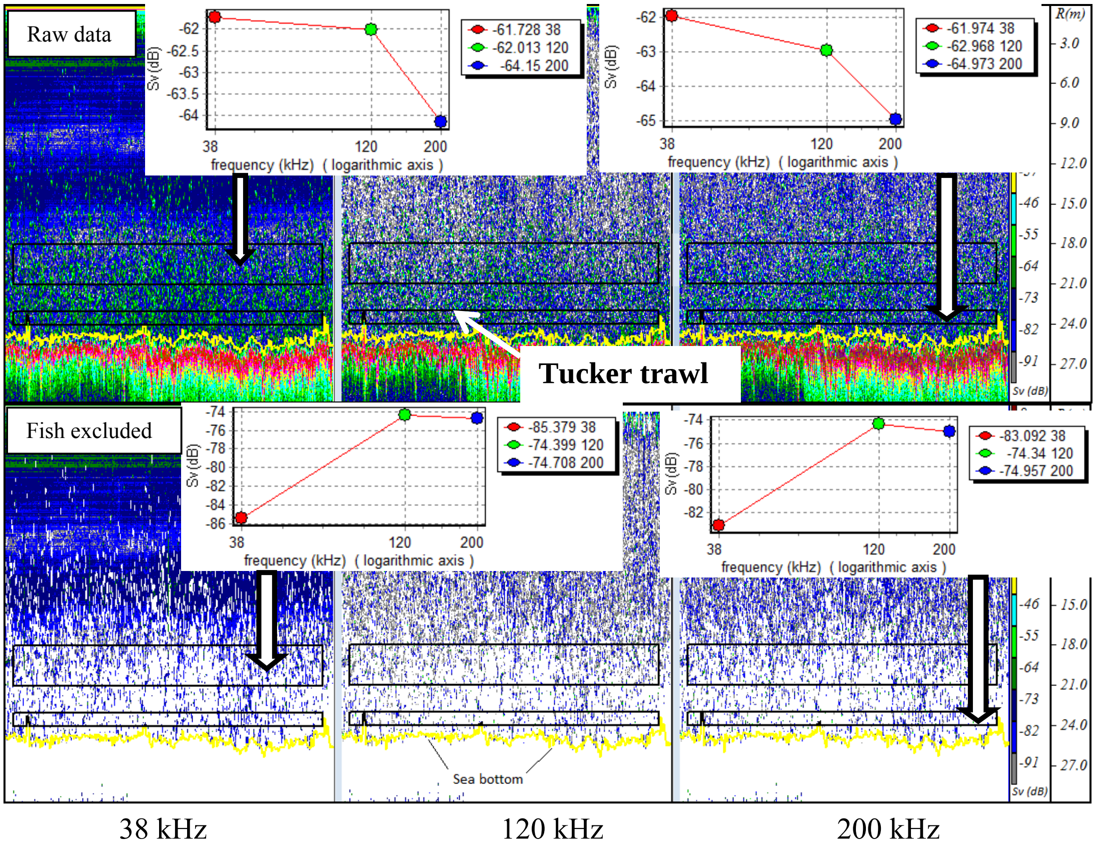
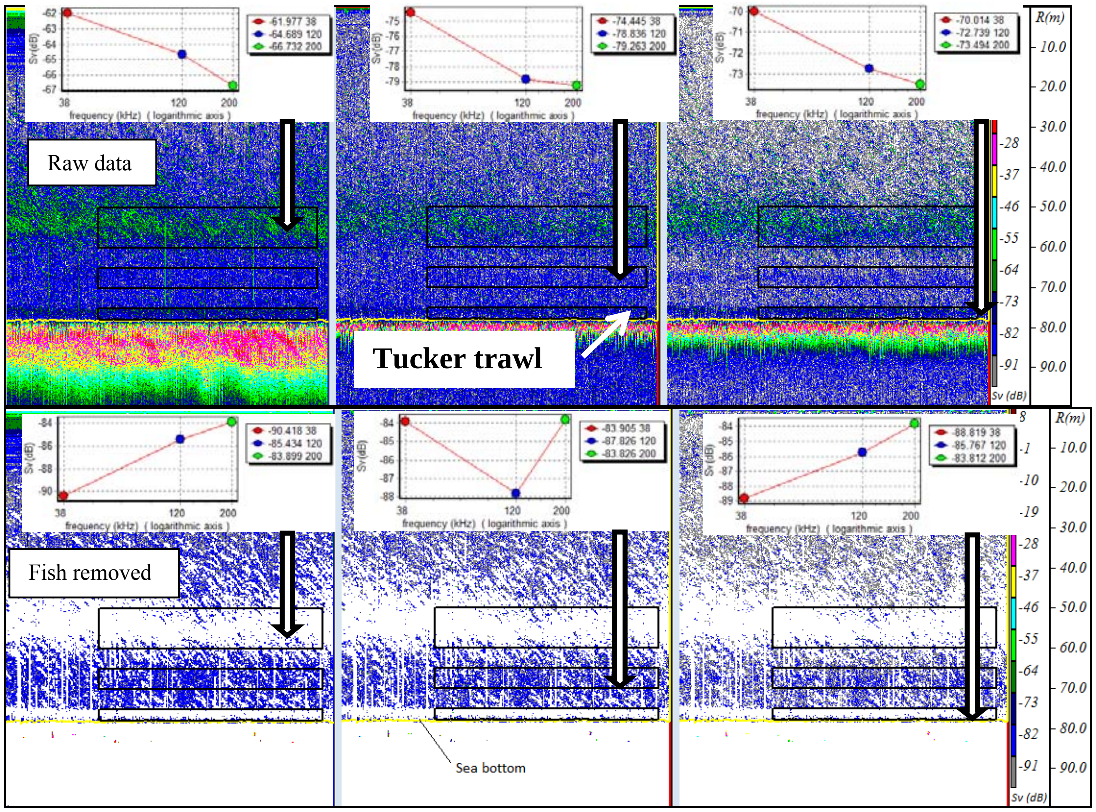


Figure 11. Raw data (upper panel) and fish echo removal (lower panel; -65dB FRT + 5x5 pings to acoustic samples dilution window), and frequency response of selected echogram regions. Tucker trawling confirmed presence of mysids in the layer close to seabed.



38 kHz 120 kHz 200 kHz

Figure 12. Raw data (upper panel) and fish echo removal (lower panel; -65dB FRT + 5x5 pings to acoustic samples dilution window), and frequency response of selected echogram regions. Tucker trawling confirmed absence of mysids in the layer close to seabed.

The fish masking method was used to analyze acoustic data with known presence (Fig. 11) and absence (Fig. 12) of mysids (confirmed by Tucker trawl sampling). In all samples common jellyfish (*Aurelia aurita*) were present, but it was even more abundant in mysid free areas (Fig. 12). After fish removal, frequency response curve shapes and slopes were rather similar in mysid presence areas (Fig. 11), while in mysid free areas frequency response curves had clearly different shape (Fig. 12).

DISCUSSION

In order to make possible analysis of organisms other than fish in acoustical data, echoes of fish and other organism have to be differentiated. We tested two potential multi-frequency acoustic data separation methods.

Frequency response thresholding was used for fish removal and often resulted in some incomprehensible results and rather strangely shaped frequency response curves with similar slopes. We saw one theoretically important disadvantage of this technique when filtering fish for zooplankton backscattering analysis. It was based on the predefined size

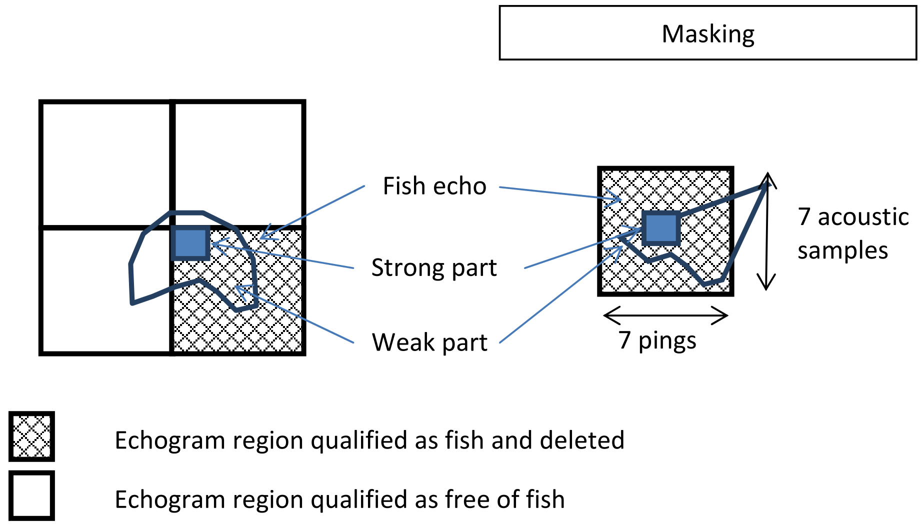


Figure 13. Frequency response thresholding technique is based on the predefined size echogram cells; therefore, it does not guarantee that entire fish echo is fully removed from the data. Fish masking method is based on detected targets/echo intensity and so is considered to be more effective in order to remove entire fish echo.

cells in the echogram, but not the detected objects (Fig.13). The fish echo, as seen on the echogram, often has strong energy central part surrounded by weaker part (e.g. when fish was detected further away from the axis of the acoustic beam, i.e. when entering/leaving the beam). The entire fish echo then might be distributed between few cells in the echogram. Sometimes only a small part of fish echo (weak "echo edge") can be present in the echogram filtering cell. Therefore, it can happen that echo energy in this cell is not strong enough to be detected and removed by the filter at 38 kHz, but it still contains residual energy resulting from fish echo, which affects remaining backscattering of other organisms. Fish backscattering is usually much stronger than one from mysids Therefore, any unfiltered fish backscattering (even weak "echo edges") can bias later mysid and/or zooplankton acoustical analysis. For this reason, we consider that frequency response thresholding method should not to be used for fish echoes removal from multi-frequency acoustic data.

Both fish filtering methods we tested, assume perfect transducer beam overlap, however practically this is almost impossible to achieve. The fish echo identified at one frequency could potentially be found at slightly different time and/or depth region of the echogram recorded at another frequency. In order to overcome this problem, filter windows of different sizes were tested and used. Analysis results showed, that in fish masking filters with increased window size were removing all residual fish echo energy and were considered eliminating this problem entirely.

Both fish filtering methods do not guarantee that echo energy contributions from the swim-bladder lacking fish such as flounder, which was quite abundant in pelagic trawl hauls, was not totally removed from the acoustic data. Mean length of flounders in trawl hauls was 24 cm, and very few fish were < 17 cm. We were not able to find any information in literature about flounder target strength or any other acoustical properties.

However, target strength to length relationships were available to other fish species lacking swim-bladder. McClatchie et al. (1996) reported that Atlantic mackerel has TS > -72 dB. We used their relationship to calculate TS for 24 cm long (mean length) flounder, and it resulted in -44.4 dB. When using target strength relationship developed for sandeel (measured at 38 kHz; Armstrong and Edwards, 1985, 1986), 24 cm flounder target strength was calculated as -67.4 dB. However, these fishes have completely different body shape, which probably plays major role in swim-bladder lacking fish target strength. Therefore, these target strength extrapolations are most probably far from reality, and results should be interpreted with caution. When fish masking method was used with FRT of -65 dB, most of the flounder backscattering contribution to the total volume backscattering was probably removed. Rudstam et al. 2008 reported that 9 mm long *Mysis relicta* target strength measured at 120 kHz was -86.3 dB in fresh water. Therefore, we considered that applied -65 dB FRT at 38 kHz did not remove any mysid backscattering from acoustic data. Single mysid target strength is quite low, but when these organisms are aggregating, it can be expected that their backscattering is higher also. Due to this reason using FRT with lower than -65 dB filter increases possibility that mysids are also removed from the data and therefore it should be done with caution.

Fish rich layers and layers with confirmed mysid presence showed slightly different shapes of frequency response curves (Fig. 10 and 11). Mysids were probably absent or their densities were lower in areas with high fish densities due to increased predations risk (Aneer, 1980). On the other hand, we were not able to differentiate echoes from flounder and it was difficult to know how much they contribute to total acoustical energy backscattering and how this influenced shapes and/or slopes of filtered frequency response curves.

Frequency response thresholding and masking techniques were initially considered equally promising in removing the swim bladder-bearing fish contribution to the total S_v. However, after developing filters and testing both differentiation techniques, masking was considered as more accurate in filtering process, and was preferred as the better option.

FUTURE DEVELOPMENTS

Future work with multi-frequency hydroacoustics in the Baltic Sea should preferably concentrate on better understanding of acoustical properties of fish and mysids, as well as other pelagic organisms (e.g. zooplankton). Experiences from this project shows that previously considered acoustically unimportant and benthic flounder, can cause problems when differentiating echoes of various necto-bentic and pelagic organisms. Knowledge about acoustical properties of this swim-bladder lacking fish is lacking, therefore it is very important to fill this gap. Future work on flounder should include both theoretical modelling and empirical experiments.

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ANNEX I

Technical specifications of the hydroacoustic system for pelagic studies

Hydroacoustic system for pelagic studies consisting of multi-frequency hydroacoustic (MFH) and sampling gear monitoring (SGM) systems. This system is primarily planed to be used in the project for development of quantitative methods for assessment of main food items (mysid and zooplankton) for commercial pelagic fish (herring and sprat), and development of new target strength (TS) to fish size relationship in order to enhance accuracy of the international acoustic fish stock assessments in the Baltic Sea (methodology improvement). The geographical scope of using the system in the project will cover mostly pelagic areas of the Baltic Sea as well as Lithuanian coastal zone to the depth ranges from 5 up to 150 m. Furthermore, system can be used in fresh water bodies.

Multi-frequency hydroacoustic system (MFH)

In order to use multi-frequency acoustic data for marine organism classification and identification, it must be collected simultaneously with at lest with three frequencies. The multi-frequency hydroacoustic system may consist of combination of single-frequency systems with the possibility to run them synchronized. The set of the optimal frequencies for the system to be used in this project should include low, intermediate and high frequencies in the range of ultrasound frequencies used for fisheries research (10-1000 kHz), and should be able to monitor different organism groups such us: fish possessing swimbladder in the size range from 70 to >1000 mm (e.g. cod, herring, sprat, i), as well as their early life stages (size range from 20 to 70 mm), macro nektobenthos in the size range from 5-30 mm (e.g. mysids and gamarids), and larger zooplankton in the size range from 0.5 to 3 mm. Each single system and/or their combination should meet the same requirements as for the fisheries research hydroacoustic system (see e.g. ICES, 2003). The multi-frequency system should meet following requirements (Korneliussen et. al, 2004):

1. Collect physically comparable data:
   - 1.1. All echo sounder and transducer systems must be calibrated (both for TS and S_A/S_v);
   - 1.2. Insignificant noise (see Korneliussen, 2000):
     - 1.2.1. Measurements should not be biased by noise,
     - 1.2.2. Noise should not reduce sampling volume;
   - 1.3. Insignificant interference between frequencies.
2. Acoustic data must be spatially comparable:
   - 2.1. Identical pulse lengths and pulse shapes at all frequencies;
   - 2.2. Individual pings identifiable in the data files at all times;
   - 2.3. Similar acoustic sampling volumes at all frequencies for comparable ranges to the scatters, i.e. targets of interest should by acoustically visible in all parts of the sampled volume for the ranges use. Providing there is insignificant noise, this implies:
     - 2.3.1. Similar half-power beam widths,
     - 2.3.2. All transducers should have same centre (including identical transducer depth),
     - 2.3.3. Same acoustic axis for the transducers;
   - 2.4. Simultaneous transition of pulses.

MFH system should include computer software capable to operate and visualize echograms of all frequencies from one PC, as well as record raw data. The MFH system should be supplemented with hydroacosutic post-processing software capable to use raw data format and calibration parameters. Post-processing software should be able to analyze multi-frequency acoustic data using relative frequency response approach.

Sampling gear monitoring system (SGM)

The sampling gear monitoring system will be used to monitor depth of the towed sampling gears such as trawls, nekton and zooplankton samplers. The main requirements for the SGM are:

1. Provide real-time information about sampling gear depth (in SI units, e.g. meters),
2. Interface to the multi-frequency hydroacoustic system,
3. Wireless connection to the depth sensor on the gear.

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ANNEX II

```
#  Calibration  Version   2.1.0.12
#
#  Date:  2009-08-10
#
#  Comments: calibration of MF system with 38, 120 and 200 kHz
#
#
#  Reference Target:
#    TS                  -33.80 dB       Min. Distance         16.00 m
#    TS Deviation           5.0 dB       Max. Distance         19.00 m
#
#  Transducer:  ES38B  Serial No.   30961
#    Frequency            38000 Hz       Beamtype                Split
#    Gain                 24.00 dB       Two Way Beam Angle   -20.5 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.00 deg       Along. Beam Angle    7.30 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 1.00  m
#
#  Transceiver:  GPT  38 kHz 00907205fbb0 3-1 ES38B
#    Pulse Duration       0.256 ms       Sample Interval     0.047   m
#    Power                 1000  W       Receiver Bandwidth   3.68 kHz
#
#  Sounder Type:
#    EK60 Version  2.2.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing            100 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          80 %
#    Max. Phase Dev.          8.0        Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.   2.1 dB/km       Sound Velocity     1477.6 m/s
#
#  Beam Model results:
#    Transducer Gain    = 23.03 dB       SaCorrection       = -0.72 dB
#    Athw. Beam Angle   = 6.77 deg       Along. Beam Angle  = 6.85 deg
#    Athw. Offset Angle = 0.08 deg       Along. Offset Angle= 0.01 deg
#
#  Data deviation from beam model:
#    RMS =    0.17 dB
#    Max =    0.61 dB  No. =   170  Athw. =  3.4 deg  Along = -2.2 deg
#    Min =   -0.51 dB  No. =   237  Athw. = -1.1 deg  Along = -4.6 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.14 dB
#    Max =    0.53 dB  No. =   170  Athw. =  3.4 deg  Along = -2.2 deg
#    Min =   -0.43 dB  No. =   172  Athw. =  3.0 deg  Along = -2.8 deg
#
```

```
#  Calibration  Version   2.1.0.12
#
#  Date:  2009-08-10
#
#  Comments: calibration of MF system with 38, 120 and 200 kHz
#
#
#  Reference Target:
#    TS                   -40.40 dB       Min. Distance         16.00 m
#    TS Deviation            5.0 dB       Max. Distance         19.00 m
#
#  Transducer:  ES120-7C  Serial No.   644
#    Frequency            120000 Hz       Beamtype                Split
#    Gain                  27.00 dB       Two Way Beam Angle   -20.5 dB
#    Athw. Angle Sens.       23.00        Along. Angle Sens.      23.00
#    Athw. Beam Angle      7.20 deg       Along. Beam Angle    7.20 deg
#    Athw. Offset Angle    0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection           0.00 dB       Depth                 1.00  m
#
#  Transceiver:  GPT 120 kHz 0090720603fa 1-1 ES120-7C
#    Pulse Duration        0.256 ms       Sample Interval     0.047   m
#    Power                   200  W       Receiver Bandwidth   8.71 kHz
#
#  Sounder Type:
#    EK60 Version  2.2.0
#
#  TS Detection:
#    Min. Value            -50.0 dB       Min. Spacing            100 %
#    Max. Beam Comp.         6.0 dB       Min. Echolength          80 %
#    Max. Phase Dev.            8.0       Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.  11.8 dB/km       Sound Velocity     1477.6 m/s
#
#  Beam Model results:
#    Transducer Gain    = 26.76 dB       SaCorrection       = -0.59 dB
#    Athw. Beam Angle   = 6.42 deg       Along. Beam Angle  = 6.41 deg
#    Athw. Offset Angle = 0.09 deg       Along. Offset Angle=-0.01 deg
#
#  Data deviation from beam model:
#    RMS =    0.21 dB
#    Max =    0.60 dB  No. =    74  Athw. =  3.7 deg  Along = -1.9 deg
#    Min =   -0.53 dB  No. =   135  Athw. =  4.5 deg  Along = -0.5 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.20 dB
#    Max =    0.59 dB  No. =    74  Athw. =  3.7 deg  Along = -1.9 deg
#    Min =   -0.57 dB  No. =    18  Athw. =  0.6 deg  Along =  3.5 deg
#
```

```
#  Calibration  Version   2.1.0.12
#
#  Date:  2009-08-10
#
#  Comments: calibration of MF system with 38, 120 and 200 kHz
#
#
#  Reference Target:
#    TS                  -45.00 dB       Min. Distance         16.00 m
#    TS Deviation          5.0 dB        Max. Distance         19.00 m
#
#  Transducer:  ES200-7C  Serial No.   528
#    Frequency           200000 Hz       Beamtype               Split
#    Gain                 27.00 dB       Two Way Beam Angle   -20.7 dB
#    Athw. Angle Sens.      23.00        Along. Angle Sens.      23.00
#    Athw. Beam Angle     7.00 deg       Along. Beam Angle    7.00 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 1.00  m
#
#  Transceiver:  GPT 200 kHz 00907206042c 2-1 ES200-7C
#    Pulse Duration       0.256 ms       Sample Interval     0.047   m
#    Power                   90  W       Receiver Bandwidth  10.64 kHz
#
#  Sounder Type:
#    EK60 Version  2.2.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing            100 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          80 %
#    Max. Phase Dev.          8.0        Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.  21.5 dB/km       Sound Velocity     1477.6 m/s
#
#  Beam Model results:
#    Transducer Gain    = 26.37 dB       SaCorrection       = -0.39 dB
#    Athw. Beam Angle   = 6.39 deg       Along. Beam Angle  = 6.39 deg
#    Athw. Offset Angle = 0.08 deg       Along. Offset Angle= 0.18 deg
#
#  Data deviation from beam model:
#    RMS =    0.30 dB
#    Max =    0.68 dB  No. =   226  Athw. =  2.4 deg  Along = -4.2 deg
#    Min =   -0.69 dB  No. =   178  Athw. = -2.9 deg  Along = -0.2 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.27 dB
#    Max =    0.74 dB  No. =   186  Athw. = -3.3 deg  Along = -1.0 deg
#    Min =   -0.64 dB  No. =   216  Athw. =  3.1 deg  Along = -3.4 deg
#
#  Data:
#  No.    Time    Distance  TS-c    TS-u      Athw.    Along     sA
#                   [m]     [dB]    [dB]      [deg]    [deg]  [m2/nm2]
#
```

```
#  Calibration  Version   2.1.0.12
#
#  Date:  2009-08-10
#
#  Comments: calibration of MF system with 38, 120 and 200 kHz
#
#
#  Reference Target:
#    TS                  -33.80 dB       Min. Distance         16.00 m
#    TS Deviation           5.0 dB       Max. Distance         19.00 m
#
#  Transducer:  ES38B  Serial No.   30961
#    Frequency            38000 Hz       Beamtype               Split
#    Gain                 26.00 dB       Two Way Beam Angle   -20.5 dB
#    Athw. Angle Sens.       21.90       Along. Angle Sens.      21.90
#    Athw. Beam Angle     7.00 deg       Along. Beam Angle    7.30 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 1.00  m
#
#  Transceiver:  GPT  38 kHz 00907205fbb0 3-1 ES38B
#    Pulse Duration       0.512 ms       Sample Interval     0.095   m
#    Power                 1000  W       Receiver Bandwidth   3.28 kHz
#
#  Sounder Type:
#    EK60 Version  2.2.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing            100 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          80 %
#    Max. Phase Dev.           8.0       Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.   2.1 dB/km       Sound Velocity     1477.6 m/s
#
#  Beam Model results:
#    Transducer Gain    = 24.73 dB       SaCorrection       = -0.78 dB
#    Athw. Beam Angle   = 6.89 deg       Along. Beam Angle  = 6.94 deg
#    Athw. Offset Angle = 0.11 deg       Along. Offset Angle=-0.02 deg
#
#  Data deviation from beam model:
#    RMS =    0.19 dB
#    Max =    1.60 dB  No. =   129  Athw. = -2.8 deg  Along = -4.3 deg
#    Min =   -0.53 dB  No. =    64  Athw. = -4.6 deg  Along =  1.8 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.15 dB
#    Max =    1.00 dB  No. =   129  Athw. = -2.8 deg  Along = -4.3 deg
#    Min =   -0.48 dB  No. =   257  Athw. =  3.4 deg  Along = -2.9 deg
#
```

```
#  Calibration  Version   2.1.0.12
#
#  Date:  2009-08-10
#
#  Comments: calibration of MF system with 38, 120 and 200 kHz
#
#
#  Reference Target:
#    TS                  -40.40 dB       Min. Distance         16.00 m
#    TS Deviation           5.0 dB       Max. Distance         19.00 m
#
#  Transducer:  ES120-7C  Serial No.   621
#    Frequency           120000 Hz       Beamtype                Split
#    Gain                 27.00 dB       Two Way Beam Angle   -20.5 dB
#    Athw. Angle Sens.      23.00        Along. Angle Sens.      23.00
#    Athw. Beam Angle     7.20 deg       Along. Beam Angle    7.20 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 1.00  m
#
#  Transceiver:  GPT 120 kHz 0090720603fa 1-1 ES120-7C
#    Pulse Duration       0.512 ms       Sample Interval     0.047   m
#    Power                  200  W       Receiver Bandwidth   8.71 kHz
#
#  Sounder Type:
#    EK60 Version  2.2.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing            100 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength          80 %
#    Max. Phase Dev.          8.0        Max. Echolength         180 %
#
#  Environment:
#    Absorption Coeff.  11.8 dB/km       Sound Velocity     1477.6 m/s
#
#  Beam Model results:
#    Transducer Gain    = 26.80 dB       SaCorrection       = -0.38 dB
#    Athw. Beam Angle   = 6.42 deg       Along. Beam Angle  = 6.42 deg
#    Athw. Offset Angle = 0.04 deg       Along. Offset Angle=-0.05 deg
#
#  Data deviation from beam model:
#    RMS =    0.29 dB
#    Max =    0.80 dB  No. =   279  Athw. = -0.4 deg  Along =  4.3 deg
#    Min =   -0.83 dB  No. =    23  Athw. = -2.7 deg  Along =  3.2 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.26 dB
#    Max =    0.71 dB  No. =     7  Athw. = -2.3 deg  Along =  4.4 deg
#    Min =   -0.92 dB  No. =    23  Athw. = -2.7 deg  Along =  3.2 deg
#
```

```
#  Calibration  Version   2.1.0.12
#
#  Date:  2009-08-10
#
#  Comments: calibration of MF system with 38, 120 and 200 kHz
#
#
#  Reference Target:
#    TS                  -45.00 dB       Min. Distance         16.00 m
#    TS Deviation          5.0 dB       Max. Distance         19.00 m
#
#  Transducer:  ES200-7C  Serial No.   428
#    Frequency           200000 Hz       Beamtype                 Split
#    Gain                 27.00 dB       Two Way Beam Angle   -20.7 dB
#    Athw. Angle Sens.      23.00       Along. Angle Sens.      23.00
#    Athw. Beam Angle     7.00 deg       Along. Beam Angle    7.00 deg
#    Athw. Offset Angle   0.00 deg       Along. Offset Angle  0.00 deg
#    SaCorrection          0.00 dB       Depth                 1.00  m
#
#  Transceiver:  GPT 200 kHz 00907206042c 2-1 ES200-7C
#    Pulse Duration       0.512 ms       Sample Interval     0.095   m
#    Power                   90  W       Receiver Bandwidth   5.97 kHz
#
#  Sounder Type:
#    EK60 Version  2.2.0
#
#  TS Detection:
#    Min. Value           -50.0 dB       Min. Spacing             100 %
#    Max. Beam Comp.        6.0 dB       Min. Echolength           80 %
#    Max. Phase Dev.          8.0       Max. Echolength          180 %
#
#  Environment:
#    Absorption Coeff.  21.5 dB/km       Sound Velocity     1477.6 m/s
#
#  Beam Model results:
#    Transducer Gain    = 26.47 dB       SaCorrection        = -0.37 dB
#    Athw. Beam Angle   = 6.45 deg       Along. Beam Angle  = 6.52 deg
#    Athw. Offset Angle = 0.16 deg       Along. Offset Angle= 0.19 deg
#
#  Data deviation from beam model:
#    RMS =    0.39 dB
#    Max =    0.77 dB  No. =    19  Athw. = -2.1 deg  Along =  2.6 deg
#    Min =   -0.76 dB  No. =    29  Athw. =  2.7 deg  Along =  1.3 deg
#
#  Data deviation from polynomial model:
#    RMS =    0.37 dB
#    Max =    0.79 dB  No. =    61  Athw. = -0.6 deg  Along =  4.3 deg
#    Min =   -0.90 dB  No. =    29  Athw. =  2.7 deg  Along =  1.3 deg
```

ANNEX III

Tel. +370 5 210 26 00. Faks. +370 5 210 26 06

ĮMONIŲ, ĮSTAIGŲ, ORGANIZACIJŲ TURTO DRAUDIMO POLISAS Nr. ĮT- 008897

Turto draudimo nuo gaisro ar gamtinių jėgų grupė
Turto draudimo nuo kitų žalų grupė

Draudėjas KLAIPĖDOS UNIVERSITETAS, į/k 211951150
(įmonės, įstaigos, organizacijos rūšis, pavadinimas, įmonės kodas)

H. Manto g. 84, Klaipėda
(adresas)

Tel.: (darbo) Tel.: (namų) El. p./faks.:

Draudimo objektas DAUGIADAŽNĖ HIDROAKUSTINĖ SISTEMA
(draudžiamo objekto pavadinimas)

(adresas)

Draudimo laikotarpis Pradžia: 200 9 m. Rugsėjo mėn. 05 d.
Pabaiga: 200 11 m. Gegužės mėn. 01 d.

Draudimo objektas	Draudimo objekto vertė (Lt)	Draudimo suma (Lt)	Franšizė (Lt)	Draudimo įmoka (Lt)	Draudiminiai įvykiai
1. Nekilnojamasis turtas	-	-	-	-	-
2. Kilnojamasis turtas	511 700,00	511 700,00	3 000,00	2 558,99	Draudimo apsaugos sąlyga Nr. NKT
3. Apyvartinis turtas	-	-	-	-	-
4. Parodų eksponatai	-	-	-	-	-
5. Darbuotojų daiktai (taisyklių 1.5 punktas)	-	-	-	-	-

Draudimo objektas draudžiamas: atstatomąja verte x likutine verte ☐ (reikalingą pažymėti x)

Draudimo įmoka 2 558,99 Lt Lt Du tūkstančiai penki šimtai penkiasdešimt aštuoni litai, 99 ct.
(suma skaičiais) (suma žodžiais)

Įmokos mokėjimo tvarka ir terminai: grynais ☐ pavedimu x (reikalingą pažymėti x)

1.	2 558,99 Lt	Lt	Iki	2009.09.05	7.	-	Lt	Iki	-
2.	-	Lt	Iki	-	8.	-	Lt	Iki	-
3.	-	Lt	Iki	-	9.	-	Lt	Iki	-
4.	-	Lt	Iki	-	10.	-	Lt	Iki	-
5.	-	Lt	Iki	-	11.	-	Lt	Iki	-
6.	-	Lt	Iki	-	12.	-	Lt	Iki	-

Pastabos:

Draudimo sutartis sudaryta remiantis UAB BTA Draudimas Įmonių, įstaigų ir organizacijų turto draudimo taisyklėmis Nr. 004 ir Draudėjo prašymu. Su Įmonių, įstaigų ir organizacijų turto draudimo taisyklių Nr. 004 sąlygomis susipažinau, draudimo polisą gavau

Draudėjas

Su UAB BTA Draudimas Įmonių, įstaigų ir organizacijų turto draudimo taisyklėmis Nr. 004 susipažinau, draudimo polisą gavau:

(vardas, pavardė)

(parašas)

Draudikas

Vyriausioji draudimo specialistė
(atstovo pareigos, vardas, pavardė)
Edita Anužienė
(parašas)

Draudimo polisas išduotas 2009 m. Rugsėjo mėn. 04 d.

AB SEB Vilniaus bankas, banko kodas 70440, a/s LT13 7044 0600 0174 9259

Verkių g. 29, 18 korpusas, LT-09108 Vilnius, Lietuva
Tel. (+370 5) 210 26 60, faks. (+370 5) 210 26 66, www.bta.lt, el. p.: bta@bta.lt
Įmonės kodas 110079036
Registro tvarkytojas VĮ REGISTRŲ CENTRAS

BTA DRAUDIMAS

I priedas prie "Įmonių, įstaigų, organizacijų turto draudimo" poliso serija JT, Nr. 008897

PAPILDOMOS SĄLYGOS:
Nešiojama įranga papildomai apdrausta nuo apiplėšimo draudėjo darbuotojų komandiruočių metu, kai:
- draudėjo ar jo darbuotojo atžvilgiu panaudojama fizinė ar psichologinė prievarta, jam priešinantis prieš apdrausto turto atėmimą;
- draudėjas ar jo darbuotojas apdraustą turtą atiduoda ar leidžia atimti, nes draudimo vietoje jam grasoma fizinės ar psichologinės prievartos veiksmais;
- atimamas apdrausta turtas iš draudėjo ar jo darbuotojo, esančio bejėgiškos būklės dėl šio įvykio ar dėl nelaimingo atsitikimo, ar dėl kitos, ne dėl jo kaltės susidariusios priežasties ir jam negalint priešintis.
Draudimo apsauga nuo apiplėšimo rizikos galioja draudimo vietoje arba už draudimo vietos ribų Lietuvos Respublikos teritorijoje.
Draudimo apsauga nuo apiplėšimo už draudimo vietos ribų rizikos galioja aukščiau išvardintai nešiojamai įrangai, kurią draudėjas ar jo darbuotojas turi su savimi jam esant už polise nurodytos draudimo vietos ribų, tačiau Lietuvos Respublikos teritorijoje.
Draudimo apsauga už draudimo vietos ribų apiplėšimo padarytiems nuostoliams dėl sugadintos, sunaikintos ar prarastos apdraustos nešiojamos įrangos galioja tuomet, jei bus policijos patvirtintas draudėjo ar jo darbuotojų apiplėšimo faktas ir dėl šio fakto iškelta byla.
Draudimo išmoka už draudimo vietos ribų apdraustą nešiojamą įrangą apskaičiuojama nuostolio dydžio, tačiau draudėjui atlyginama įvertinant nustatytas besąlygines išskaitas.
Nuostoliai dėl apiplėšimo neatlyginami už nešiojamąją įrangą, jei ji į jų atėmimo vietą pristatoma nusikaltėlio reikalavimu.
Draudiminė apsauga galioja vandenyje.

Draudėjas:	Draudikas:
KLAIPĖDOS UNIVERSITETAS	UAB „BTA Draudimas",
įm. kodas 211951150	įm. kodas 110079036
H. Manto g. 84, Klaipėda	Verkių g. 29, 18 korpusas, Vilnius,
	tel.: (370 5 210 26 60; faks.: 210 26 66
	A/s "SEB Vilniaus bankas",
	LT13 7044 0600 0174 9259
	Banko kodas 70440

Draudėjas (jo atstovas):	Draudikas (jo atstovas):
Doc. dr. ... Infrastruktūros prorektorius	Vyriausioji draudimo specialistė Edita Anužienė
2009 ...	A.V.
(Data, miestas)	