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Report of the Study Group on Target Strength Estimation in the Baltic Sea (SGTSEB)

30 March 2006

Hobart, Australia

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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1 Executive Summary

John Horne, USA was elected Chair of the Study Group on Target Strength Estimation in the Baltic Sea (SGTSEB) in 2005.

The Study Group activities and new modelling results from Natalia Gorska (Poland) were presented at the 2006 WGFAST meeting in Hobart, Australia.

WGFAST members did not endorse the publication of an ICES Cooperative Research Report.

Baltic herring modelling results will be combined and published by J. Horne and N. Gorska.

2 Meeting report

2.1 Participation

This report was presented to the ICES WGFAST during a regular working group session. People who have participated in the Study Group and were present WGFAST meeting include:

Bo Lundgren	Denmark
John Horne	USA
Michael Jech	USA
Andrzej Orlowski	Poland

2.2 Terms of Reference

According to the Annual Science Conference Resolution (2005/2/FTC08) in Aberdeen, the **Study Group of Target Strength Estimation in the Baltic Sea** [SGTSEB] (Chair: John Horne, USA) will meet in Hobart, Australia from 26–30 March 2006 during the WGFAST meeting to:

a) prepare a new revised and updated version of the document already existing to submit to WGFAST in Hobart, Australia, 27–30 March 2006;

b) prepare a draft report o n the work of the Study Group for possible publication in the *ICES Cooperative Research Report* series, to be submitted at the Fisheries Technology Committee session during the 2006 ASC.

2.3 Meeting activities

On behalf of Natalia Gorska, John Horne presented results of the study, "Target strength of Baltic Herring (*Clupea harengus* L.) results of modelling."

John Horne (USA) summarized the activities of the Study Group on Target Strength Estimation in the Baltic Sea (SGTSEB). An outline was presented for potential contents of a report, which included the following topics:

- Current Status of Baltic Herring Target Strength Use
- Literature Review of Herring Target Strength
- Factors Potentially Affecting Target Strengths of Baltic Herring
- Protocol for Target Strength Measurements
- Backscatter Modelling of Baltic Herring
- *In situ* TS measurements of Baltic Herring
- Conversion of Acoustic Size to Fish Size for Baltic Herring and Sprat

A discussion was held on the potential contributions of the group and how this work will be finished.

3 Review of previous ToR's

Annex A contains ToR's and comments from 2000, 2001 and 2002.

4 Summary of the Gorska paper

This study used Stanton's (1989) Modal-Based, Deformed-Cylinder Model (MG-DCM) to investigate the combined effects of depth, orientation, and frequency on predicted backscatter of Baltic Herring

4.1 Approach

Backscattering cross-sections were averaged over fish orientations:

$$<\sigma_{bsc}(z)>=\iint d\theta\, W(\theta,z)\left|f_{tot}(\theta,z)\right|^2$$

where z is the depth, function $W(\theta, z)$ describes fish distribution over orientation θ and $f_{tot}\ (z)$ denotes the total backscattering length. Fish orientations were normally distributed with a mean of 0 degrees and a width of 5 degrees. Total backscatter (f_{tot}) is estimated using contributions from the fish body (f_b) and swimbladder (f_{sb}) as a function of depth (z):

$$f_{tot}(z) = f_{sb}(z) + f_b$$

The fish body and swimbladder are described as prolate spheroids with major axes corresponding to fish standard length and swimbladder length, and minor axes lengths corresponding to body width and swimbladder width.

Swimbladder volume as a function of depth was calculated using:

$$V(z) = V_0(1 + z\rho g / P_0)^{-1}$$

where swimbladder volume (V_0) is influenced by atmospheric pressure at the surface (P_0), water density (ρ), and acceleration due to gravity (g).

Swimbladder dimensions change by:

$$a_0^{sb}(z) = a_{sb}(0)\ (1 + z\rho g / P_0)^{-\alpha}$$

$$l_{sb}(z) = l_{sb}(0)\ (1 + z\rho g / P_0)^{-\beta}$$

where α and β are compression factors for the corresponding dimensions. Boyle's law requires that $2\alpha + \beta = 1$. Atmospheric pressure and sea water density values of 101300 N m^{-2} and 1005 kg m^{-3} were used in all modelling. Fish body and swimbladder density (1.04; 1.04) and sound speed (0.00129; 0.23) contrasts were constant for all fish. Compression factor values were based on results from Norwegian Spring Spawning herring (Gorska and Ona, 2003, a, b) where the diameter of the swimbladder reduces more rapidly than its length. Compression factor values were set at $\beta = 0$ and $\alpha = 0.5$.

Dorsal and lateral radiographs of 26 fish with a mean total length of 18.26 cm were used in the analysis.

4.2 Results and discussion

Predicted target strengths (TS) were sensitive to depth and frequency (Figures 1, 2), especially for the larger fish. TS monotonically decreased with depth at 38 kHz for fish in all size classes (blue lines in the figures). For larger fish predicted target strengths at 70 and 120 kHz (Figure 2) TS initially increased near the surface and then decreased with depth.

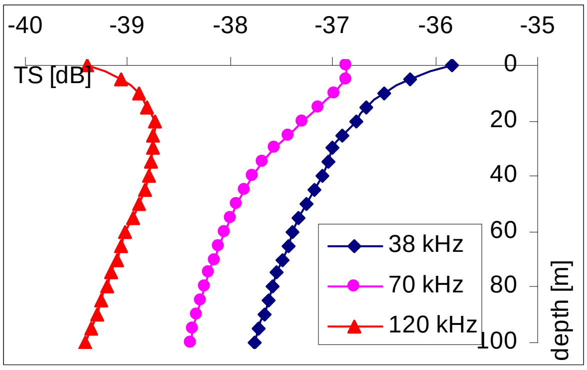

Figure 1: The depth dependence of herring TS at different frequencies (fish total length 21 cm).

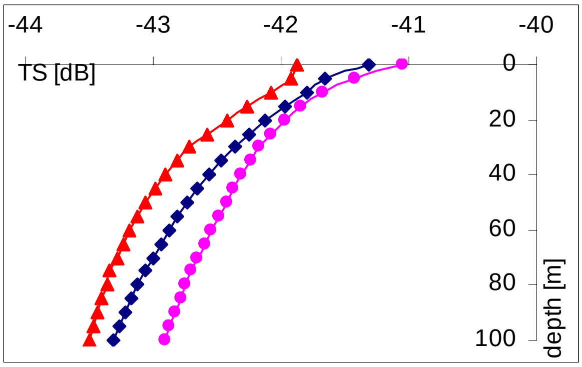

Figure 2: The depth dependence of herring TS at different frequencies (fish total length 15 cm).

Variability in target strength (the difference between maximum and minimum TS over entire depth range) with depth depends on fish size (Figure 4). Polynomial regressions were fitted to predicted target strengths at each frequency. Depth variability of herring target strength decreases with increasing fish length and frequency.

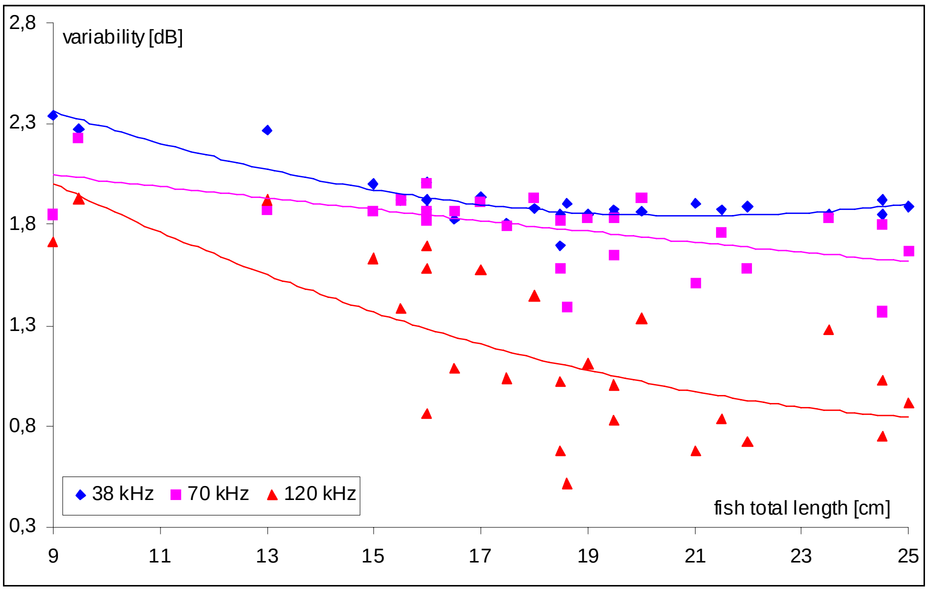

Figure 4: Depth variability of herring at different frequencies.

Target strength to length relationship incorporating depth was modelled using: $TS = b\ log_{10}L + d$, where L is fish total length in cm, for the sets of the data calculated at different depth ranges.

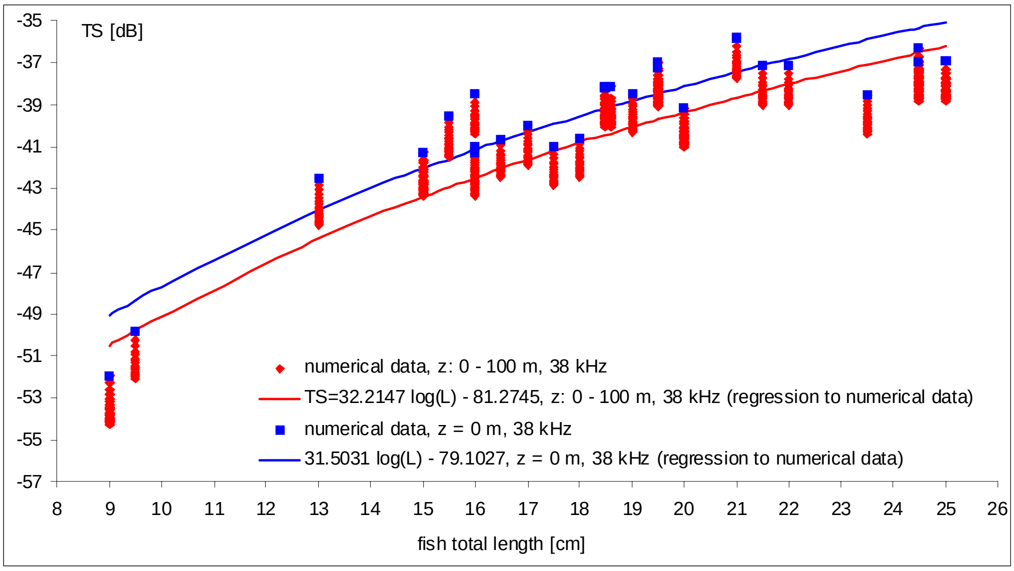

Figure 5: Impact of swimbladder contraction on TS-length relationship at 38 kHz and 0 m (blue) and 0 to 100 m (red) depth.

Predicted depth averaged target strengths are approximately 2 dB lower than fish at the surface. Modelled and measured fish target strength to fish length and depth relationships from this study were compared to others published for Baltic Herring (Figure 6) at 38 kHz.

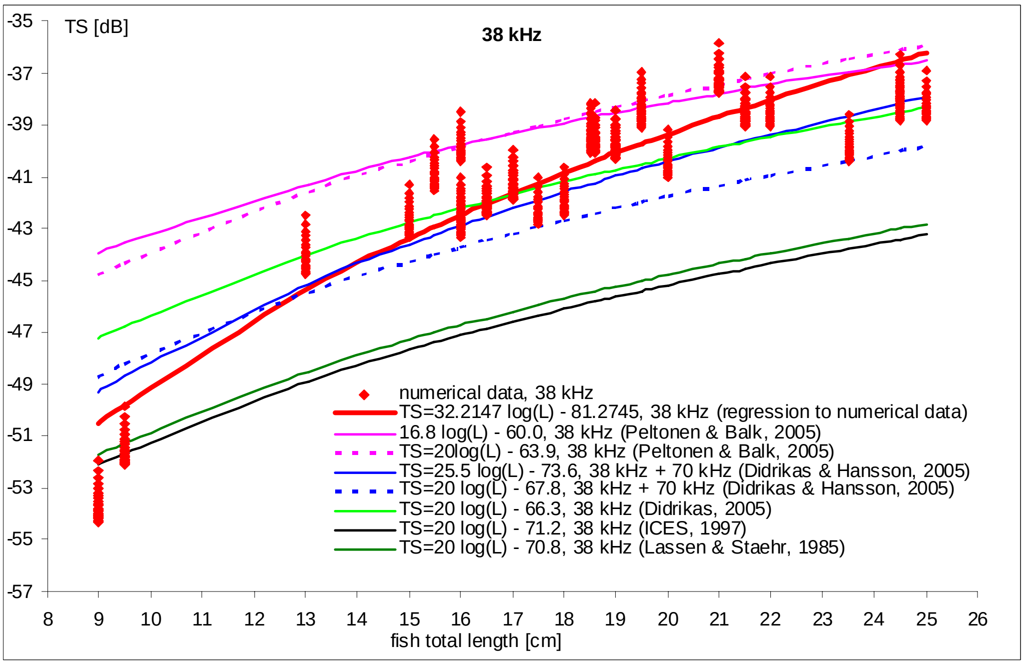

Figure 6: Comparison of calculated and measured TS-length relationships for Baltic herring at 38 kHz.

Depending on the regression equations used for comparison, predicted target strengths of fish at any length can differ by up to 8 dB. Potential reasons why results differ include (cf Peltonen and Balk 2005):

a) data sets were collected under different bathymetric (depth) and hydrographic (salinity and temperature) conditions;

b) surveys varied in survey platforms and fishing gears used for direct capture;

c) data sets differed in species composition and frequencies:

- Peltonen and Balk (Peltonen and Balk, 2005) analyzed only herring data, while the other investigators (Didrikas, 2005; Didrikas and Hansson, 2004) did not separate herring and sprat data,
- Didrikas and Hansson (Didrikas and Hansson, 2004) considered the data, collected at two frequencies (38 kHz and 70 kHz), like one data set, while the other investigators separately analyzed the data, acquired at different frequencies.

Results from this study can be used to interpret some of the observed target strength relationship variability:

1) Depth and tilt orientation were shown to contribute 2.34 dB and 2.7 dB difference in target strength at 38 kHz.

2) Frequency-dependent target strength differences at 38 and 70 kHz (up to 1.5 dB) depend on fish size and depth

4.3 Gorska Paper Conclusions

Examining sensitivity of backscatter to biological, acoustical and environmental parameters for Baltic herring demonstrated that:

1) herring target strength can vary with depth and depends on fish size and acoustic frequency. The difference between maximum and minimum *TS* over a 100 m depth range varies between 1.70 – 2.34 dB at 38 kHz, 1.37 – 2.23 dB at 70 kHz, and 0.52 – 1.93 dB at 120 kHz;

2) TS-length relationships for Baltic herring are sensitive to the frequency, depth, and tilt orientation;

3) agreement between the predicted and measured target strengths verifies MB-DCMmodel reliability. Variability of measured Baltic herring *TS* in different study areas is attributed to herring morphology, tilt orientation, and depth;

4) changes in swimbladder shape due to depth and tilt orientation can contribute up to 2.34 dB and 2.7 dB difference in herring *TS* at 38 kHz;

5) a definitive TS-length relationship for Baltic herring requires additional, controlled measurements over the range of conditions observed in the Baltic Sea.

5 Discussion of Study Group contributions

This Study Group has met since 2001 and the group is ready to complete its work. Some of these topics have been contributed as documents to the Study Group, and some have been published in both the primary and secondary literature. There was a discussion at the 2006 WGFAST meeting on whether a *Cooperative Research Report* on the subject was warranted. The consensus was that the research fragments are not a complete package at this time. There is no time for additional work. It was suggested to have a special session on Baltic herring at the 2007 ICES Annual Science Conference; this would be a helpful way to disseminate the activities of the Study Group to a wider audience. No one volunteered to follow up on this suggestion. J. Horne and N. Gorska are planning to combine modelling results into a single primary literature paper. No other activities are planned at this time.

6 Reporting

Reports from 2001, 2002, and 2003 have been submitted to ICES.

7 References

Didrikas, T. 2005. Estimation of *in situ* target strength of the Baltic Sea herring and sprat. Unpublished Report.

Didrikas, T., and Hansson, S. 2004. *In situ* target strength of the Baltic Sea herring and sprat. ICES Journal of Marine Science, 61: 378–382.

Gorska, N., and Ona, E. 2003a. Modelling the acoustic effect of swimbladder compression in herring. ICES Journal of Marine Science, 60: 548–554.

Gorska, N., and Ona, E. 2003b. Modelling the effect of swimbladder compression on the acoustic backscattering from herring at normal or near-normal dorsal incidences. ICES Journal of Marine Science, 60: 1381–1391.

Lassen, H. and Stæhr, K. J. 1985. Target strength of Baltic herring and sprat measured in in-situ. ICES CM. 1985/B:41:1–14.

Peltonen, H., and Balk, H. 2005. The acoustic target strength of herring (*Clupea harengus* L.) in the northern Baltic Sea.

Stanton, T. K. 1989. Sound scattering by cylinder of finite length. III. Deformed cylinders. Journal of the Acoustical Society of America, 86: 691–705.

Annex 1: Terms of Reference

Brugge 2000

2B02 A **Study Group on Target Strength Estimation in the Baltic Sea** [SGTSEB] (Chair: F. Arrhenius, Sweden) will be established and will meet in Seattle, USA from 22–23 April 2001 to:

a) prepare and disseminate as soon as possible a protocol for TS measurements on the Baltic herring, based upon the state of the art and especially the recommendations of the *Cooperative Research Report* on TS measurements, 1999), adapting these recommendations to the special case of the Baltic Sea;

Done (Section 4, 2002-report)

b) establish a list of the main factors affecting the herring TS and study the effects through comparative analysis and measurements on various herring stocks (e.g. Baltic and Norwegian spring spawning herrings);

Initial assessment done in 2001 and 2002 reports. Modifications in process.

c) collate the existing information and measurements on herring TS;

Done

d) apply modelling methods on the case of the herring and compare their results to the existing information;

Modelling on herring and sprat done. Comparisons underway.

e) measure the variability of TS in situ under various conditions (day-night, winter/summer, etc.) using databases available from WGFAST members;

Only limited variations possible due to cruise pattern (spring-autumn only).

f) encourage experimental measurements through conventional and non-conventional methods. SGTSEB shall make its report available to WGFAST and will report by 22 May 2001 for the attention of the Fisheries Technology and Baltic Committees.

Done

Oslo 2001

2B04 The **Study Group on Target Strength Estimation in the Baltic Sea** [SGTSEB] (Chair: F. Arrhenius, Sweden) will meet in Sète, France from 7–8 June 2002 to:

a) discuss the results of the biological properties that affect backscattering of Baltic fish, i.e., swim bladder volume and shape, fat content, and stomach content and fullness;

No *in situ* data obtained, but discussed in relation to model data from X-rayed fish.

b) discuss the result of backscatter models, especially change in biological and physiological factors affecting the TS;

Done

c) evaluate the single target TS measurements on herring and sprat during the 2001 surveys in the Baltic Sea;

Planned for final report using 2002 and possibly 2001 data.

d) review the latest literature on TS of herring and sprat;

Done and continues.

e) review current information of diel cycles of fat content and stomach fullness in different parts of the Baltic Sea area;

Done and continues.

SGTSEB will report by 30 June 2002 for the attention of the Fisheries Technology Committee.

Report delayed until 2003.

Copenhagen 2002

2B04 The **Study Group of Target Strength Estimation in the Baltic Sea** [SGTSEB] (Chair: B. Lundgren, Denmark) will meet in Bergen, Norway from 17–18 June 2003 to:

a) evaluate the single target TS measurements on herring and sprat during the surveys in 2001–2002 and from cage experiments in the Baltic;

Cage experiment tried but not successful. For survey data planned for final report.

b) apply the modelling methods on the case of the herring and sprat and compare their results to the existing information and single target TS measurements and cage experiments in the Baltic Sea

Planned for final report.

c) recommend TS length relationships for herring and sprat in the Baltic Sea.

Initiated by 2003-meeting. Planned for final report.

SGTSEB will make its report available by 31 July 2003 for the attention of the Fisheries Technology Committee and the Baltic Committee. It will also make it available to WGFAST.

Preliminary meeting report being submitted. Final report within 1 year. Planned as Cooperative Research Report.