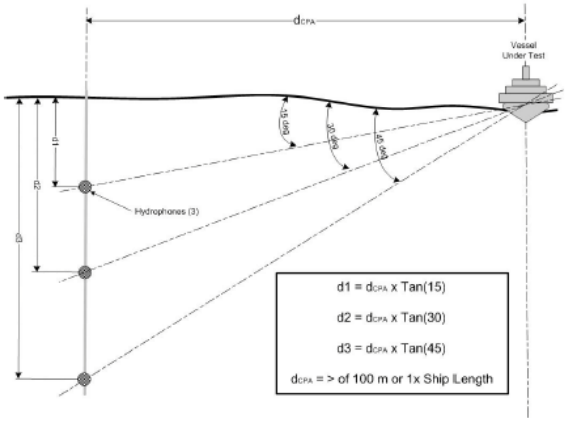
Underwater sound measurements from fishing vessel “Brennholm”



Héctor Peña, Jan Tore Øvredal, Bjørn Totland and Nils Olav Handegard

Observation methodology and catch working groups

Institute of Marine Research

August, 2011

Abstract

A methodology for measuring underwater sound from free running vessels was implemented inside IMR, following American National Standard ANSI/ASA S12.64-2009 grade B. An array of 3 calibrated NEXUS hydrophones was mounted in a drifting buoy provided with DGPS and radio communication. The sound measurement was recorded at different speed and engine settings (rpm and pitch) inside Osterfjørd on December 8, 2010. Optimal weather conditions and almost absent marine traffic prevailed during the data collection. Analysis of the data was done at 1/3 and 1/24 octave band filter, and sound pressure levels were normalized for distance from the hydrophones to the centre of the vessel. Sound pressure spectrum of radiated underwater sound from "Brennholm" showed a higher (*ca*. 30 dB) than recommended levels by the ICES CRR 209, at vessel speeds of 9, 11 and 12 knots.

Introduction

The levels of radiated underwater sound from vessels, has been a major concern in the fisheries acoustics scientific community, due to the potential effect on altering the natural behavior of the target species during the acoustic surveying. The ICES Cooperation Research Report no. 209 (ICES, 1995), showed the efforts of the experts in the field and proposed ways how to mitigate the unwanted high levels of vessel underwater noise. After the CRR 209, several of the new research vessels build were designed aiming to target the report recommended noise levels, and in most cases were reached and even improved (Mitson and Knudsen, 2003)

The CRR 209 report was oriented to research vessels, but it implications and recommendations could be applied to any type of vessel, including fishing vessels. Recently, and due to many different factors, the number of fishing vessels used in scientific surveys has increased dramatically, and levels of underwater radiated sound has become an important issue again.

In Norway, underwater sound measurements have been traditionally carried out by the Royal Norwegian Navy Material Command, for measuring the large IMR vessels but also for some commercial fishing vessels, mostly combined purse seiner/pelagic trawlers (Peña, 2009). The motivation of the commercial vessels to have these measurements was to have increased their chances when applying for participating in the chartering of vessels for IMR research surveys.

The aim of the present study was to establish a methodology based in the American National Standard ANSI/ASA S12.64-2009 grade B (American national standard institute, 2009) for measuring the underwater sound from free running vessels. Also, aimed to measure the underwater sound of the commercial fishing vessel "Brennholm" at different sailing speeds.

Methodology

The measurements were carried out the 08 December 2010, in the Osterfjord (60°33.393’ N and 5° 24.711’E), *ca*. 1 hour north from Bergen (Figure 1). The weather conditions were optimal with no wind and almost no maritime traffic during the whole experiment.

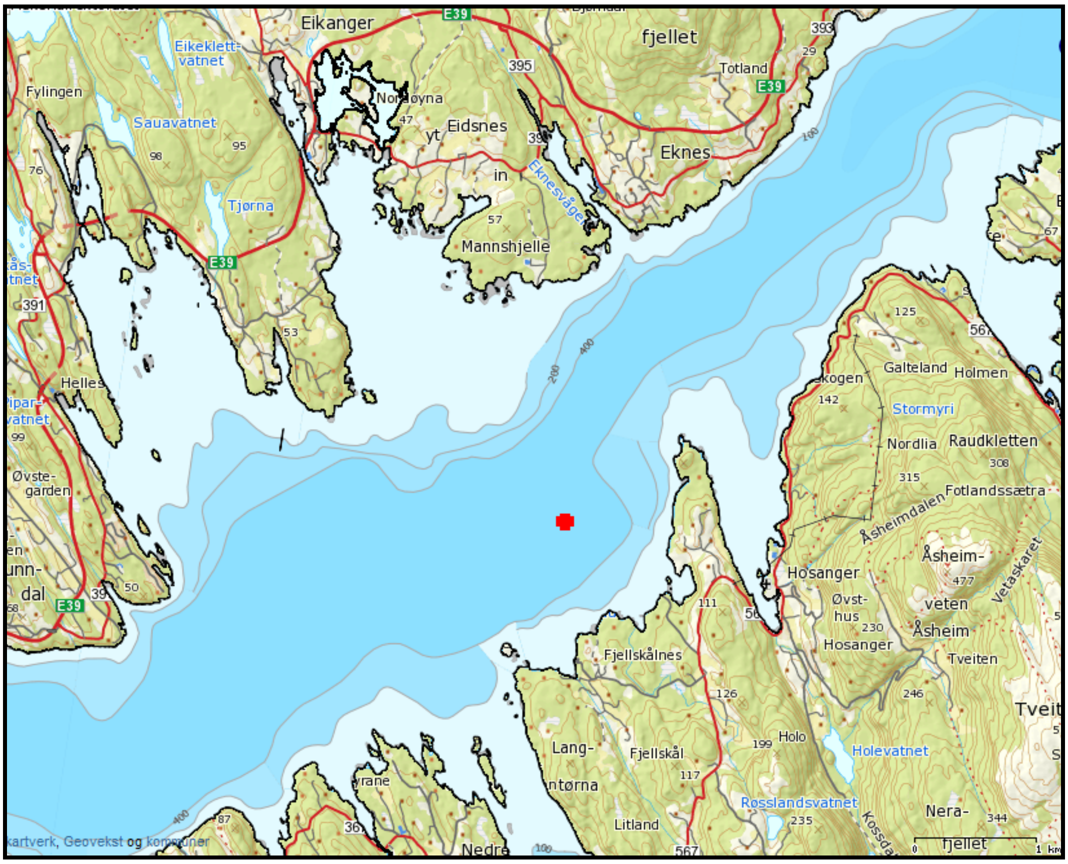


Figure 1. Map of Osterfjørd with the location of the buoy (red mark). The vessel runs were made north of the buoy in the centre and deeper part of the fjord.

The dimensions of “Brennholm” are; length o.a.: 75.4 m, breadth (mld): 14.6 m, depth (mld): 8.97 m.

Following the ANSI/ASA standard grade B, three Nexus Ethernet hydrophones model 02345 were mounted in an array with a drifting buoy (Figure 2). The hydrophones were connected via Cat 5 Ethernet to a pressure sailed container in the buoy, provided with a processing and storing unit. The depth of the hydrophones was set to 25, 54 and 94 m following the standard recommendations (Figure 2).

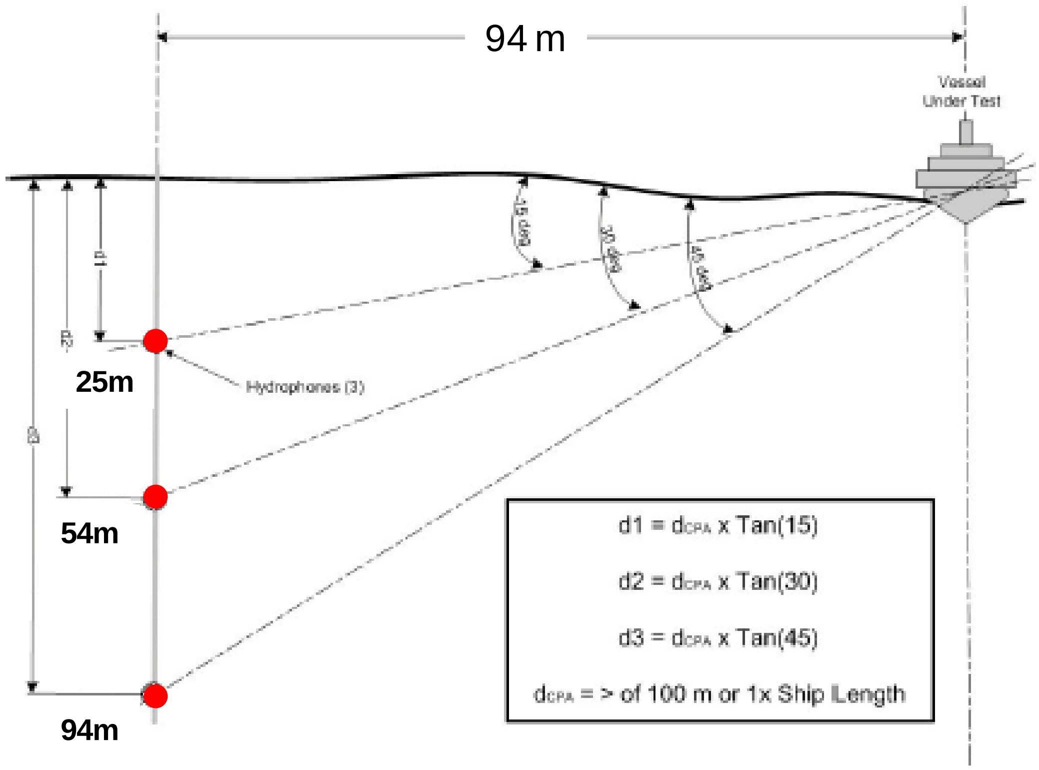


Figure 2. Scheme with a lateral view of the location of the buoy with three hydrophones in relation to the vessel sailing line (modified from ANSI/ASA S12.64-2009).

The buoy had a differential GPS JRC DGPS-212 and a VHF radio communication system for hydrophone performance monitoring from the vessel. Another differential GPS was located at mid-point between propeller and engine of the vessel, mounted at the end of the net stacker adjusted to the desired location. The recordings from the three hydrophones, and the DGPS data were stored in the ad-hoc container in the buoy for later processing.

The hydrophones were calibrated previously using a B&K filed calibration type 4229. The recorded calibration tone was used to calibrate the analyzer for each hydrophone.

The experimental design for the grade B from the ANSI/ASA standard, consist in 3 runs from port side and 3 from starboard side for each sailing condition (Figure 3). Each run had a straight trajectory aiming to keep a distance of 94 m from the buoy.

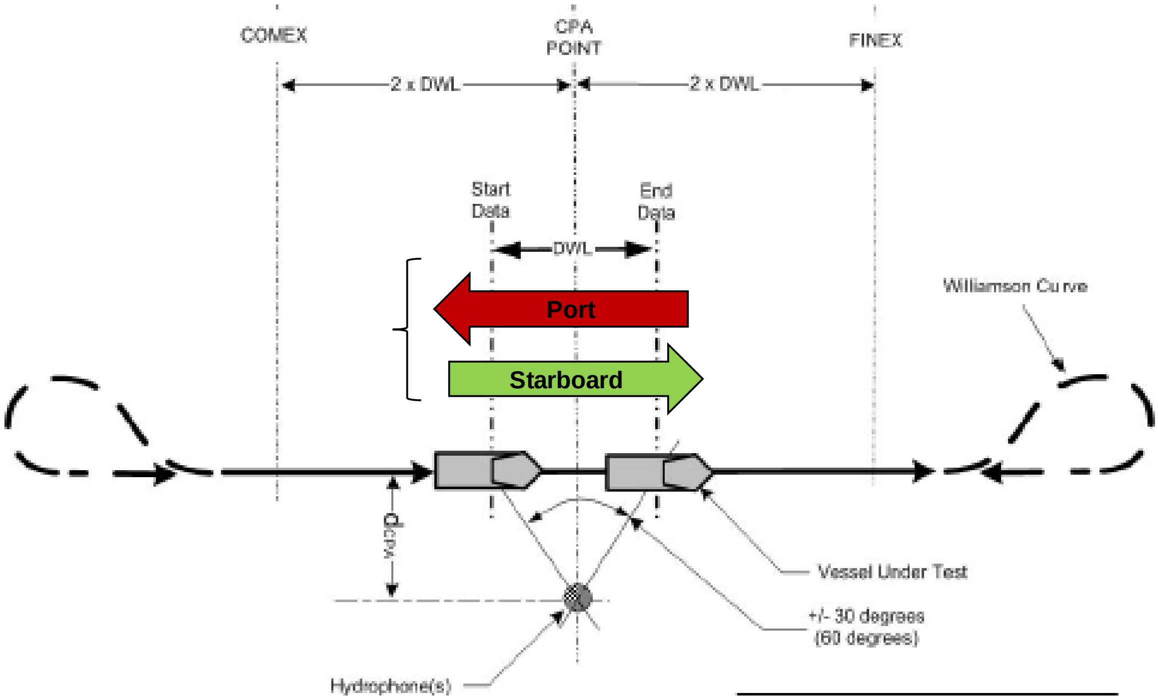


Figure 3. Scheme with a top view of the vessel track during the measurements (modified from ANSI/ASA S12.64-2009).

Using the geographical positions from the DGPS of the buoy and acoustic centre of the vessel position, the closest point of approach from vessel to buoy was calculated, using Haversine formula (Sinnott, 1984). Data from GPS and hydrophones was synchronized using time stamp where data window length (DWL) was found (Figure 3). Data from hydrophones was collected continuously, and only data from the DWL was processed, giving one 1/3 and 1/24 octave average specter. Sound pressure levels for each hydrophones where normalized for distance from hydrophones to acoustic centre of the vessel.

Sound pressure levels were averaged for the three hydrophones and three runs for each vessel speed, rpm and pitch settings, for 1/3 octave band analyzes. 1/3 octave band analyzes was presented as source level in dB re to 1 µPa 1 Hz. Sound pressure levels for one hydrophone and three runs for each vessel speed, rpm and pitch settings, was used for 1/24 octave band analyzes. Background noise during the experiment was so low that it was not necessary to take account of it (<10 dB compared to ship noise).

Results

A total of 22 runs were made by “Brennholm”, from vessel speed of 9.2 to 12 knots (Table 1). The pitch varied from 40 to 60% and the engine operated constant at 900 RPM. In the last 4 runs (run 20 to 23), the fisheries sonar and echo sounder were operating normally.

Run	Side to the buoy	Speed (knots)	Pitch (%)	Rpm	Sonar/ Echo sounder
1	Starboard	11	50	900	No
3	Starboard	11	50	900	No
5	Starboard	11	50	900	No
2	Port	11	50	900	No
4	Port	11	50	900	No
6	Port	11	50	900	No
7	Starboard	12	60	900	No
9	Starboard	12	60	900	No
11	Starboard	12	60	900	No
8	Port	12	60	900	No
10	Port	12	60	900	No
12	Port	12	60	900	No
13	Starboard	9.2	40	900	No
15	Starboard	9.2	40	900	No
17	Starboard	9.2	40	900	No
19	Starboard	9.2	40	900	No
14	Port	9.2	40	900	No
16	Port	9.2	40	900	No
18	Port	9.2	40	900	No
21	Starboard	9.2	40	900	Yes
20	Port	9.2	40	900	Yes
23	Starboard	12	60	900	Yes
22	Port	12	60	900	Yes

Table 1. Sailing conditions during the different runs by “Brennholm”.

The results from the analysis at 1/24 octave for the hydrophone at 54 m depth at the three vessel speed (12, 11 and 9.2 knot), showed a detailed and similar spectrum (Figures 4, 5 and 6). First, an increase in the noise level from 140 to 170 dB in the band spectrum between 8 to *ca*. 50 Hz. For higher frequencies, a gradually decrease back to 140 dB level is observed up to 4 kHz. The high peaks observed at lower frequencies at the three different speed (more clear at 11 knots, Figure 5), could corresponds to; propeller blade rate at *ca*. 10 kHz, second harmonics of propeller blade rate at *ca*. 16 kHz, and main motor blower shaft rate at 25 Hz (Wood, 2011). The stronger peaks, maximum 20 dB increase, were observed at 11 knots with 50% pitch and 900 rpm.

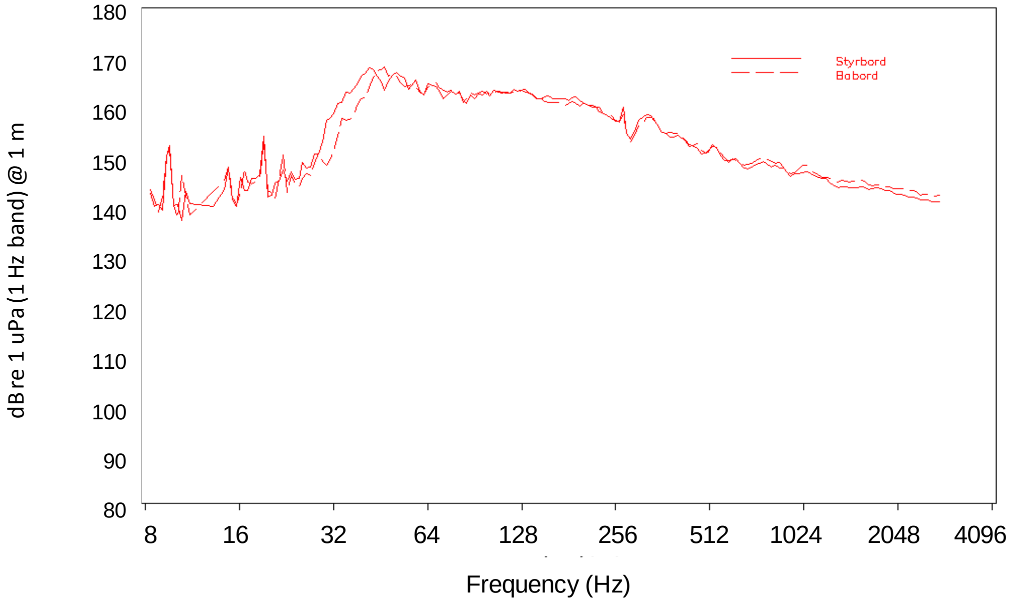


Figure 4. Sound pressure spectrum (1/24 octave) of radiated underwater sound at 12 knots (60% pitch, 900 rpm) from “Brennholm” measured at 54 m deep hydrophone.

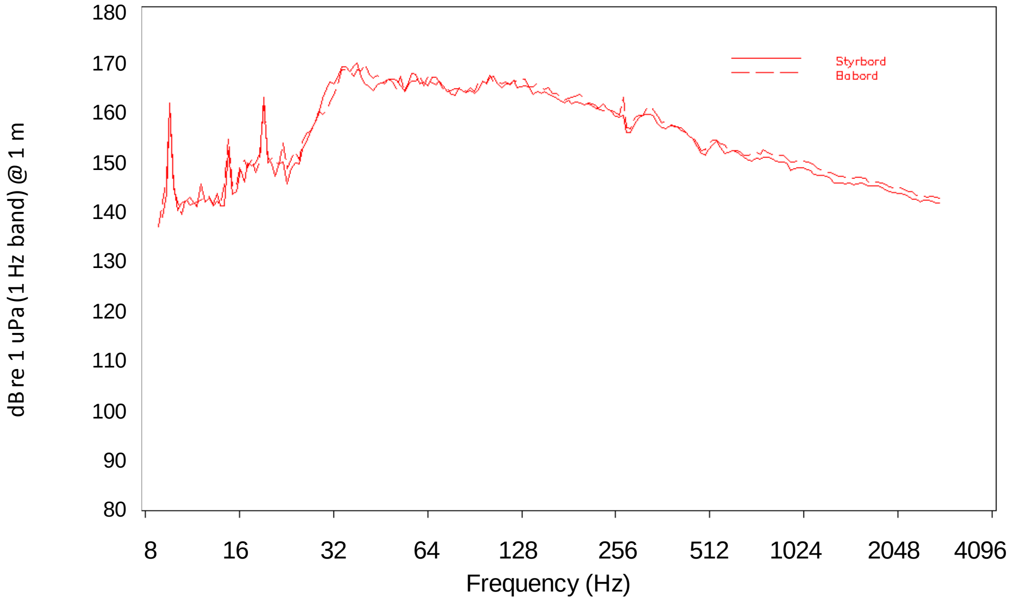


Figure 5. Sound pressure spectrum (1/24 octave) of radiated underwater sound at 11 knots (50% pitch, 900 rpm) from “Brennholm” measured at 54 m deep hydrophone.

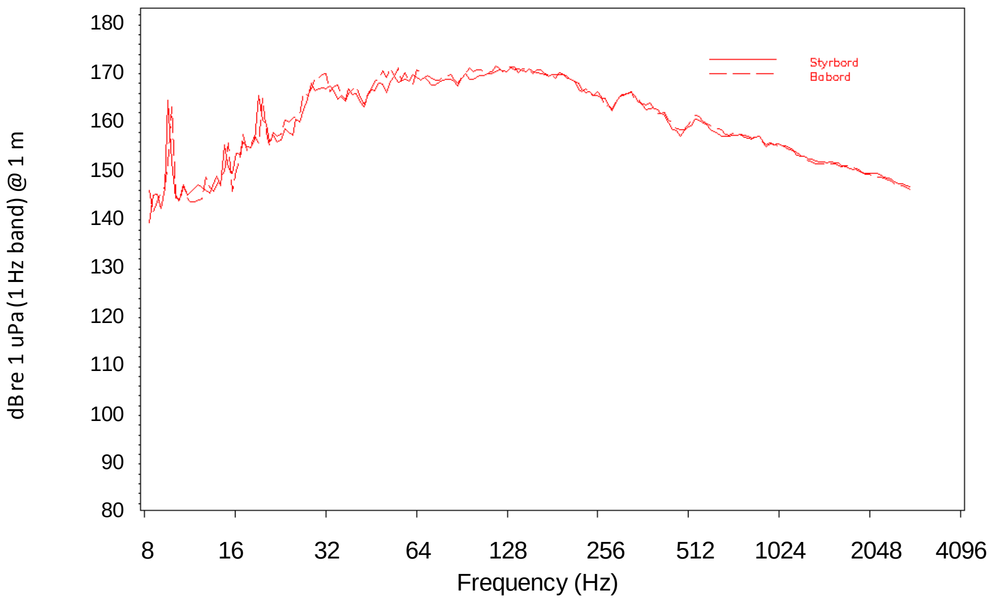


Figure 6. Sound pressure spectrum (1/24 octave) of radiated underwater sound at 9.2 knots (40% pitch, 900 rpm) from “Brennholm” measured at 54 m deep hydrophone.

The results of the analysis at 1/3 octave, showed a smoother spectrum, with relatively lower levels in the run at 12 knots, in comparison with the runs at 11 and 9.2 knots (Figure 7). The higher levels were from the runs at 9.2 knots where the lower pitch was used (40%), without the clear decrease at lower frequencies observed in the spectrum at 11 and 12 knots. The three curves are between 20 to 40 dB higher than the maximum underwater radiated noise levels recommended by the ICES CRR 209.

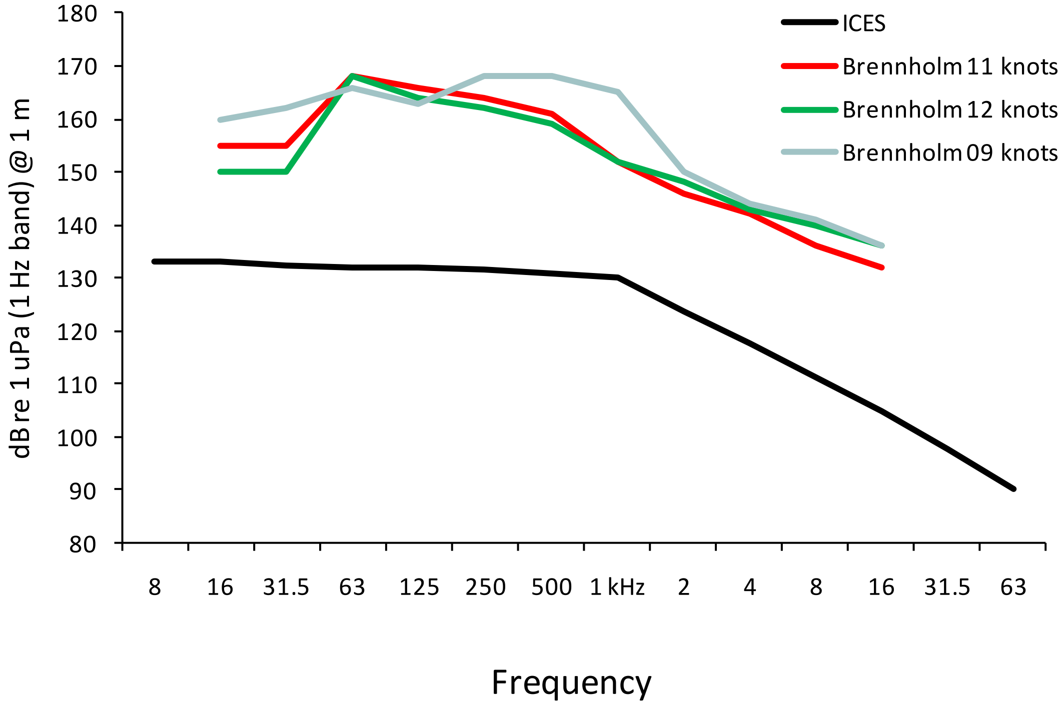


Figure 7. Sound pressure spectrum (1/3 octave) of radiated underwater sound at 9.2, 11 and 12 knots from “Brennholm”. Black line indicates the maximum underwater radiated noise levels recommended by the ICES CRR 209.

Previous measurements made at the Royal Norwegian Navy Material of radiated underwater noise from 3 Norwegian commercial vessels (“Libas”, “Endre Dyrøy” and “Møgsterbas) and research vessel “Johan Hjort” are available (Peña, 2009). The sailing conditions of these vessels during the measurements are showed in Table 2.

Vessel	Pitch (%)	RPM	Build
”Johan Hjort”*[ψ]	71	108 (propeller)	1990
”Libas” * [τ]	85	95 (propeller)	2004
”Endre Dyrøy” * [τ]	No info.	No info.	2001
”Møgsterbas” * [τ]	76	700 (engine)	2004
”Brennholm” ¤ [τ]	50	900 (engine)	2007

Table 2. Characteristics of vessel runs at 11 knots during underwater sound measurements for research vessel (ψ) and commercial vessels (τ). Measurement carried out at the Royal Norwegian Navy Material Command (*) and measurements in present study (¤).

The results of available sound pressure spectrum for theses previous measurements together with the recent results from "Brennholm" are presented in Figure 8. Is important to note, that both methodologies were done using different standards; Norwegian navy used the STANAG 1136-MIS standard (Anon., 1994), and the present study used ANSI/ASA S12.64-2009 grade B standard, therefore comparison of the results should be done with caution. Results showed similar noise level of "Brennholm" and "Møgsterbas", especially below 1 kHz frequencies. For higher frequencies lower levels for "Brennholm" are observed. The other commercial vessel showed a lower noise level, however, higher (*ca*. 10 dB) than the recommended ICES CRR 209 at frequencies below 1 kHz, and similar (*i.e*. "Endre Dyrøy") or lower (i.e. "Libas") to the recommended levels at higher frequencies.

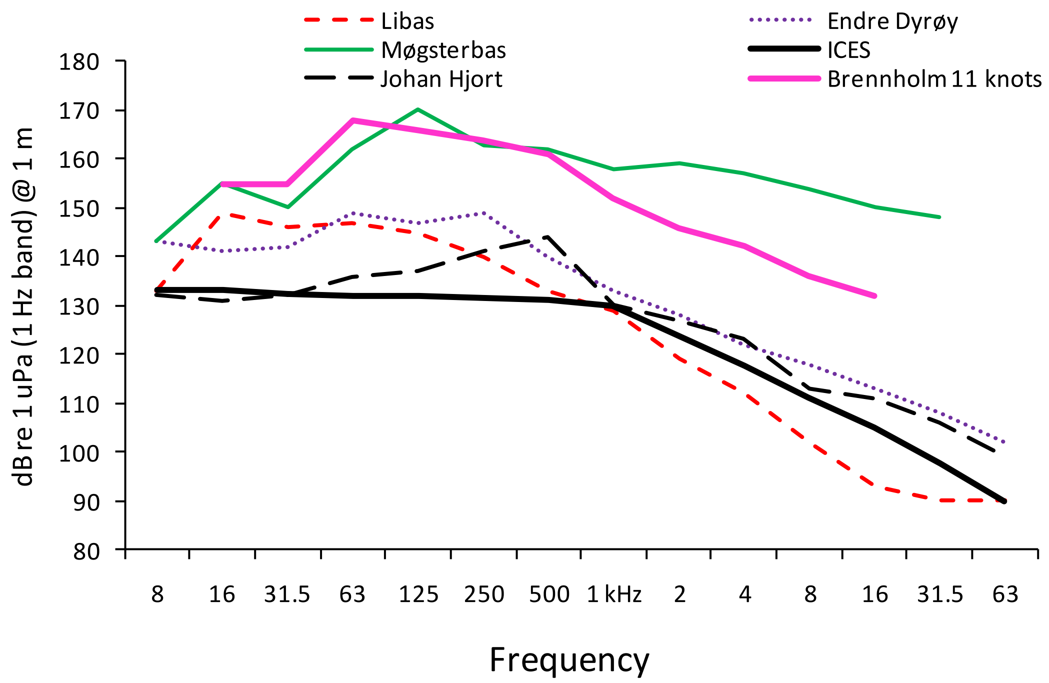


Figure 8. Sound pressure spectrum (1/3 octave) of radiated underwater sound at 11 knots from research vessel "Johan Hjort", and fishing vessels "Brennholm", "Libas", "Endre Dyrøy" and "Møgsterbas". Black line indicates the maximum underwater radiated noise levels recommended by the ICES CRR 209.

Discusion and recommendations

An adequate procedure has been established for underwater sound measurements, following the ANSI/ASA S12.64-2009 grade B standard. The use of a drifting buoy provides with flexibility for establishing the best location for the measurements data. If weather conditions or heavy maritime traffic occurs, all the system onboard the vessel easily could be carried to a more suitable place. The deployment of the hydrophones array was a relatively easy procedure onboard the commercial vessel, with adequate deck equipment and help of experienced crew. During this first set of measurements, many runs with different sailing conditions were carried out. However, for future measurements is intended only some selected runs, *i.e.* at normal survey conditions, reducing the duration of the experiment to *ca*. 6 h, if the selected site is in the vicinity (less than 1 h sailing) from port.

The processing of the collected data required the development of ad-hoc codes to enable an efficient treatment of the large amount of sound measurements data, and to combine them with the DGPS data, following the ANSI/ASA standard. This was a time consuming activity that could be reduced for future measurements by compiling these codes into free access software like R (R Development Core Team, 2011).

The current procedure could be used to measure the underwater sound irradiated from the vessels from the pelagic high seas, members of IMR reference fleet. This information will become relevant to several initiatives inside IMR that consider the collection of acoustic data from these vessels, not only during standard abundance surveying, but also during normal fishing operations.

Results showed higher level of underwater radiated noise from “Brennholm” at different speed and engine settings in comparison with the ICES recommendation. An average value of 30 dB higher than ICES CRR 209 was observed for all the different runs analyzed. Commercial fishing vessels, like “Brennholm”, are built with no consideration of reducing the radiated noise, as the new research vessels are (Mitson and Knudsen, 2003).

The Royal Norwegian Navy has an acoustic range facility in Heggernes (in the island of Askøy northwest of Bergen), and all large research vessels from IMR have been measured in this facility following the STANAG 1136-MIS standard (Anon., 1994). The navy facilities are equipped with a dynamic test range system which consists of two chains with two hydrophones connected to the shore station via cables. These cables allow regulating the depth of the hydrophones according to the vessel and measurements needed. The hydrophone chains are stabilized by a buoy 15 m above the upper hydrophone (Breitzke *et al*., 2008). The standard used at Heggernes differs from the ANSI/ASA standard used in the present study, therefore, is recommended to coordinate a new experiment to measure the noise from a vessel recently recorded by the Royal Norwegian Navy, in order to compare the results between the two procedures. The more recent measurements available from Hegernes are from “Møgsterbas” (now “Birkeland”) in 2006, and “Libas” and “Endre “Dyrøy” done in 2004.

Acknowledgements

Lars Einar Sandtorv (ship owner), Captain and crew of “Brennholm” are thanked for their cooperation and practical assistance during this project.

References

American national standard institute, 2009. Quantities and procedures for description and measurement of underwater sound from ships. ANSI/ASA S12.64-2009. Part 1: general requirements.

Anonymous, 1994. NATO standardization agreement (STANAG). STANAG 1136-mis (Third Edition, first draft). Standards for use when measuring and reporting radiated noise characteristics of surface ships, submarines, helicopters, etc. in relation to sonar detection and torpedo acquisition risk. NATO unclassified document. Military Agency for Standarization (MAS), Brussels.

Breitzke, M., Boebel, O., El Naggar, S., Jokat, W., Werner, B., 2008. Broad-band calibration of marine seismic sources used by R/V Polarstern for academic research in polar regions. Geophysical journal international, vol. 174, Issue 2, pp. 505-524.

ICES, 1995. Underwater noise of research vessels: review and recommendations. ICES Cooperative Research Report, vol. 209. 61 pp.

Mitson, R. B. and Knudsen, H. P., 2003. Causes and effects of underwater noise on fish abundance estimation. Aquatic living resources, 16, pp. 255-263.

Peña, H., 2009. Comparison of scientific echo sounder from commercial vessels in the Norwegian Sea. *In* Improving acoustic abundance estimates of pelagic fish using commercial fishing vessels. Ph. D. dissertation. University of Bergen, Norway.

R Development Core Team, 2011. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria.

Sinnott, R. W., 1984. "Virtues of the Haversine", *Sky and Telescope* 68 (2), 159.

Wood, B. R., 2011. Fish reaction to tonal vessel noise - Comparison with ICES CRR 209 methodology. Applied acoustics, 72, pp. 399-411.