Monitoring of acoustic background in the area of the offshore wind farm "Bałtyk Środkowy III"

Final report with research results

Bałtyk Środkowy III Sp. z o.o.

Final Report, v3

August 2014

The expert in **WATER ENVIRONMENTS**

Monitoring of acoustic background in the area of the offshore wind farm “Bałtyk Środkowy III”

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Project number	30800051-4
Approval date	1 August 2014
Revision	Final 3.0
Classification	Confidential

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GLOSSARY

Decibel (dB)	The logarithmic measure of sound intensity / pressure. The decibel value for sound pressure is 20 log10 (P / P0) with P = actual pressure and P0 = reference pressure
Hertz (kHz)	The unit for frequency where 1 Hz = 1 cycle per second. One Kilohertzare 1,000 cycles per second
Impulsive sound	Transient signals emitted in brief sequences (pulses) with short duration and often high peak sound pressure levels
Octave band	Interval between two discrete frequencies having a frequency ratio of two.
1/3 Octave band	Interval of 1/3 of an octave. Three adjacent 1/3 octave bands span one octave.
Pascal	Unit of pressure equal to one Newton per square metre
Permanent threshold shift	A permanent elevation of the hearing threshold due to physical damage to the sensory hair cells of the ear
Power Spectrum Density Level	10 $\log_{10}$ of squared sound pressure in 1 Hz bands (1 Hz bands) unit = dB re 1 μPa^2/Hz
Propagation loss (Transmission loss)	Loss of sound power with increasing distance
Source level	Acoustic pressure at a standard reference distance of 1m. Unit in dB re 1 μPa at 1m (sometimes given as: @ 1m)
Sound pressure level	Expression of the sound pressure in decibel (dB)
Temporary threshold shift	A temporary elevation of the hearing threshold due to fatigue of the sensory hair cells of the ear

ABBREVIATIONS

Bft	Bofourt
dB	Decibels
GES	Good Environmental Status
Hz	Hertz
Kg	Kilogram
Km	Kilometer
m	Meter
MSFD	European Union Marine Strategy Framework Directive
nM	Nautical mile
OWF	Offshore wind farm
OWF BŚ II	Offshore wind farm Central Baltic II

OWF BŚ III	Offshore wind farm Central Baltic III
PSZW	License for construction and use of the artificial islands, installations and devices in the Polish maritime areas
PSD	Power spectral density
UTC	Coordinate Universal Time

1 Non-technical summary

1 Nowadays, offshore wind farms experience a growing interest around the world. In Poland they have also recently become an area of interest as a potential source of renewable energy. Thus, plans for the construction of a marine wind farm within the Polish EEZ have been implemented. As one of the areas for a potential power plant, the BŚ III site, nearby the Słupsk Bank, was chosen.

As the construction, operation and decommissioning of a marine wind farm are associated with a number of activities which can impact the marine ecosystem, such impacts need to be assessed. Among the animals potentially vulnerable to the offshore wind farm construction are marine mammals in the Baltic Sea, particularly harbour porpoises and grey, harbour and ringed seals. In order to assess the impact of the investment on these animals, the background noise conditions at the site have to be known. The aim of the background noise measurements is to describe the baseline (zero-point) situation with regard to underwater ambient noise. This will aid in the identification of the BŚ III site with regard to already existing pressures due to underwater noise. The background noise levels will then be used in the EIA insofar as the change in that baseline situation can be documented with regard to the construction of the wind farm and its operation.

2 This report refers to the monitoring of the ambient noise conducted as a part of the environmental impact assessment (EIA) for the planned offshore wind farm in the BŚ III area between October 2012 and November 2013. The monitoring was carried out with the use of acoustic means, with the acoustic recorder SM2M (Wildlife Acoustics). As there are no national standards concerning ambient noise measurements in Poland, the German BSH standards were used as a guideline (as those standards were established for the region adjacent to Polish waters). In addition, we used advice from experts participating in the Noise Task Group for the Marine Strategy Framework Directive and recent reports where best practices for ambient noise data collection and analysis are described. Following those, research was focused on investigating ambient noise levels in different seasons of the annual cycle, as well as in different sea state conditions.

During the monitoring period the acoustic recorder rotated between three deployment locations, which aimed at recording the ambient noise in different part of the study area. The device was recording all underwater sounds in the frequency range of 2 Hz-22 kHz. The range is sufficient to record most man-made low-mid frequency sound such as shipping, pile driving, seismic survey and explosion sounds. At the beginning of the recording campaign the device recorded every 15 minutes of each hour. This was later on changed to 1 minute of recording every 15 minutes. The change in the settings was introduced in order to increase the effectiveness of the ambient noise data collection by minimizing the risk of running out of memory in the device during data collection and was in line with international standards for ambient noise measurements.

All acoustic data collected were quality checked before analysis. For the data analysis subsamples of five seconds recordings were produced for four seasons of the annual cycle – autumn (October – November 2012, September – November 2013), winter (December 2012, January – February 2013), spring (1-13 March 2013), summer (21 – 31 August 2013). The sample size represented a subset of 10% of all the recordings collected for the season. Based on the samples the power spectrum density levels (PSD) in 1 Hz bands were calculated to identify the main frequencies of the ambient noise and the overall loudness in the sample. The calculations of PSD provided information on the sound energy distribution in the different frequency bands. In addition a 1/3 octave band analysis was carried out as most of marine mammals integrate the noise over frequency ranges which resemble 1/3 octave filter bandwidths. Moreover, the noise levels in the 1/3 octave bands 63 and 125 Hz were calculated, as these are relevant to the Marine Strategy Framework Directive (MSFD).

Finally, to compare the obtained results with the results from other studies the broadband sound pressure level (2 Hz – 5 kHz) was calculated.

Moreover, following the BSH standards as a guideline, the ambient noise levels in different sea state conditions were investigated. The analysis aimed to compare the sound pressure levels at 63 Hz and 125 Hz, as well as the mean broadband SPL in two categories of sea state conditions. The first category included the sea state in 1 – 3 Bft (wind speed of 3 – 5,4 m/s), while the second one was in 4 – 6 Bft (wind speed 5,5 – 13,8 m/s). For this comparison, based on the meteorological data collected by the Maritime Institute, 100 samples from each sea state category were randomly selected from the subset of samples covering all the seasons.

3 The monitoring of acoustic background at BŚ III area resulted in collection of 16300 recordings, data covered 235 days, which comprises 56% of the research period. Due to harsh weather conditions at the site and malfunctions of recording device the dataset does not cover the whole spring/summer period, although the differences in overall ambient noise levels between months were very small, and acoustic data was analysed in samples covering only a fraction of recorded time. The amount of data collected per season and winds state still exceeded by far the requirements as set forth in EIAs in other areas (for example in Germany). Therefore, the investigation resulted in fully valid data.

For all the seasons most of the acoustic energy in PSD calculated in1 Hz bands was below 1 kHz. Energy distribution in 1/3 octave bands up to 11 kHz was fairly even in all seasons.

There was a statistically significant difference in the mean broadband sound pressure level between seasons, with the highest values recorded for winter 2012/2013 and spring 2013 season (114 dB re 1µPa). Mean sound pressure level at 63 Hz was the highest in the autumn 2012 and for 125 Hz again winter 2012/2013 and spring 2013. This can be explained with the better sound propagation in the Baltic during the cold vs. warm months.

The analysis of broadband sound pressure levels under different wind conditions clearly indicates an effect of wind speed, with higher levels recorded at higher wind speeds. This is very much in line with results from other studies undertaken in the southern North Sea but also in the Baltic. By comparing ambient noise levels from the study area with results obtained in other parts of the Baltic Sea and the North Sea it can be concluded that the BŚ III site is characterized by medium pressure due to ambient noise.

4 The results of the study revealed that the sound levels at BŚ III site are typical for the coastal areas, with differences both between seasons and sea state conditions. Based on ambient noise measurement results for the spring 2013 season, when the highest broadband sound pressure level values were obtained, it can be concluded that ambient noise levels exceed the known hearing thresholds in the water for harbour and ringed seal (Nedwell et al, 2004), and its likely to be the case for grey seals as well, although no audiogram is available for that species. At frequencies above 400 Hz ambient noise from the BŚ III site can be detected by harbour porpoises. It is important to note that the levels obtained in this study do not exceed the threshold values for hearing loss in seals and harbour porpoises and it is unlikely to have an impact on hearing of these animals, although masking of sounds produced mainly by seals can occur. In conclusion, the study area was shown as the location having medium potential impact on seals and harbour porpoises when considering the ambient noise conditions.

2 Introduction

This report relates to the research of acoustic environment for the offshore wind farm project planned in the OWF BŚ III area – in the vicinity of the Słupsk Bank, made on behalf of Bałtyk Środkowy III Sp. z o.o. The results of the study are a part of the Environmental Impact Assessment (EIA) and will contribute to a characterisation of the site with regard to the existing noise pressures, as well as will be representative for the studied part of the Baltic Sea.

The construction of a marine wind farm is associated with a number of activities, for example pile driving, seabed preparation, sediment removal and deposition, cable laying and vessel movement. These activities will generate underwater noise which impacts on marine life (marine mammals and fish) have to be assessed. Operational wind farms emit noise as well although to a much lesser extent than during construction. In order to assess the changes in the noise field due to construction and operation of a wind farm one must investigate the baseline situation (=zero point) with regards to ambient noise, ideally through own measurements.

Ambient noise is the ever-present background noise in the marine environment and can consist of biological sources such as snapping shrimp or choruses of fish, as well as sounds generated by humans such as shipping, dredging or offshore wind farm related sounds. Previous research has shown that ambient noise levels have increased in some areas, mainly due to increased shipping (OSPAR 2009; Figure 1).

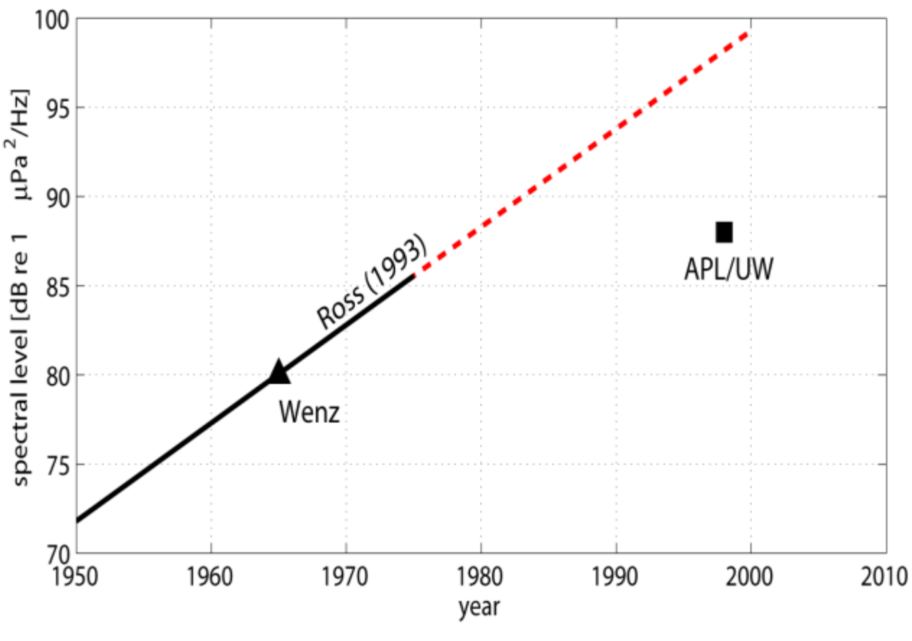


Figure 1 Ambient noise measurements in the 100-200 Hz band measured off California in the 1950's (Ross 1993) and APL/UW (Applied Physics Laboratory, University of Washington) noise measurements in the late 1990's (Andrew et al. 2011) showing a projected and realized increase, as a function of increased large vessel activity in the area over this period.

Elevated levels of ambient noise can affect marine mammals in various ways: they can lead to behavioural disturbance, mask biological important sounds such as underwater call of harbour seals, and ultimately, potentially cause stress, which may lead to physiological effects (review in OSPAR 2009; Figure 2). Furthermore, the range over which sound from offshore wind farm construction and operation is detectable by marine mammals is directly dependant on the relationship between impact sound and ambient noise (Thomsen et al. 2006).

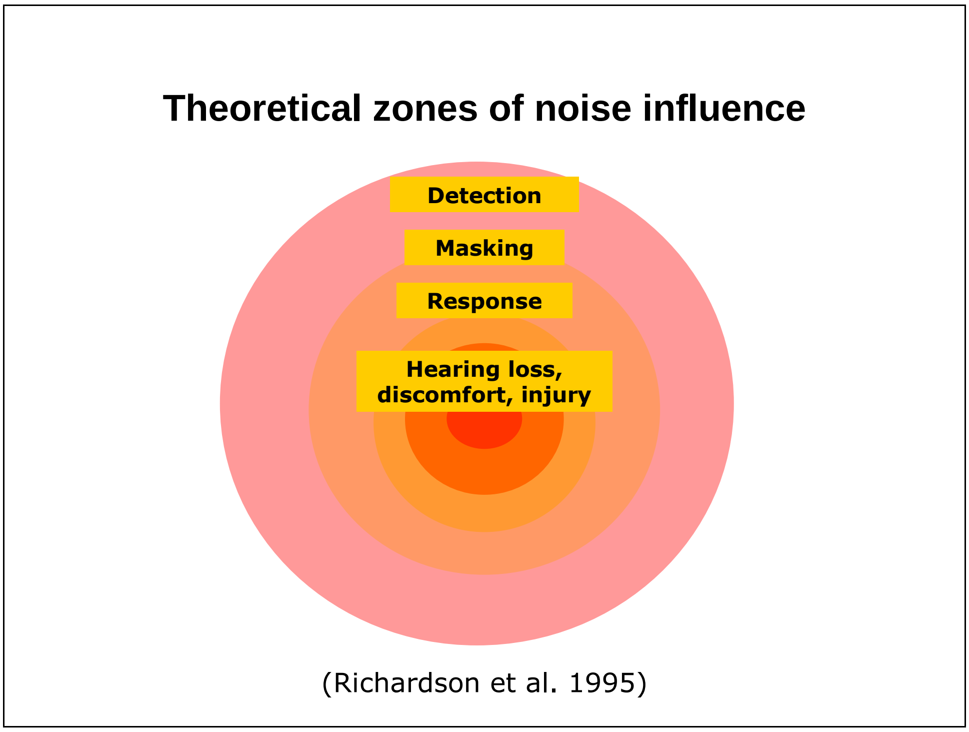


Figure 2 Theoretical Zones of noise influence (after Richardson et al. 1995; taken from OSPAR 2009).

For any marine construction project it is therefore advisable to describe the baseline situation with regard to the ambient noise, in order to identify any existing pressures and to describe the change of the noise field due to construction activities. A further incentive to the ambient noise monitoring is given by the EU regulation, since it is required under the EU Marine Strategy Framework Directive (MSFD) (see Van der Graaf et al. 2012; Dekeling et al. 2013b). The MSFD aim is to protect, conserve, and where possible, restore the marine environment in order to maintain biodiversity and provide diverse and dynamic oceans and seas which are clean, healthy and productive. The Directive requires Member States to achieve 'Good Environmental Status' (GES) in their marine environment by 2020 at the latest. Annex 1 of the MSFD lists the 11 qualitative descriptors for GES, one of which states that *'the introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.'* Based on advice from an expert group (see Tasker et al. 2010) the EU has decided on two indicators that further specify GES. The second indicator deals with continuous low frequency sound (details in EC 2010). It involves measuring ambient noise, perhaps at a regional level which would represent huge progress in identifying trends in existing pressures such as the ones stemming from shipping (see Tasker et al. 2010, van der Graaf et al. 2012). Details of requirements for such monitoring have recently been updated by Dekeling et al. 2013a.

2.1 Aim of the study

The aim of the background noise measurements was to describe the baseline (zero-point) situation with regards to underwater ambient noise. This will aid in the identification of the BŚ III site with regards to already existing pressures due to underwater noise. The background noise levels will then be used in the EIA insofar as the change in that baseline situation can be documented with regards to the construction of the wind farm and its operation. For the assessment of baseline noise conditions, ambient noise monitoring was conducted using submersible long-term passive acoustic recorders. We aimed to set up several monitoring stations in the study area, at which successive data collections would be undertaken to provide representative spatial coverage. Ambient noise should then have been monitored for the whole baseline period of one year and one month (not complete) when the monitoring started. We planned to follow methods outlined by BSH 2011 and the Task Group of Underwater Noise within the MSFD (to which one of us (F. Thomsen) is a member and therefore has direct access to all relevant methodological papers) (see Van der Graaf et al. 2012). In addition to analysis of the whole recorded frequency spectrum the documentation of ambient noise was planned to be done also in MSFD relevant frequency bands (63 Hz, 125 Hz). Finally, the temporal ambient noise trends were planned to be investigated at relevant seasonal intervals.

3 Project area

The project “Bałtyk Środkowy III” is situated outside the borders of Polish territorial waters, approximately 23 km from the shore (Figure 3, Table 1).

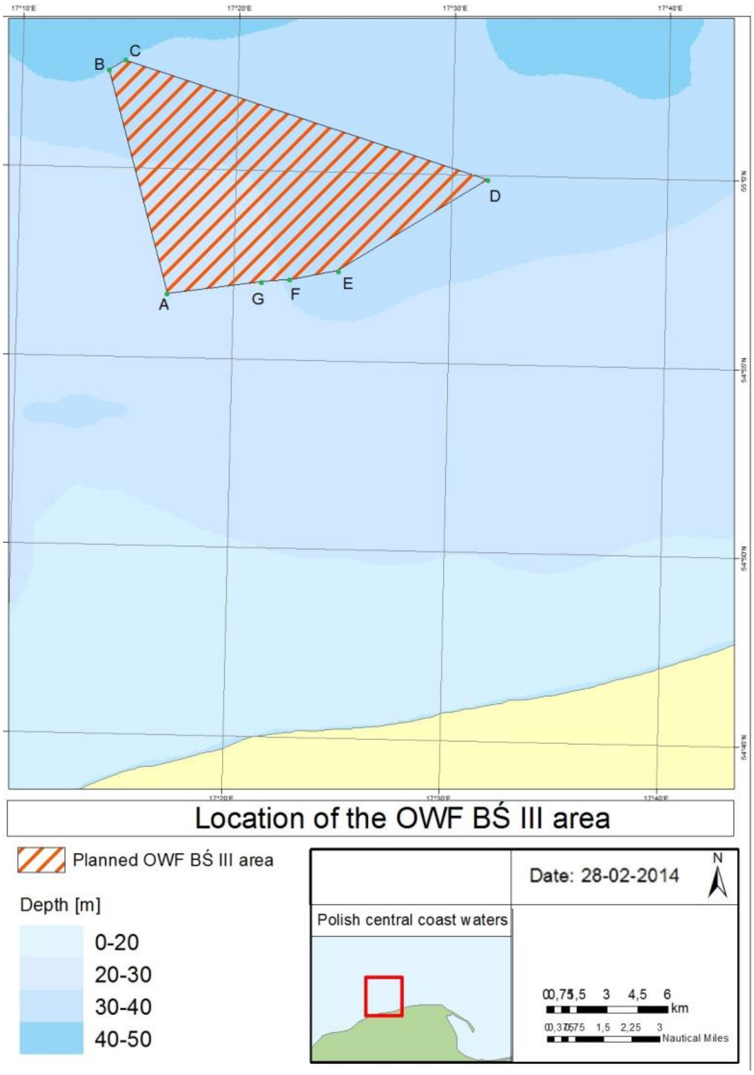


Figure 3 Location of the OWF BŚ III area in relation to the Polish coast

Table 1 Coordinates of the points defining the boundaries of the OWF BŚ III area

OWF BŚ III location (WGS 84)		
Point	**Latitude**	**Longitude**
A	54° 56' 42,424"N	17° 16' 57,430"E
B	55° 02' 35,801"N	17° 14' 00,653"E
C	55° 02' 52,125"N	17° 14' 45,028"E
D	54° 59' 55,268"N	17° 31' 37,853"E
E	54° 57' 24,641"N	17° 24' 47,597"E
F	54° 57' 09,443"N	17° 22' 42,654"E
G	54° 57' 05,517"N	17° 21' 25,617"E

The total area of the farm is approximately 117 km^2 according to PSZW (license for construction and use of the artificial islands, installations and devices in the Polish maritime areas, obtained on 30 March 2012).

This area, as defined in PSZW, is reduced by the 500 m buffer zone from the inner boundary of the project implementation area, excluded from location of any structural elements of the farm. Therefore the maritime area available for implementation of the project is the area defined by PSZW, reduced by the area of buffer and reaches from approximately 89 km^2 .

The BŚ III area is localised within the region characterised by humid – temperate climate conditions typical for the southern Baltic Sea.

4 Methodology and activities carried out during the research period

4.1 Data collection methodology

Background noise was measured with the SM2M acoustic recorder from Wildlife Acoustics (Figure 4). The device records all underwater sound in the frequencies from 2 Hz to 40 kHz (depending on the sample rate). It is 80 cm long, has 17 cm in diameter and weighs 10 kg. The recorder has a built-in underwater microphone (hydrophone) that records all sounds in the chosen frequency range (in this case 2 Hz – 22 kHz according to the recommendations of the EU Task Expert Group of Underwater Noise; see (Van der Graaf et al. 2012)). The data is stored in a chip card and retrieved via computer.

The recorder detects sounds from nearby sources, such as passing ships, as well as low frequency sounds from very distant sources, as the low frequency sound can travel over long distances underwater. Thus, the ambient noise recordings contain information on the acoustic situation both at the study site and a wide area beyond it. The exact detection range is very difficult to ascertain as sounds from very far sources merge with one another and are thus not identifiable. In theory, any sound above the ambient sound recorded at the hydrophone can be distinctively picked up. In the case of shipping sound 1/3 octave band sound source pressure levels at 125 Hz can be as high as 170 dB re 1 µPa (see, for example WODA 2013). Providing transmission loss of 15 log (r) and ambient noise levels of 100 dB re 1 µPa, this sound can be distinguished from other sounds in the recording at app. 40 km distance. Yet, sound further away will also be recorded but is not distinguishable in the recordings.

Figure 4 Ambient noise recorder from Wildlife Acoustics

For deployment of the acoustic devices a safe anchor system was used (Figure 5). A yellow warning buoy with a flashing lantern (2 nm range) marked the position of a heavy 600 kg concrete anchor block. The anchor was meant to protect the system against drifting by heavy currents or fishing gear. The anchor was connected via a 50 m long Tajfun rope to a small 90 kg anchor stone. A 10 m long danline rope with two loops (5 and 7 m above ground) was connected to the anchor. C-PODs (continuous porpoise detectors) were attached to the upper loop at each of the stations. Originally, for service procedures and security of the systems, an acoustic release system was used (Figure 5). The acoustic release equipment was connected to the top of the danline rope. When the releaser was triggered, a submerged floating ball (size: 28 cm) surfaced and the small anchor stone could be retrieved together with the C-POD. However, as during the project works there were some problems with such a release system, at the later stages of the project it was changed into the simpler one.

Instead of the acoustic releasers, the pop-up buoys and floating ropes were used, which were much easier to operate and thus, retrieve the instruments (Figure 6).

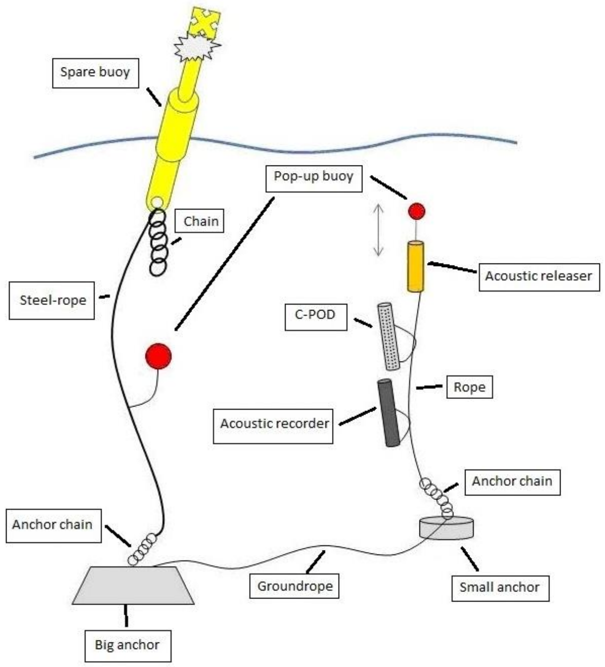


Figure 5 Scheme of the anchor system used in the study area with the acoustic releasers system.

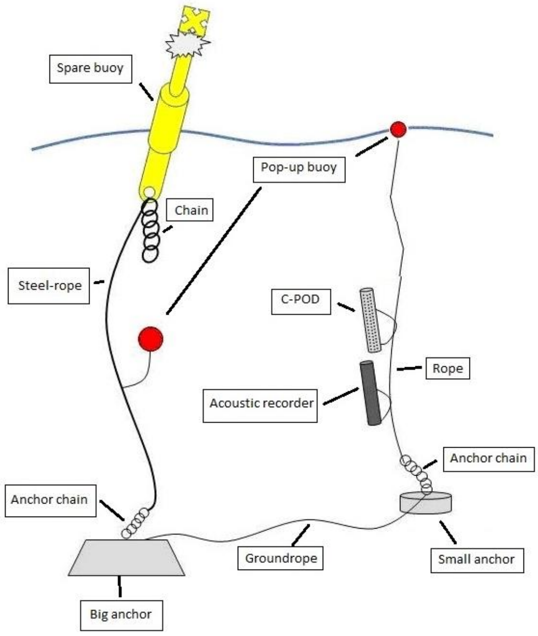


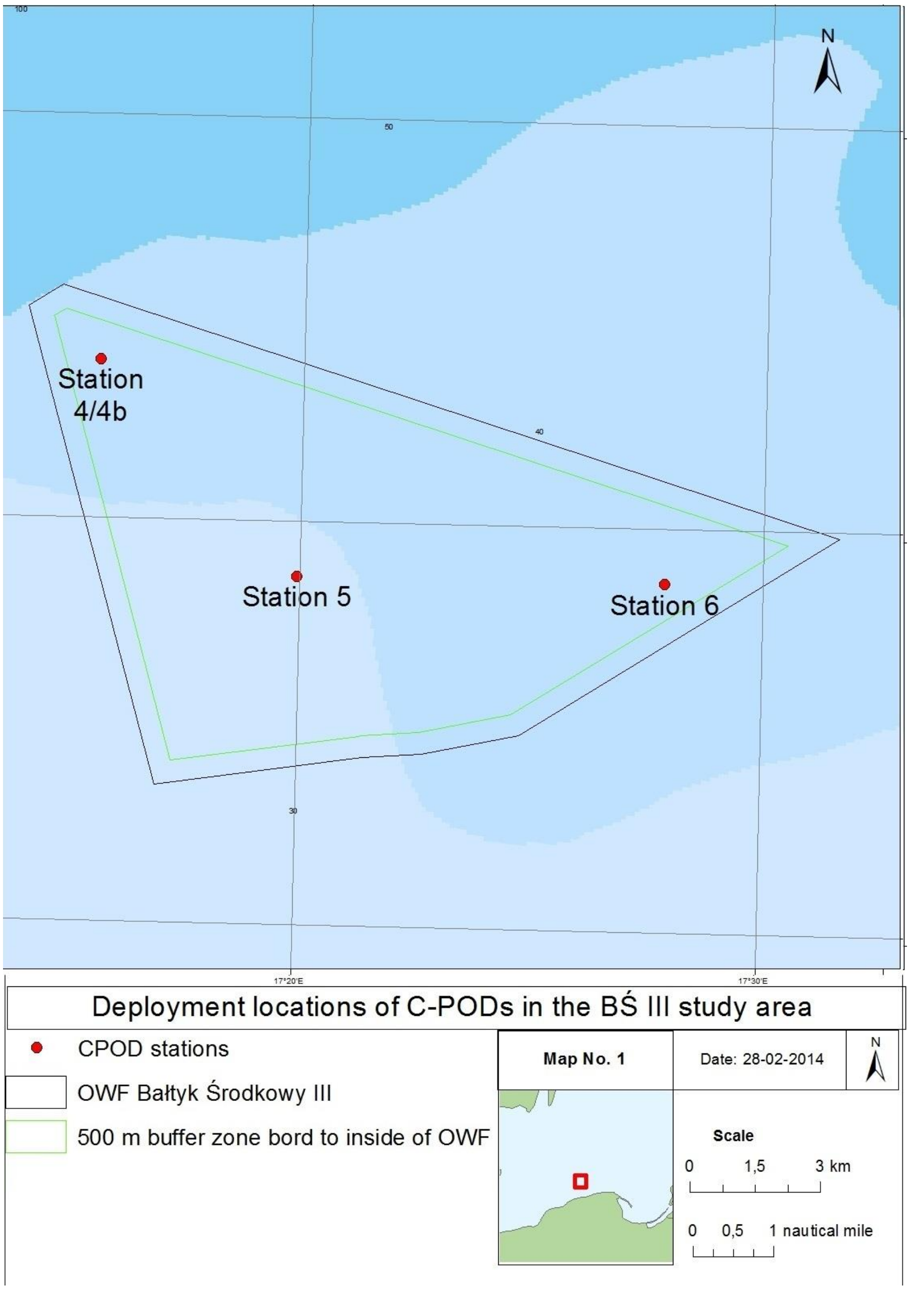
Figure 6 Scheme of the anchor system used in the study area after replacing acoustic releasers by pop-up buoys.

The ambient noise monitoring at the BŚ III study site started on 14 October 2012, when the mooring system with one acoustic recorder was deployed at the study site. The deployment of the instruments was carried out on the vessel owned by the Maritime Institute – r/v IMOR.

During the monitoring period the recorder rotated between three deployment locations– stations 4, 5 and 6, which aimed at recording the ambient noise in different parts of the study area. Distances between the stations were between ca. 7 and 14 km and the instruments were localised at the depth around 30 m. The locations designed for the BŚ III site were placed so that they had a good coverage of the area. The map with these locations and geographic coordinates is presented in Figure 8.

The acoustic recorder deployment location was changed during the maintenance cruises, when the instrument was also serviced and data was collected. The maintenance was carried out on the private ship-owner vessel - m/y Doktor Lubecki. Originally, the maintenance was planned to be carried out at six weeks' intervals, which aimed at decreasing the possibility of data losses. However, during the project changes to the planned schedule had to be introduced, as many times the weather conditions made it impossible to work on the sea. Yet, the memory cards and the batteries used in SM2M can record data for much longer periods than our planned intervals (several months). Therefore, the six weeks' intervals were planned for safety reasons and longer breaks between the service cruises were acceptable. Detailed information on the cruises is presented in Table 2.

The ambient noise monitoring finished on 30 November 2013, when the last set of data was collected (Table 2). The data collection period was in line with formerly agreed length of the measurement campaign.



Station	Coordinates	
	Latitude	Longitude
4	55°01'56,800" N	17°15'36,100" E
5	54°59'18,948" N	17°19'56,835" E
6	54°59'18,909" N	17°27'52,932" E

Figure 7 Map of the BŚ III study area with the acoustic recorder deployment locations marked (red circles) together with geographic coordinates, The recorder can detect low frequency sound over the entire area of the map

Figure 8 The acoustic devices ready for the deployment

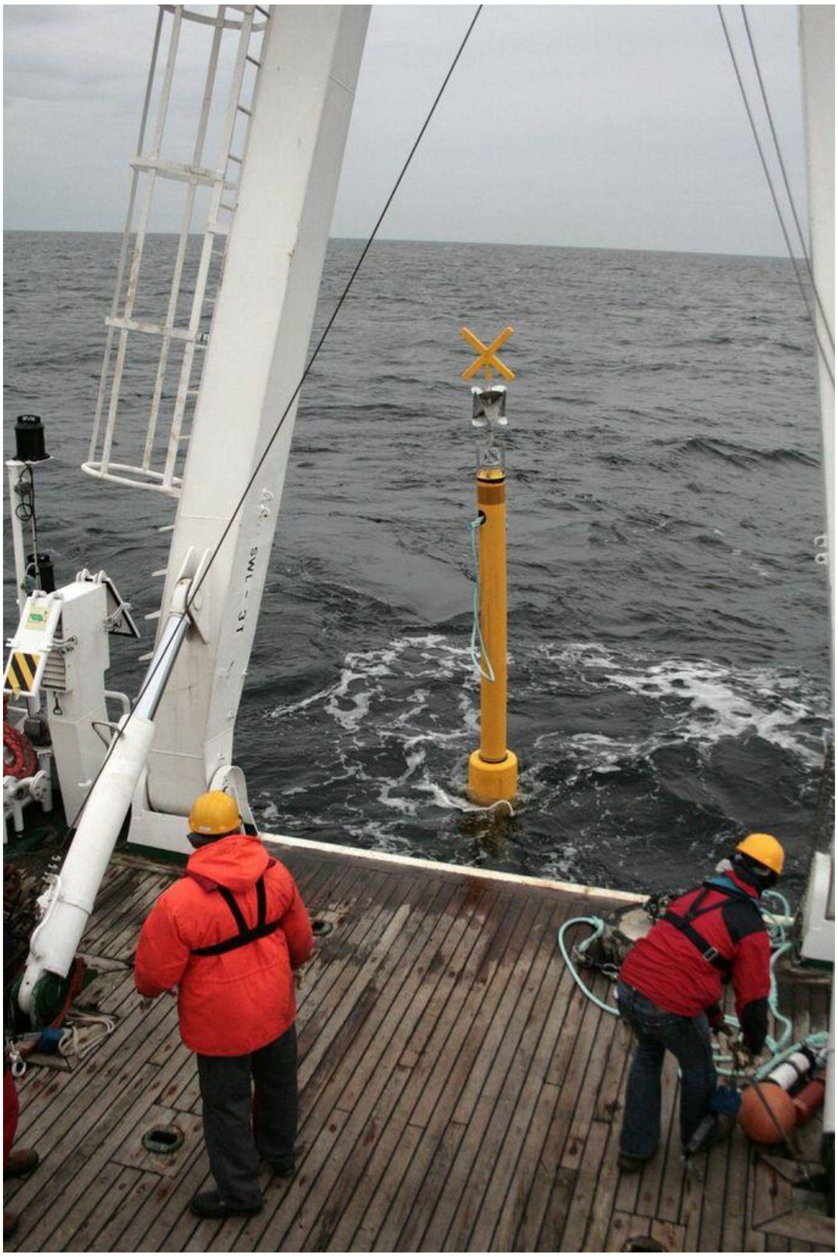


Figure 9 Deployment of the mooring system

Table 2 Detailed information on the acoustic recorders collecting data during the monitoring period

year	month	date of the cruise	n° of the station	n° of the SM2M	retrieval	deployment	comments
2012	October	14.10.2012	6	681168		+	first deployment of the equipment
	November	28.11.2012	6	681168	+		service successful - data collected, deployment location changed
			5	681165		+	
	December	no cruise					
2013	January	8.01.2013	5	681165	+		data collected, deployment not possible due to deterioration of the weather
		25.01.2013	4	681165		+	successful deployment
	February						
	March	13.03.2013	4	681165	+		service conducted, data collected
			6	681165		+	
	April	16.04.2013	6	681165	+		service conducted, collected data not viable due to the equpment failure, deployment location changed
			5	681165		+	
	May	no cruise					
	June	12.06.2013	5	681165	+		service conducted, collected data not viable due to the equpment failure, deployment location changed
			4	681165		+	
	July	10.07.2013	4	681165			not found
	August	21.08.2013	4	681165			retrieval not possible
			5	681168		+	
	September	no cruise					
	October	3.10.2013	4	681165			retrieval not possible
			5	681168	+		service successful, data collected
			4b	681168		+	deployment of the new set of instruments
	November	30.11.2013	4b	681168	+		successful last retrieval of the instrument, data collected

The SM2M records sounds at the frequency and time intervals set up prior to deployment (Figure 10). From 14 October 2012 until 8 January 2013, the device recorded sound during the first 15 minutes of each hour, while from 25 January 2013 until the end of the monitoring (30 November 2013) the recording intervals were changed into shorter but more frequent ones – 1 minute of recording every 15 minutes. The change in the settings was introduced in order to increase the effectiveness of the ambient noise data collection by minimizing the risk of running out of memory in the device during data collection and was in line with the recommended practice for ambient noise measurements (see BSH, 2011 and Johansson and Andersson 2012). The frequency range of the detections was the same during the entire period of the monitoring and ranged from 2 Hz to 22 kHz. The range used was sufficient to record most of man-made low-mid frequency sound such as pile driving (major amplitude 100-500 Hz), seismic surveys (major amplitude 10 – 120 Hz), explosions (major amplitude 6 - 21 Hz) . (Van der Graaf et al. 2012) or shipping noise (major amplitude >1000 Hz) (OSPAR,2009).

Figure 10 Set up of the acoustic recorder before the deployment

In order to improve the methodology used and increase the effectiveness of EIA activities carried out at the BŚ III area, there was a number of discussions within DHI staff, as well as between DHI and other institutions involved in the project (e.g. Maritime Institute in Gdańsk, Envia (vessel broker) and owners of individual vessels).

On 18 and 19 October 2012 a meeting was held in the Maritime Institute in Gdańsk. The main objective of the meeting was to discuss the methodologies of different aspects of baseline studies/surveys and EIA reporting being the main part of the development project for Bałtyk Środkowy III. The meeting also aimed to exchange information on the division of responsibilities and the schedule of the project, in order to facilitate common understanding, increase productivity and ensure safety during operations at sea.

Among the important issues which was the topic of numerous discussions were the methodology of data collection and improvements to the mooring system used, so that the monitoring would be more efficient. Changes to the original methodology included for example a new solution for the acoustic releasers' installation in the mooring system (upside-down in relation to their previous position in the water), which was accepted by Palle Østlund Brogaard (DHI Senior Surveyor and Field Survey Coordinator). The scheme of the ambient noise data collection was also changed into shorter but more frequent recordings (1 minute every 15 minutes, instead of 15 minutes every hour). Moreover, a topic often discussed concerned the improvement of the mooring system, so that the shackle noise was not recorded by the SM2M. As a result it was decided that the solution could be to cover metal parts of the mooring system with rubber, which was applied during the maintenance of instruments. Unfortunately this solution was not effective, as the noise came from the main anchor and there was no possibility to retrieve it. To test if the shackle noise brings bias to the broadband sound levels additional analysis was carried out, showing that there were no significant differences in the overall sound pressure level between recordings with and without shackle noise (for more information go to point 6.1 Assessment of data and result quality in this report).

Other important topics taken into consideration during the project meetings were safety during the activities on board, as well as improvements to the vessel 'Doctor Lubecki' used for the service of the instruments. One of the suggestions implemented by the owner of the ship was the installation of a new winch.

During the entire duration of the project a lot of attention was directed towards increasing qualifications of people involved in the project, as well as expanding knowledge in the topics covered by the project. For this reason DHI staff participated in different courses, conferences and workshops held around the world.

4.1.1 Overview of the project activities carried out and the results obtained

The harsh weather conditions appearing at the study site relatively often along the year, as well as problems with the instruments losses meant that it was impossible to carry out the project activities exactly according to the original plans. Table 3 presents an overview of the activities carried out and data obtained, as well as reasons for changes to the plans originally made for the monitoring. Table 4 includes a summary of completeness and quality of collected data. We have to point out that the measurement campaign was designed to account for potential data losses due to equipment failure. According to the BSH guidelines (BSH 2007, 2011), the background noise measurements shall comprise three hours, each for three classes of wind (corresponding to sea state 1 and two higher wind classes). BSH 2007 recommends just one measurement campaign before the start of construction but the updated and more detailed instructions (BSH 2011) mention that seasonal characteristics shall be documented (BSH 2011). This is the reason why we measured ambient noise covering a whole year. However, it is important to consider that this does not mean a continuous recording of ambient noise over the whole period but seasonal recordings (3 hours per wind class per season). With the 10 days in August and three months from September to the end of November, our data is covering all seasons and is fully sufficient for the baseline description of ambient noise.

Table 3 Overview of the activities planned for the ambient noise monitoring at the BŚ III study site, activities carried out and comments

Activities planned during the ambient noise monitoring for the EIA in the OWF BŚ III area	Activities carried out during the ambient noise monitoring for the EIA in the OWF BŚ III area	Comments
Ambient noise measurements in the period October 2012 – end of October 2013, using the SM2M acoustic recorder (Wild-life Acoustics). One recorder de-ployed at the study site, the de-ployment location changed in six weeks' intervals during mainte-nance cruises.	Ambient noise measurements between 14 October 2012 and 30 November 2013 using the SM2M acoustic recorder (Wild-life Acoustics). One recorder de-ployed at the study site and ro-tating between three locations – stations 4, 5 and 6. Eleven maintenance cruises – on 14 October 2012, 28 Novem-ber 2012, 8 and 25 January 2013, 13 March 2013, 16 April 2013, 12 June 2013, 10 July 2013, 21 August 2013, 3 Octo-ber 2013 and 30 November 2013. During the cruise on 8 January 2013, deterioration of weather made deployment of the device impossible. the deployment was postponed until improvement of the weather - 25 January 2013. Thus gap in the January data. In spring 2013 failure of the de-ployed measuring instrument meant that no viable data for the period 13 March 2013 – 11 June 2013 were collected. During the summer of 2013 loss of the de-ployed recorder resulted in no monitoring results for the timespan 12 June 2013 – 20 August 2013.	Ambient noise measurements one month longer than the planned period. Service cruises at changed in-tervals due to harsh weather conditions at sea made it impos-sible to carry out all the mainte-nance activities according to the planned dates. Data loss for the periods 9 – 24 January and 13 March 2013 – 20 August 2013 due to weather conditions, failure of the acoustic recorder and subsequent impos-sible maintenance caused by entanglement of the set of in-struments and harsh weather conditions made it impossible to conduct a complicated action of retrieval.

Table 4 Overview of data collected during the ambient noise monitoring at the BŚ III study site

ambient noise monitoring at the BŚ III area			
viable data collected	quality of the viable data collected	non-viable data collected	data lost
56%	good	22%	22%

4.2 Data analysis methodology

4.2.1 Analysis of sounds

The ambient noise data obtained with the SM2M acoustic recorder was up-loaded to the computer and initially quality checked. The preliminary quality check aimed to look for zero data and to evaluate if the instrument recorded properly. In a second quality check the waveforms and spectrograms of selected samples were investigated visually to verify if the recordings were not overloaded (=recorded with too high amplitude) and that system noise, for example from shackles, did not reduce recording quality. We also looked for unusual sounds.

To account for seasonal variability for the quantitative analysis of data a number of random sub-samples of five seconds recordings were produced for four seasons of the annual cycle – autumn (October – November 2012, September – November 2013), winter (December 2012, January – February 2013), spring (1-13 March 2013), summer (21 – 31 August 2013). The sample size represented a subset of 10% of all the recordings collected for the season. The time interval was chosen for practicality, as overall sound levels change little during this short period and sound pressure levels can thus be better calculated from the sound sample. The duration of the sample is in line with common practice as discussed in the Marine Strategy Framework Directive Expert Group on Sound (see Dekeling et al. 2013a) and with the recommendation by BSH 2011. Based on the samples the power spectrum density levels (PSD) were calculated. These show frequency on the x-axis and sound level (in dB re 1 μPa / Hz) on the y-axis and are important when identifying the main frequencies of the ambient noise and the overall loudness in the sample. The power spectral densities (PSD) were calculated in both 1 Hz bands and 1/3 octave bands. The calculations of noise in 1 Hz bands provided information on the sound energy distribution in the different frequency bands. For most investigated mammals they integrate the noise over frequency ranges which more closely resemble 1/3 octave bands. These levels are therefore very important when discussing noise impact on marine mammals (Thomsen et al. 2006). Moreover, the noise levels in the 1/3 octave bands 63 and 125 Hz were calculated, as these are relevant to the Marine Strategy Framework Directive (MSFD). Finally, to compare the obtained results with the results from other studies the broadband sound pressure level (2 Hz – 5 kHz) was calculated by summing the mean noise of the individual 1/3 octave band levels:

$$\text{SPL SUM} = 10\log((10\text{^}(B1/10)) + (10\text{^}(B2/10)) + \cdots .10\text{^}(B32/10))).$$

Moreover, following the BSH requirements as a guideline, the ambient noise levels in different sea state conditions were investigated. The analysis aimed to compare the sound pressure levels at 63 Hz and 125 Hz, as well as the mean broadband SPL in two categories of sea state conditions. The first category included the sea state in 1 – 3 Bft (wind speed of 3 – 5,4 m/s), while the second one was in 4 – 6 Bft (wind speed 5,5 – 13,8 m/s). For this comparison, based on the meteorological data collected by the Maritime Institute, 100 samples from each sea state category were randomly selected from the subset of samples covering all the seasons.

4.2.2 Statistical analysis

The comparison between several sound samples across seasons was undertaken using a one-way analysis of variance (=ANOVA- H-Test Kruskal Wallis; see Zar 1984)

In order to compare samples collected at different wind speeds, we used a non-parametric Man Whitney U Test (See Zar 1984).

5 Results

5.1 Ambient noise results

The monitoring of acoustic background at the BŚ III area resulted in a collection of 16300 recordings of noise, 223.54 GB size. The data covered 235 days, which comprised 56% of the whole research period. The gaps in data concerned the spring and summer periods and were caused by the defect instrument, equipment loss and harsh weather conditions. In spite of the deficiencies, representative data for each season was collected. Overview of the datasets obtained during the study is presented in Table 5.

Table 5 Overview of ambient noise acoustic data collected during the monitoring at the BŚ III area

season	no. of recordings	size of recordings	period covered	lenght of recordings
autumn 2012	1153	84,98 GB	14.10. 2012 - 30.11.2012	15 min
winter 2012/ 2013	4214	84,5 GB	1.12.2012 - 8.01.2013; 25.01. - 28.02.2013	15 min and 1 min
spring 2013	1241	6,15 GB	1 - 13.03.2013	1 min
summer 2013	1011	5,01 GB	21 - 31.08.2013	1 min
autumn 2013	8681	42,9 GB	1.09.2013 - 30.11.2013	1 min
total	16300	223,54 GB	235 days of data (56 % of the monitoring period)	

5.1.1 Sound pressure levels

For the quantitative analysis of data the power spectral densities (PSD) were calculated from a representative subset of samples (see the methodology), which provided information on the sound energy distribution in different frequency bands. The PSD values obtained for different season of the annual cycle are presented in the following chapters.

5.1.1.1 Autumn

As the data representative for the autumn period was collected in two sets – autumn 2012 and 2013, both of these sets were used in the analyses and compared. The PSD values obtained are resented in Figure 11 - Figure 14.

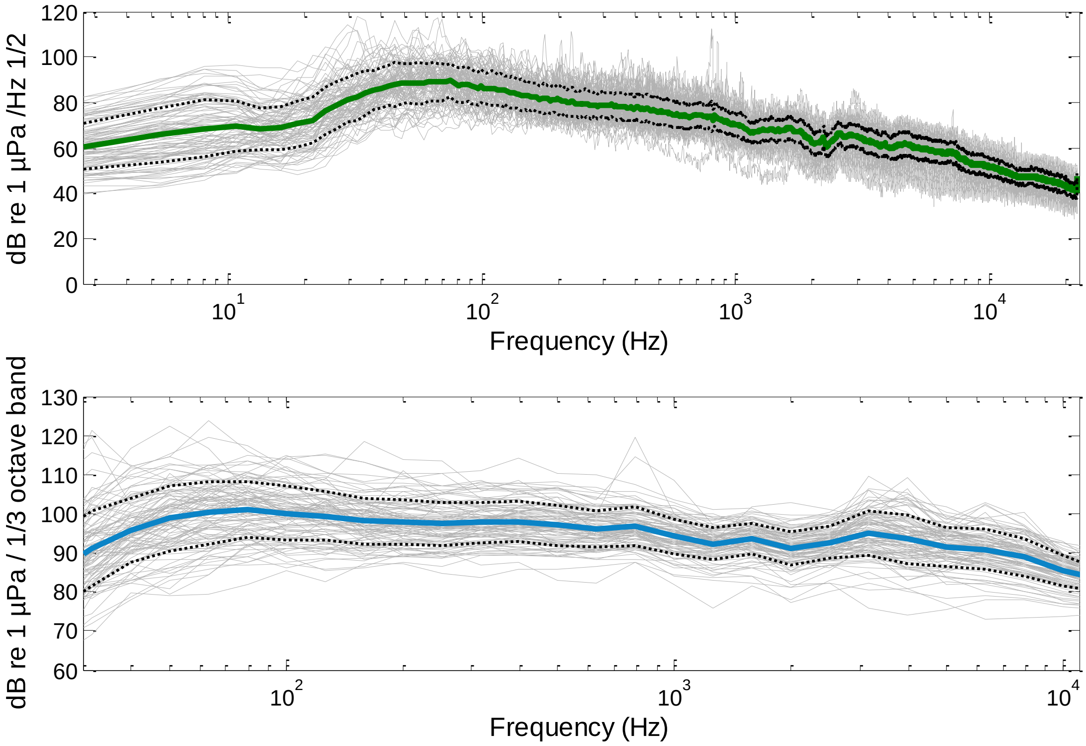


Figure 11 Top panel: Power spectral density in 1Hz bands of the sample subset from the autumn period October 14th to November 30th 2012 (n= 105). Grey lines are the power spectral densities of individual samples. The green line is the mean power spectral density, and the dashed lines are one standard deviation from the mean. Bottom panel: Power spectral density in third octave bands of sample subset from the autumn 2012 period. Grey lines are the power spectral densities of individual samples. The blue line is the mean power spectral density, and the dashed lines are one standard deviation from the mean

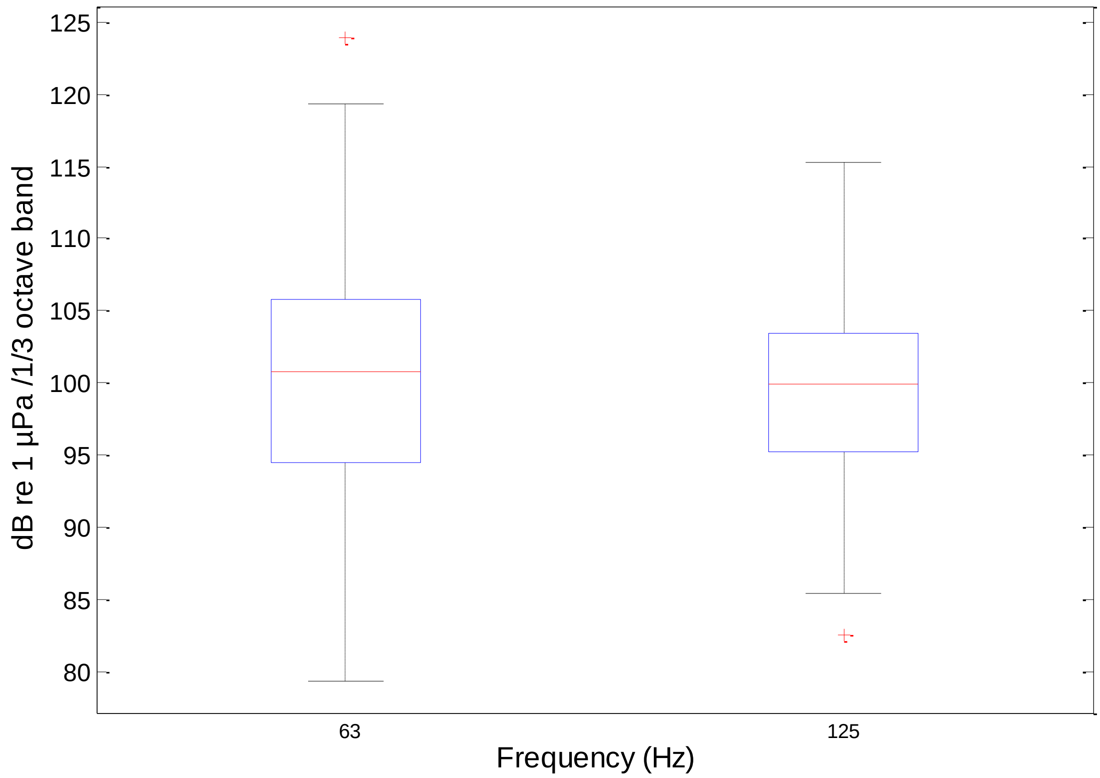


Figure 12 Boxplot of the 1/3 octave bands 63 and 125 Hz of the sample subset from the autumn period October 14th to November 30th 2012 (n = 105). The central red line are the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses

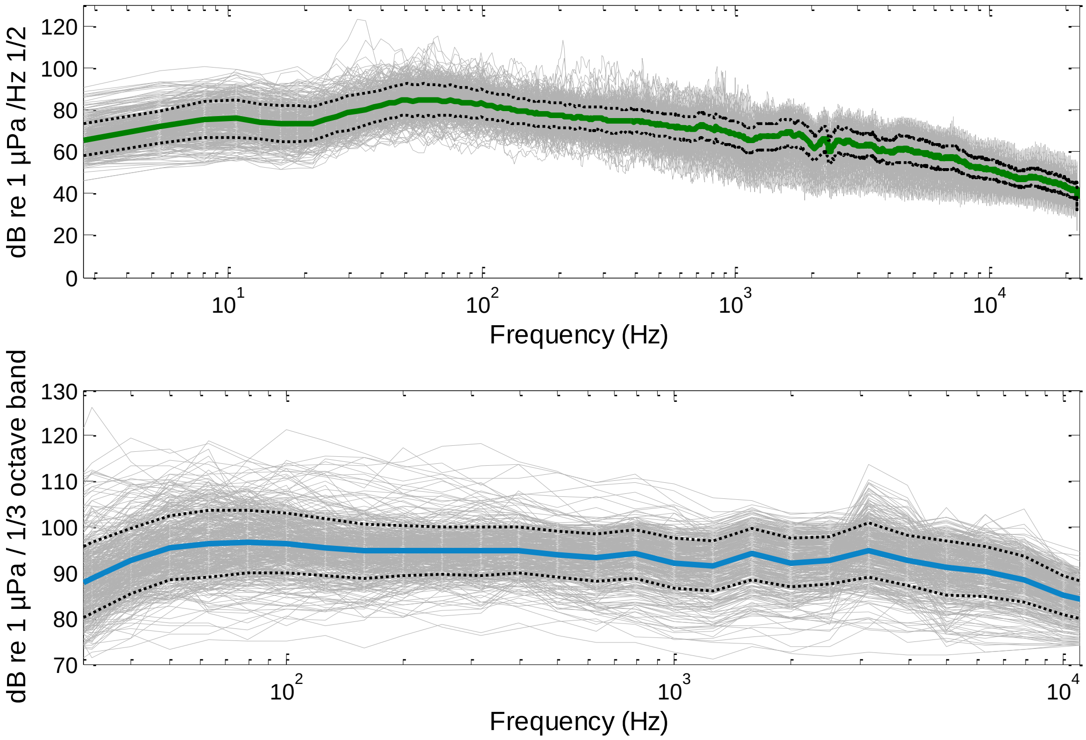


Figure 13 Top panel: Power spectral density in 1Hz bands of the sample subset from the autumn period September 1st to November 30th 2013 (n = 403). Grey lines are the power spectral densities of individual samples. The green line is the mean power spectral density, and the dashed lines are one standard deviation from the mean. Bottom panel: Power spectral density in third octave bands of sample subset from the autumn 2013 period. Grey lines are the power spectral densities of individual samples. The blue line is the mean power spectral density, and the dashed lines are one standard deviation from the mean

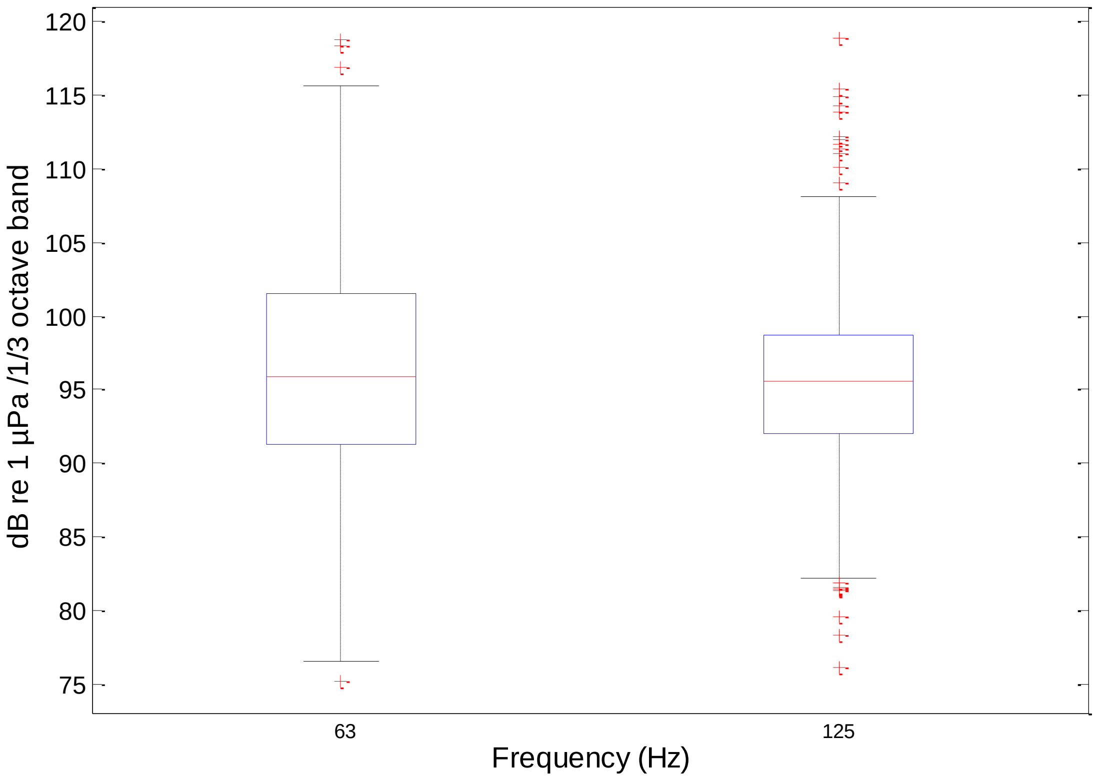


Figure 14 Boxplot of the 1/3 octave bands centred at 63 and 125 Hz of the sample subset from the spring period September 1st to November 30th 2013 (n = 403). The central red line is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses

As shown in the Figure 11 and Figure 13, both for the autumn 2012 and 2013 datasets, most of the acoustic energy in the PSD graph was below 1 kHz (upper graph). The lower graph in the figures shows the distribution in 1/3 octave bands up to 11 kHz which was fairly even. This flattening of the frequency distribution was expected, as 1/3 octave bands summarise the acoustic energy over frequency bands that are becoming wider with increasing frequency (see also Madsen et al. 2006 for comparable spectra from the Baltic and North Sea).

Based on Figure 12, for the autumn 2012 subset of samples, the mean broadband SPL covering the third octave bands 63 Hz to 10 kHz was 112 dB re 1 µPa (median 111 dB, max 125 dB, min 97 dB re 1 µPa), while the mean SPL at 63 and 125 Hz was 100 and 99 dB re 1 µPa, respectively. Figure 14 shows that for the autumn 2013 samples subset, the mean broadband SPL in the third octave bands centred at 63 Hz to 10 kHz was 109 dB re 1 µPa (median 109 dB, max 126 dB, min 91 dB re 1 µPa), while the mean SPL at 63 and 125 Hz was 96 dB re 1 µPa for both.

The U-Mann Whitney statistical test revealed that there was a significant difference in the noise level between the autumn 2012 and 2013 season, both when comparing at the individual frequencies 63 Hz and 125 Hz and when comparing mean broadband noise levels (Mann-Whitney $p<0.05$).

5.1.1.2 Winter

PSD values obtained for the winter season are presented in Figure 15 and Figure 16.

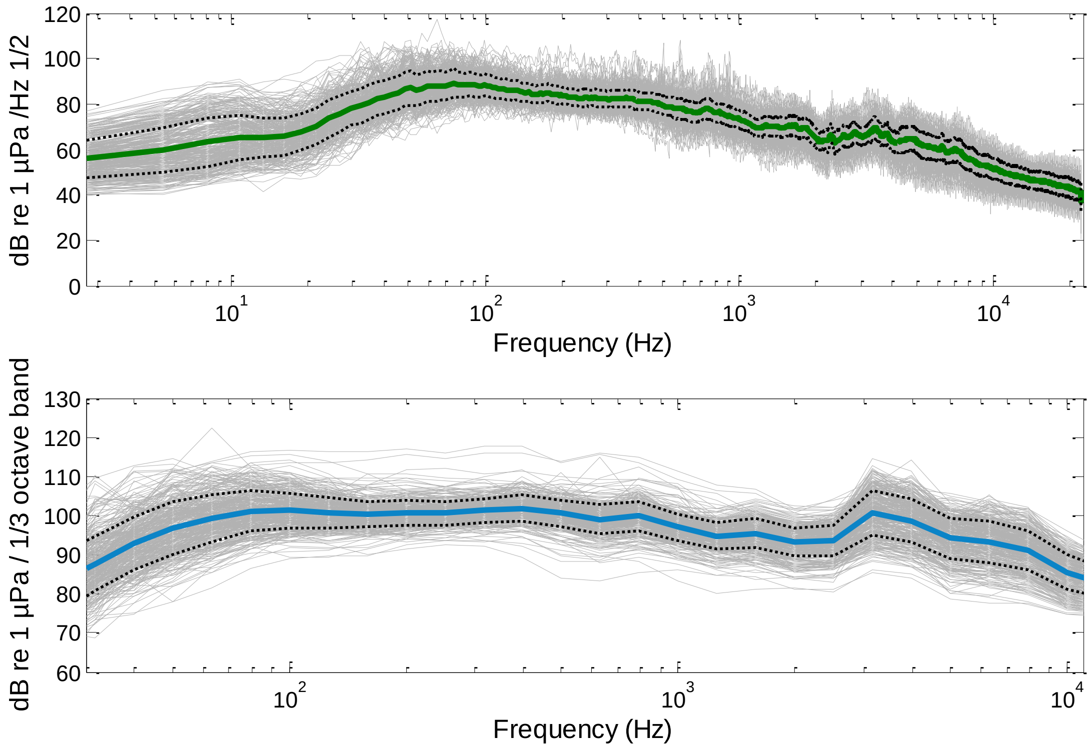


Figure 15 Top panel: Power spectral density in 1Hz bands of the sample subset from the winter period December 1st 2012 to January 8th 2013 and from January 25th to February 28th 2013 (n = 357). Grey lines are the power spectral densities of individual samples. The green line is the mean power spectral density, and the dashed lines are one standard deviation from the mean. Bottom panel: Power spectral density in third octave bands of sample subset from the winter 2012/2013 period. Grey lines are the power spectral densities of individual samples. The blue line is the mean power spectral density, and the dashed lines are one standard deviation from the mean

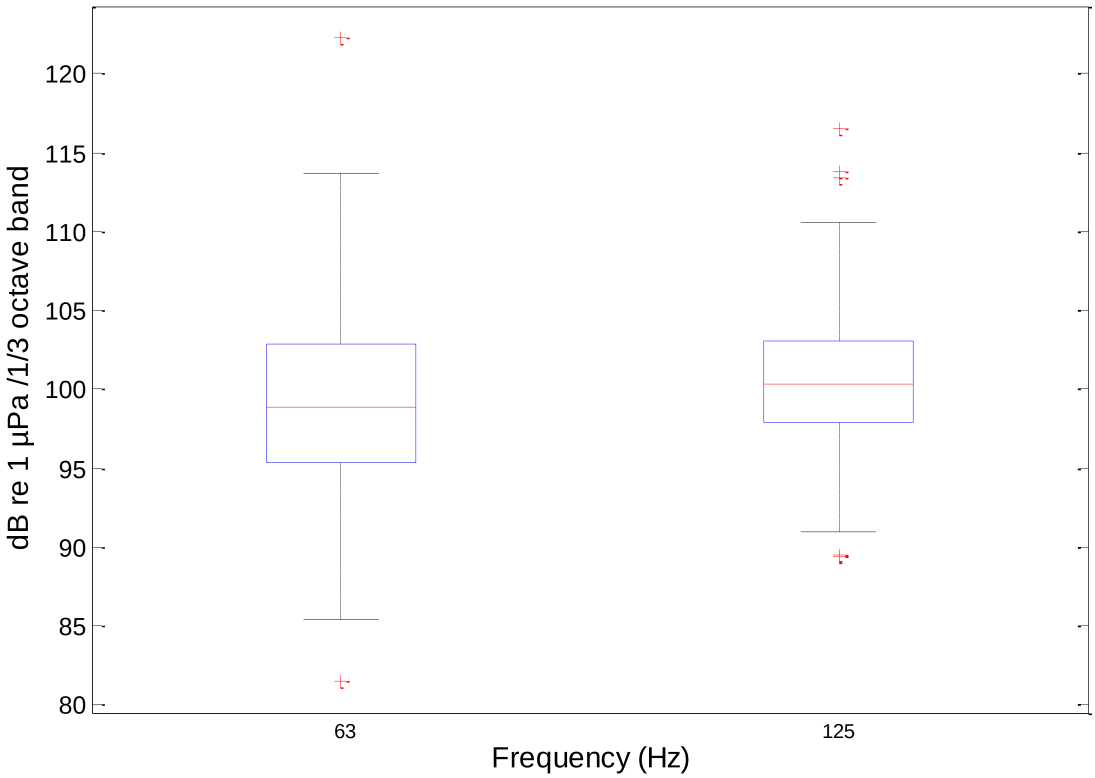


Figure 16 Boxplot of the 1/3 octave bands 63 and 125 Hz of the sample subset from the winter period December 1st 2012 to January 8th 2013 and from January 25th to February 28th 2013 (n = 357). The central red line is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses

As presented in Figure 15, in the winter recordings, most of the acoustic energy was below 1 kHz (upper graph). The lower graph in the figure shows the distribution up to 11 kHz which was fairly even.

Figure 16 indicates the mean broadband SPL covering the third octave bands 63 Hz to 10 kHz was 114 dB re 1 µPa (median 113 dB, max 127 dB, min 102 dB re 1 µPa), while the mean SPL at 63Hz and 125 Hz was 99 and 101 dB re 1 µPa, respectively.

5.1.1.3 Spring

PSD values obtained for the spring dataset are presented in Figure 17 and Figure 18.

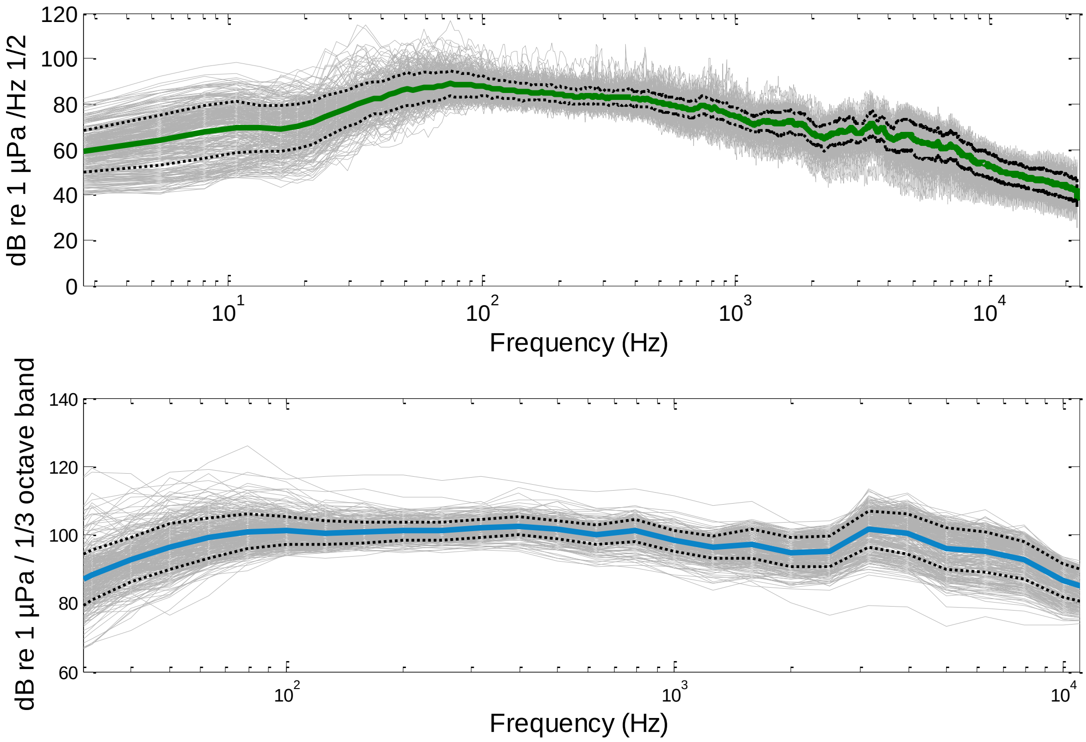


Figure 17 Top panel: Power spectral density in 1Hz bands of the sample subset from the spring period March 1st to March 13th (n = 334). Grey lines are the power spectral densities of individual samples. The green line is the mean power spectral density, and the dashed lines are one standard deviation from the mean. Bottom panel: Power spectral density in third octave bands of sample subset from the spring period. Grey lines are the power spectral densities of individual samples. The blue line is the mean power spectral density, and the dashed lines are one standard deviation from the mean

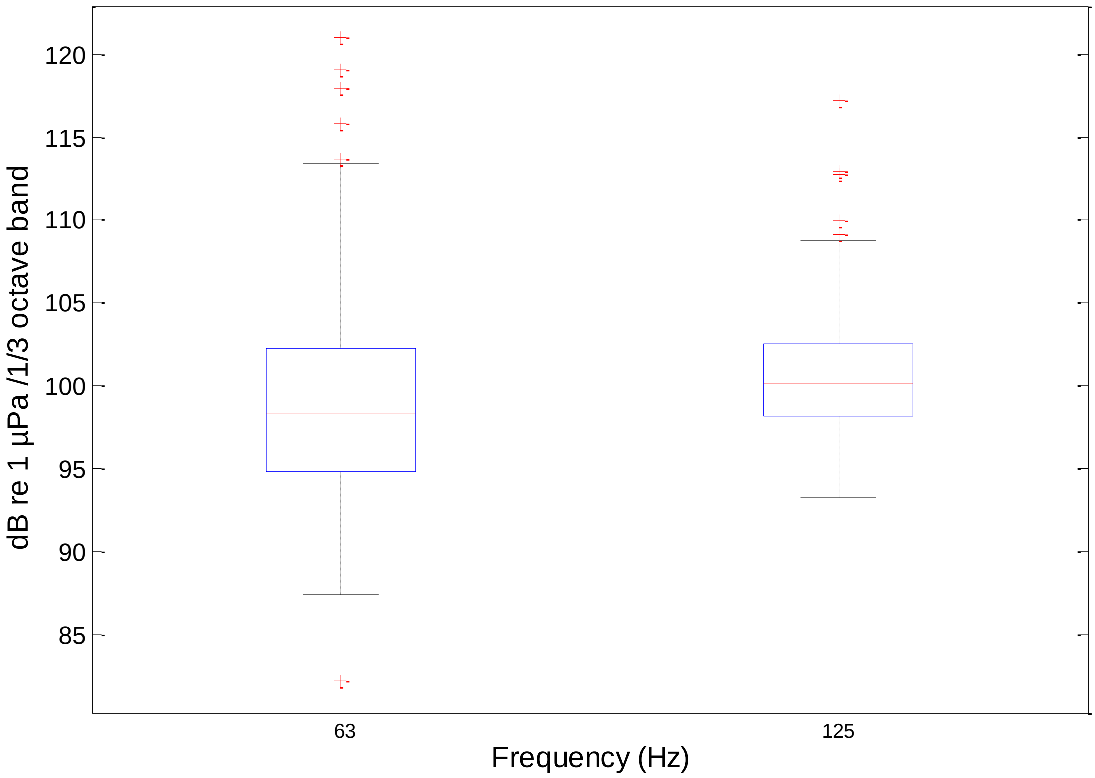


Figure 18 Boxplot of the 1/3 octave bands 63 and 125 Hz of the sample subset from the spring period March 1st to March 13th (n = 334). The central red line is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses

For the spring samples subset Figure 17 shows a similar frequency distribution as for the autumn and winter recordings.

As presented by the Figure 18, for the spring recordings, the mean broadband SPL covering the third octave bands 63 Hz to 10 kHz was 114 dB re 1 µPa (median 114 dB, max 128 dB, min 106 dB re 1 µPa), while the mean SPL at 63 and 125 Hz was 99 and 101 dB re 1 µPa, respectively.

5.1.1.4 Summer

PSD values representing the summer season are presented in Figure 19 and Figure 20 .

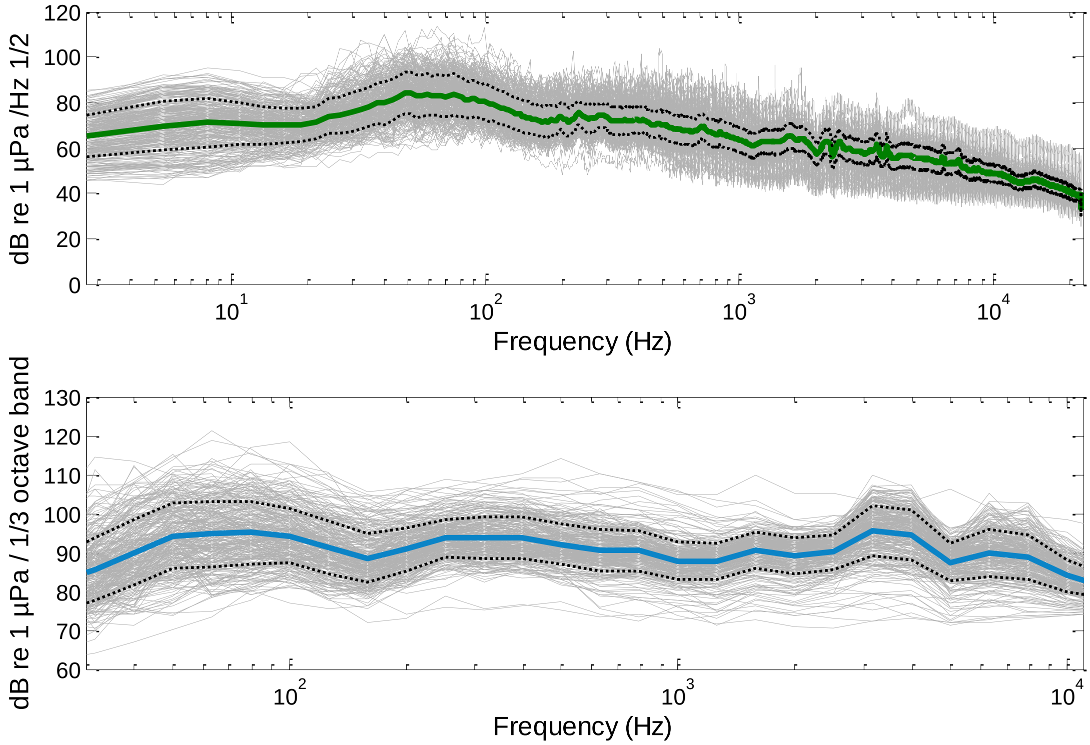


Figure 19 Top panel: Power spectral density in 1Hz bands of the sample subset from the summer period August 21st to August 31st (n = 309). Grey lines are the power spectral densities of individual samples. The green line is the mean power spectral density, and the dashed lines are one standard deviation from the mean. Bottom panel: Power spectral density in third octave bands of sample subset from the summer period. Grey lines are the power spectral densities of individual samples. The blue line is the mean power spectral density, and the dashed lines are one standard deviation from the mean

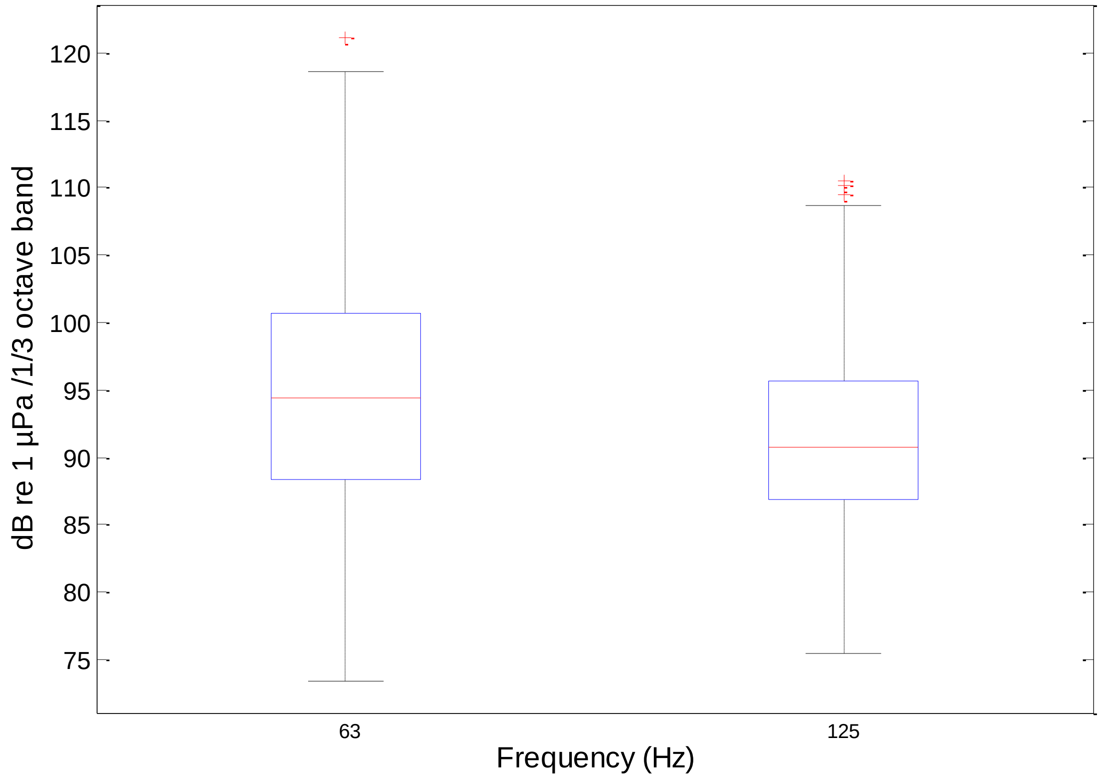


Figure 20 Boxplot of the 1/3 octave bands 63 and 125 Hz of the sample subset from the summer period August 21st to August 31st (n = 309). The central red line is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses

As indicated by Figure 19, for the summer samples subset, most of the acoustic energy was again below 1 kHz (upper graph). The lower graph in the figure shows the distribution up to 1 kHz which was fairly even, as was the case for the other seasons.

Figure 20 shows that for the summer recordings the mean broadband SPL covering the third octave bands 63 Hz to 10 kHz was 107 dB re 1 µPa (median 107 dB, max 123 dB, min 91 dB re 1 µPa), while the mean SPL at 63 and 125 Hz was 95 and 91 dB re 1 µPa, respectively.

A comparison of the values of mean broadband sound pressure levels with a use of the Kruskal-Wallis test revealed significant differences between the seasons ($p<0.05$). A comparison between the values of mean sound pressure levels at 63 Hz showed that the winter and spring samples were significantly different from summer and fall samples ($p<0.05$), but not from each other. Also the summer and autumn samples were not significantly different. Statistical test for the mean sound pressure levels at 125 Hz indicated that summer and fall samples were significantly different ($p<0.05$ in the Kruskal-Wallis test 1 way Analysis of Variance (=ANOVA) between different samples), while there were no significant differences between other seasons.

5.1.2 Ambient noise in different sea state conditions

According to BSH 2011 we undertook a comparison of the ambient noise levels in different sea state conditions. This analysis could be useful when comparing the ambient noise values in situations with very low wind farm activity with the ones where rotational speed is most likely high due to higher winds. The sound pressure levels at 63 Hz and 125 Hz and the mean broadband SPL values were compared in two groups of the wind classes – between the sea state 1 - 3 Bft class and 4 – 6 Bft class (see the methodology). The results of analyses are shown in the Figure 21 and Figure 22.

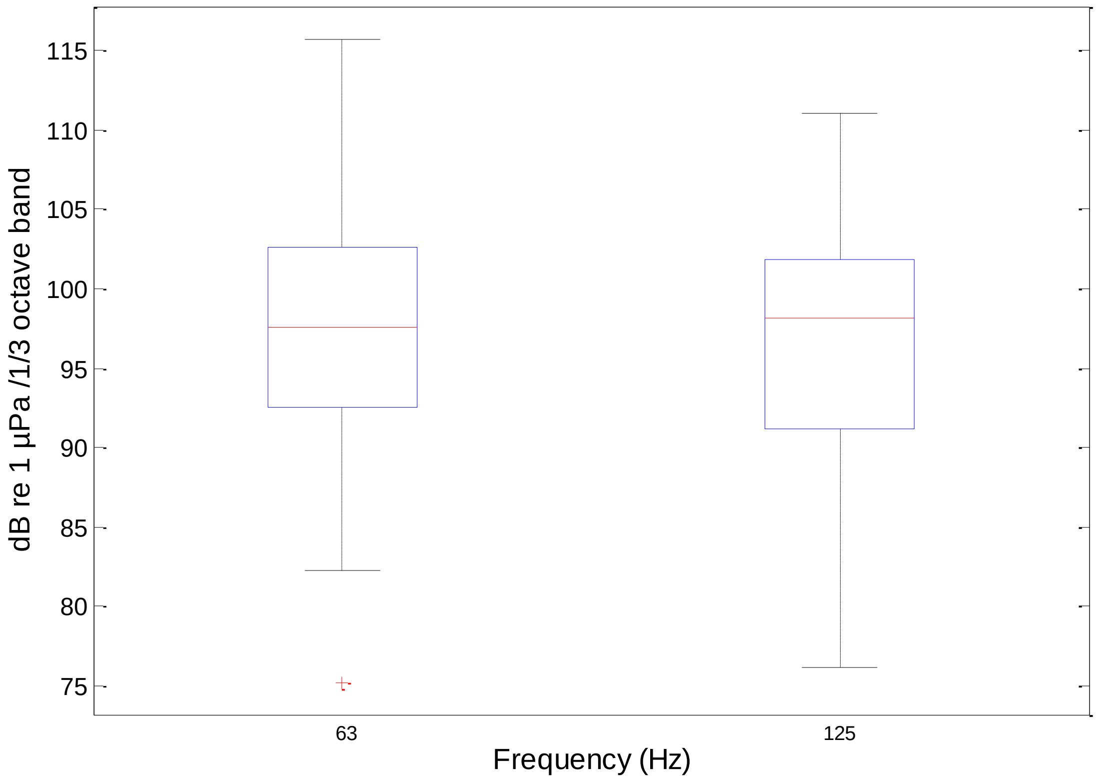


Figure 21 Boxplot of the 1/3 octave bands 63 and 125 Hz of the sample subset covering the Beaufort 1-3 sea state conditions (n=100). The central red line is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses

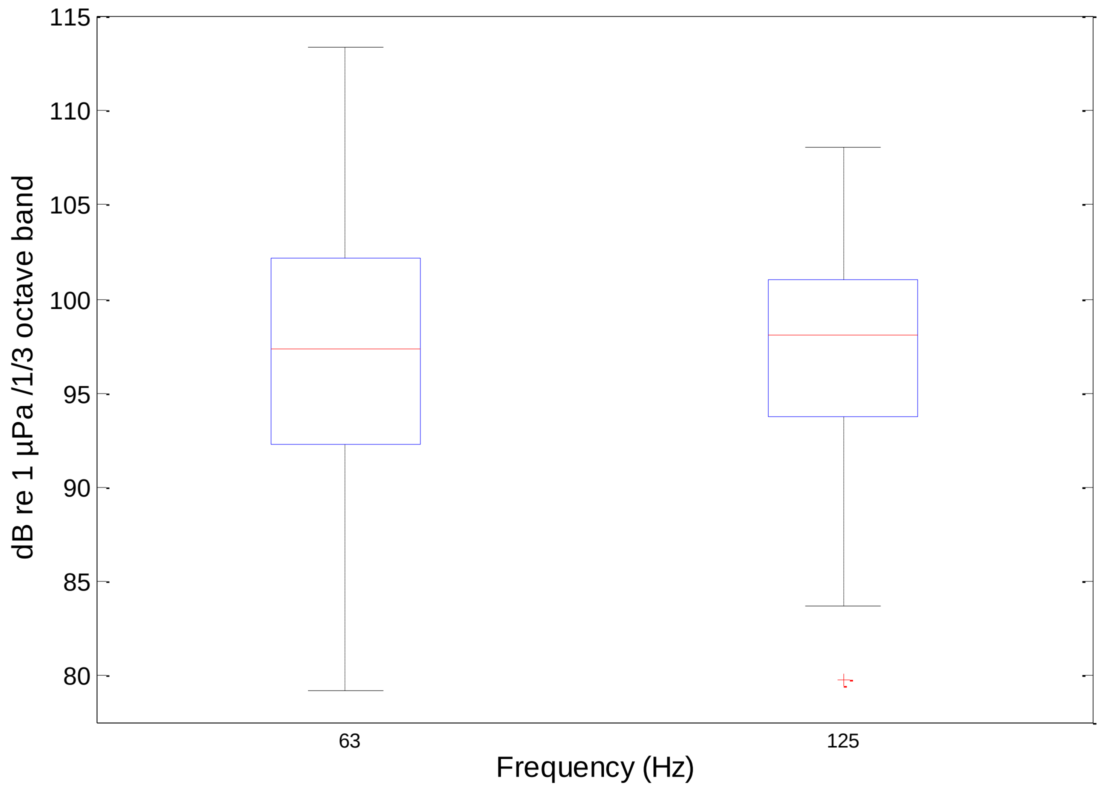


Figure 22 Boxplot of the 1/3 octave bands 63 and 125 Hz of the sample subset covering the Beaufort 4-6 sea state conditions (n=100). The central red line is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses

As presented in Figure 21, for the subset of samples covering the Beaufort 1-3 sea state conditions, the mean broadband SPL covering the third octave bands 63 Hz to 10 kHz was 110 dB re 1 µPa (median 111 dB, max 121 dB, min 91 dB re 1 µPa). The mean SPL at 63 Hz was 98 dB re 1 µPa, while at 125 Hz the mean SPL was 96 dB re 1 µPa.

Figure 22 shows that for the subset of samples representing the Beaufort 4-6 sea state conditions the mean broadband SPL covering the third octave bands 63 Hz to 10 kHz was 112 dB re 1 µPa (median 112 dB, max 120 dB, min 102 dB re 1 µPa), while the mean SPL at 63 and 125 Hz was 97 and 97 dB re 1 µPa, respectively.

The statistical Mann-Whitney U test indicated that the ambient noise values in two studied sea state conditions were not significantly different at 63 and 125 Hz, but differed significantly when comparing the mean broadband sound pressure levels ($p<0.05$).

6 Discussion

6.1 Assessment of data and result quality

The EIA assessment described in this report is the first large scale ambient noise monitoring campaign in support of an offshore wind farm license application in Polish waters. As the study site is placed in the area where poor weather conditions often prevail, various difficulties were expected. However, in spite of difficulties, a majority of the project activities was carried out according to the plan, as well as good quality acoustic data, covering 56% of the monitoring period, was collected. Obtained data included recordings representative for each season of the annual cycle and thus, the BSH standards for the ambient noise monitoring were followed as planned (see BSH 2011).

One of the major problems when recording underwater noise is the registration of system self-noise. This can be generated by the hydrophone itself and the recording system or come from noise generated by the deployment platform of mooring. According to Dekeling et al. 2013a, the self-noise equivalent sound pressure level of the equipment should be at least 6 dB below the lowest noise level to be measured in the frequency range of interest. The hydrophone used by the SM2M has self-noise equivalent sound pressures between 42 and 54 dB re 1μPa^2/Hz (10 Hz – 1000 Hz) which is very much below the PSD levels recorded in that frequency range.. We can therefore rule out that the hydrophone or other parts of the recording equipment influenced our recordings. The quality of the recorder is further confirmed by the fact that the BIAS programme (Baltic Sea Information on the Acoustic Soundscape) – which is the largest measurement campaign of underwater noise ever undertaken in the Baltic - is using the same type of equipment as we did for BŚ III. The field work in the BIAS project started in 2014 and will cover the whole calendar year. Ambient noise recordings are collected throughout the Baltic Sea, with 5 measuring stations in Polish EEZ.

However, we did record shackle noise which is visible in the PSD in most cases as a peak in the higher frequencies (3-4 kHz). Yet, the shapes of PSD's of recordings including shackle noise, and those that were 'clean' were identical at frequencies up to 3 kHz (relevant for pile driving and operational wind farm noise). Certainly, our results of the analysis of MSFD relevant frequency bands (63 and 125 Hz) were not affected by shackle noise which was several octaves higher. Recent tests with an altered mooring design (fully submerged mooring without large buoys at the surface) has resulted in the minimization of the problem.

6.2 Level of ambient noise at the OWF BŚ III site in relation to seasons and wind speed

The results of our investigation are summarized in Table 6 (*results pooled from all seasons).

Table 6 Overview of the results of the ambient noise monitoring for BŚ III.

	2012	2012/ 2013	2013		
	autumn	winter	spring	summer	autumn
Broadband SPL (dB re 1µPa)	112	114	114	107	109
SPL at 63 Hz centre frequency (dB re 1µPa)	100	99	99	95	96
SPL at 125 Hz centre frequency (dB re 1µPa)	99	101	101	91	96
Broadband SPL (dB re 1µPa) at Bft 1-3	110*	110*	110*	110*	110*
Broadband SPL (dB re 1µPa) at Bft 4-6	112*	112*	112*	112*	112*

*results cumulated for all seasons

When looking at seasonality of the results, we have to bear in mind that results from different stations were pooled. In our case this was justified by the similarity of the recording positions with regard to water depths and physical properties (e.g. bathymetry). Yet, we should note that other investigations have found differences of ambient sound across adjacent sites (FEMM 2013; Johansson & Andersson 2012), depending mostly on the location in relations to shipping lanes. Thus, our seasonal comparisons have to be viewed with caution. Looking at the results from Table 6 it is nonetheless apparent that the sound levels in summer and autumn 2013 were both lower compared with the ones from winter, spring and autumn 2012. This can be explained with the better sound propagation in the Baltic during the cold vs. warm months. In the Fehmarnbelt area, for example, the highest transmission losses occur in summer and autumn. Spring and winter result in lower transmission loss. This is due to the fact that the profiles for summer and winter exhibit an increasing sound speed with depth. This leads to sound rays bending away from the bottom, thus having less ground contact. The summer profile shows the opposite characteristics. As here the waves travel faster near the surface the resulting rays bend down to the sediment leading to an increase in bottom loss (see FEMM 2013). The results for the autumn period 2013 included September which was a relatively warm month, so the lower levels were expected.

The results clearly indicate an effect of wind speed with higher levels recorded at higher wind speeds. This is very much in line with results from other studies (see, for example Dreschler et al. 2009). This finding is important for the assessment of impact ranges of operational noise from the offshore wind farm. It could indicate that the effective space (=the distance at which a wind farm in operation can be heard) is smaller during higher wind speeds compared to lower ones as the ambient noise levels are higher.

6.3 Comparisons with other sites

Table 7 shows the results of our study in comparison with other recent investigations. We have to point out that these comparisons are not straightforward. The choice of hydrophone, amplification, overall bandwidth of the analysis and also environmental variables (sea state, wind, water depth and season) all influence the results. The standardisation of monitoring of ambient noise is one of the key goals of the MSFD and it is the hope that future measurements, for example through BIAS, are directly comparable to our findings.

In a first nearing we can conclude that the levels recorded at BŚ III fall well within the range recorded by others in similar circumstances. They are very similar to the results obtained by Gerke 2011 and FEMM 2013 (lower end of their results). It can be also seen from Table 7 that the recorded 1/3 octave band levels off Rotterdam are much higher at 63 and 125 Hz compared to our area (compare to values in Table 6). This clearly indicates that the noise levels at BŚ III are less impacted by nearby shipping. The area can thus be characterised as one with medium pressure due to ambient noise.

Table 7 Overview of studies of ambient noise in comparison with BŚ III

Location	Associated information	Recording Equipment	Broadband sound pressure levels (dB re 1 µPa)	Source
BŚ III; Polish Baltic (this study)	30-40 m depth; near shipping lanes	SM2M Wildlife Acoustics (20 Hz – 48 kHz); data analysed up to 20 kHz	109-114	This report
Fehmarnbelt (German and Danish Baltic)	30 – 40 m depth; variety of locations; quiet areas to busy shipping lane	Custom built (20 Hz-20 kHz)	104-134	FEMM 2013
German Baltic	28-40 m depth; near shipping lane	Custom built (20 Hz-20 kHz)	107-112	Gerke 2011
Norra Midjobanken, Swedish Baltic	28-40 m, near shipping lane	DSG-Ocean autonomous hydrophone system (2 Hz – 20 kHz); analysis bandwidth 20 Hz-3500 Hz	115-116	Johansson & Andersson 2012
North Sea off Rotterdam Port	20 m; near busy shipping lane	TNO custom built system; 16 Hz – 31.5 kHz	63 Hz = 113 125 Hz = 113	Dreschler et al. 2009
Moray Firth; Scottish North Sea	42 m; near shipping area but various locations	B&K Hydrophone 10 Hz – 120 kHz; analysis bandwidth 10 Hz – 96 kHz	104 – 119 (138)	Bailey et al. 2010

6.4 Comparison of noise levels with hearing of porpoises

For a better understanding of the acoustic environment of the harbour porpoise at BŚ III, we have plotted the hearing sensitivity of the harbour porpoise according to Kastelein et al. 2002 in relation to the ambient noise levels at BŚ III in spring, as the highest SPL values were obtained for winter and spring 2013 season (see Table 6) (both in 1/3 octave band and thus directly comparable; see Figure 23).

This has been done for frequencies up to 10 kHz as most shipping noise and other man-made sound, such as pile driving (major amplitude 100-500 Hz) , drilling (major amplitude< 100 Hz) , dredging (major amplitude 100 – 500 Hz), seismic surveys (major amplitude , 10 – 120 Hz) low and mid frequency sonar generated noise (major amplitude 100-8200 Hz), shipping noise (major amplitude >1000 Hz) fall within that range, (OSPAR 2009).

We have to note here that the audiogram of the porpoise extends well into the ultrasonic range (above 20 kHz) with best sensitivities at around 100 Hz. It is thus possible that higher frequency sounds, for example echo-sounders, affect porpoises at higher frequencies as well.

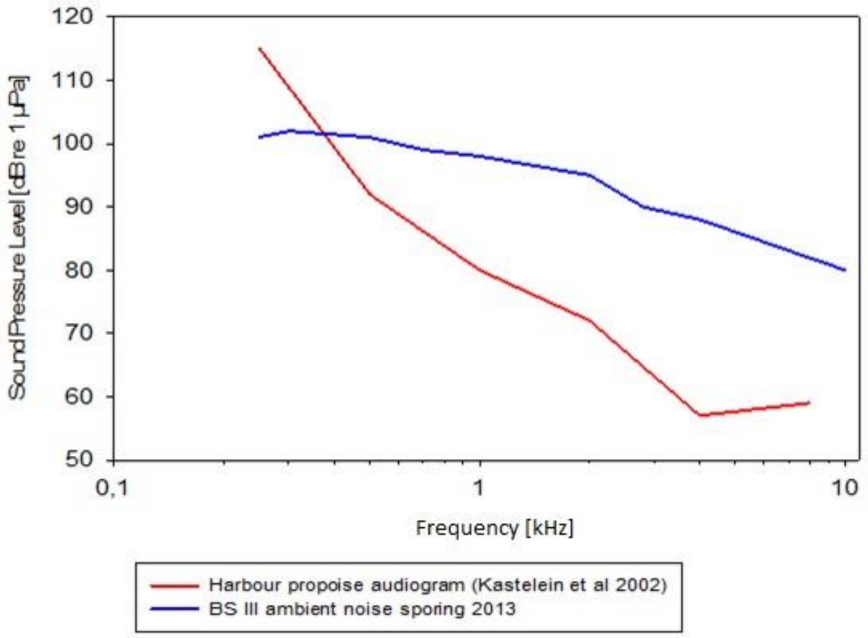


Figure 23 Ambient noise levels at BŚ III in spring 2013 in relation to the hearing sensitivity of the harbour porpoise (Audiogram)

It can be seen that ambient noise below app. 400 Hz is below the hearing sensitivity, so low frequency ambient noise is not detectable by porpoises. At frequencies > 400 Hz the ambient noise level is decreasing only slightly and hearing is getting better. At around 4 kHz, the ambient noise levels are about 30 dB higher than the audiogram values. Porpoises are thus surrounded by a constant noise level that has potentially higher impacts as the frequencies increase.

By comparing the values from the graph on ambient noise in Figure 23 with available underwater audiograms of seals with threshold levels at different frequencies, it is possible to estimate if the ambient noise levels recorded at the study site are audible to these animals.

Data available on underwater hearing of harbour seal presented in Figure 24 (Nedwell et al, 2004) indicate that ambient noise sound recorded at BŚ III is audible for this species in the whole spectrum range. At around 1 kHz ambient noise levels are about 20 dB higher than the threshold values for this species.

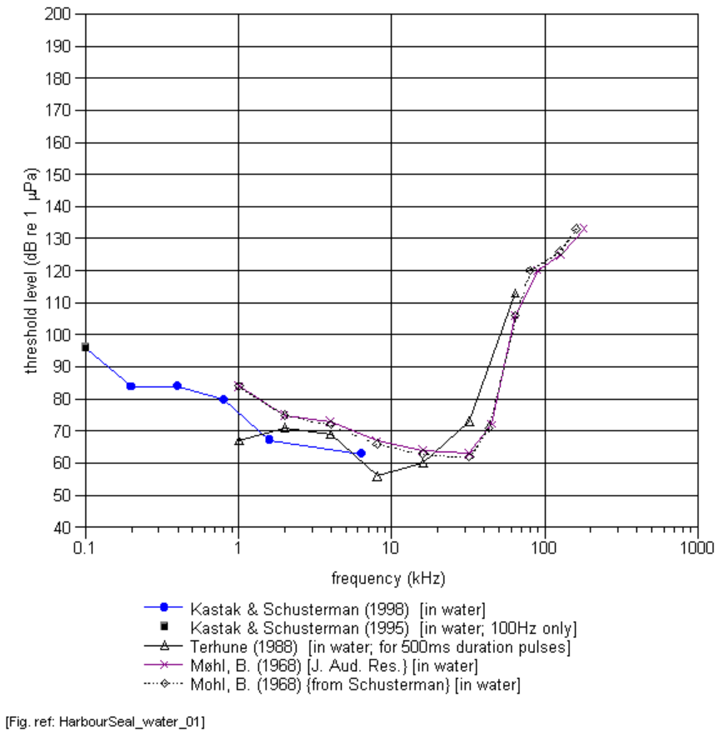


Figure 24 Summary of the existing knowledge on underwater hearing thresholds for harbour seal (Nedwell et al, 2004)

Comparison between the underwater audiogram values for ringed seal measured for frequencies ≥from 1 kHz (Figure 25) (Nedwell et al, 2004) and the ambient noise values for BŚ III also suggest that the ambient noise values ≥above 1 kHz are audible for this species. For a sound at 1 kHz ambient noise values exceed around 20 dB the threshold value for this species. It must be noted that the audiogram was composed based on the study carried out on only two individuals and thus its results should be taken into account with precaution.

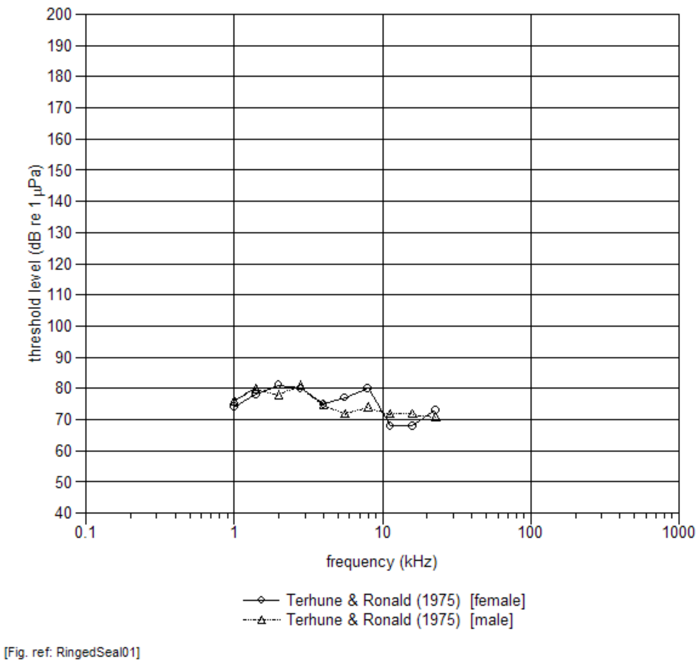


Figure 25 Summary of the existing knowledge on underwater hearing thresholds for ringed seal (Nedwell et al, 2004)

Yet, looking at the overall levels of ambient noise at the study site, these are most likely not high enough to lead to any impact on hearing of porpoises and seals (for a TTS values for harbour porpoise see Kastelein et al. 2013, for TTS values for pinnipeds see Southall, 2007). Thus, we conclude from the investigation that ambient noise levels are high enough to be detected by porpoises and seals, but that it is unlikely that they lead to any impact on hearing under normal circumstances. Although it should be noted that there is a possibility of masking of significant sounds for seals, whose hearing is more sensitive at low frequencies.

7 Conclusions

In this study, we recorded and analysed ambient noise at three sites in the Polish Baltic in five seasons (2012-2013). These measurements represent the first systematic attempt to describe ambient underwater noise values for Polish waters. The investigations followed internationally accepted standards. The monitoring was a success with 56% of the time covered and in full compliance with the German Standards for baseline investigations for offshore wind farm EIAs. The area can be characterised as one with medium pressure due to ambient noise, with broadband sound pressure levels between 107-114 dB re 1μPa. The analysis revealed differences in sound levels between seasons, with the highest values for winter 2012/2013 and spring 2013 season. This can be explained with the better sound propagation in the Baltic during the cold vs. warm months. As expected broadband sound pressure level at Bft 1-3 was lower than the value obtained for Bft 4-6 (2 dB difference), as with increasing wind speed more waves are generated, which produce noise at the sea surface but also underwater. Compared to other sites in the Baltic and the North Sea, the ambient underwater noise levels at the BŚ III area at the frequencies below 10 kHz represent only a medium potential impact on harbour porpoises and seals. Thus, noise levels will not lead to adverse effects on the function of the area for porpoises.

8 References

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9 Tables

10 Figures