

Chapter 3. Underwater noise emission during the phase I construction of the C-Power wind farm and baseline for the Belwind wind farm

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Photo Ward Van Roy / RBINS

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Abstract

The noise level under water was measured at the Bligh Bank before construction works started (reference level, T_0) and at the Thorntonbank during construction works (T_1). The reference underwater noise levels measured at the Bligh Bank were 95 to 100 dB (re 1 μ Pa) between 10 Hz and 2 kHz, levels similar to those measured previously at the Thorntonbank site during similar weather conditions (wind force 2-3 Bft, sea state 1-2). Slight differences may be due to the noise generated by the Interconnector and/or Zeepipe pipelines near the Thorntonbank site (not detected during the Bligh Bank monitoring), to local characteristics in the underwater topography, to the ad hoc shipping traffic near the monitoring stations and to meteorological conditions. Levels during high and low tide did not show significant differences. Only limited effort could be spent at measuring underwater noise during the construction works at the Thorntonbank windfarm site. The levels measured were 5 to 25 dB higher than the background noise levels, similar to increases caused for instance by passing ships. However, no specific measurements related to the construction of offshore windfarms, such as cable laying or the laying of the scour protection could be measured. Future underwater noise measurements will be focused at such activities, and at pile driving. Also efforts will be made to fine-tune the technical aspects of the measurements and the analyses, and at assessing possible impacts of the noise measured.

Samenvatting

In 2008 werden onderwater-geluidsmetingen verricht op de Bligh Bank (referentiegeluid, T_0) en tijdens constructie-activiteiten op de Thorntonbank (T_1). Het referentieniveau van het geluid onder water op de Bligh Bank was 95 tot 100 dB (re 1 μ Pa) tussen 10 Hz en 2 kHz, een niveau gelijkaardig aan dit eerder gemeten op de Thorntonbank bij nagenoeg dezelfde weersomstandigheden (windkracht 2-3, staat van de zee 1-2). Kleine verschillen kunnen toegewezen worden aan het geluid van de Interconnector en/of Zeepipe pijpleidingen nabij de Thorntonbank (niet gedetecteerd in de metingen).

op de Bligh Bank), de lokale verschillen in onderwatertopografie, het scheepvaartverkeer, en meteorologische omstandigheden. De onderwater geluidsniveaus bij hoog en laagtij vertoonden geen significante verschillen. Er konden door diverse omstandigheden slechts beperkt metingen uitgevoerd worden tijdens de constructiewerken op de Thorntonbank. De gemeten niveaus lagen 5 tot 25 dB hoger dan het achtergrond geluidsniveau, een verhoging vergelijkbaar met bijvoorbeeld voorbijvarende schepen. Tijdens specifieke constructieactiviteiten, zoals het plaatsen van de kabels of de erosiebescherming, konden echter geen metingen van het onderwatergeluid uitgevoerd worden. Toekomstige metingen zullen zich vooral richten op dergelijke activiteiten, en op het heien van palen. Daarnaast zullen inspanningen geleverd worden om technische aspecten van de metingen aan te passen, en om de mogelijke effecten van het onderwatergeluid op het ecosysteem in te schatten.

3.1. Introduction

Until recently, little attention was paid to the effects of underwater noise originating from human activities. This has changed, and human generated noise is now considered as an important form of pollution. Even if a lot of speculation still exists on the effects of increased levels of underwater noise on biota.

There has been an increasing research effort in the field of underwater noise due to the observation of negative impacts, especially on cetaceans, and due to an increasing use of sound in remote sensing methods, both in civil as in military applications, and the increasing level of offshore industrial activities in general.

As a first step towards assessing the possible effects of the underwater noise generated by the construction and exploitation of offshore wind farms in Belgian marine waters, measurements are and will be made of the level and characteristics of underwater noise before, during and after the construction activities (MUMM, 2004; MUMM, 2007, in Dutch). This monitoring report describes the results of the underwater sound and noise measurements performed in 2008 at the Thornton Bank offshore windfarm construction site (C-Power; T_1) and at the future Bligh Bank construction site (Belwind, T_0). An earlier report dealt with the underwater noise level at the Thorntonbank windpark site before the start of the construction works (Henriet *et al.*, 2006). The objective of the measurements is to qualify and quantify the physical changes in the marine environment, and to assess possible effects on biota, especially marine mammals.

3.2. Material and methods

Prior to the underwater noise measurements, a detailed measurement protocol was prepared by MUMM (Haelters *et al.*, 2008). The methodology is similar to the one used for the measurements of T_0 at the Thorntonbank site during 2005 and 2006, as described in Henriet *et al.* (2006). Below the practical implementation of the protocol as during the 2008 campaigns is described. Prior to the monitoring at the windfarm sites, the equipment was tested at MUMM's offices and in the port of Ostend.

3.2.1. Platform

As a platform for the measurements we chose small craft on which all instruments which could possibly interfere with the noise measurements can be turned off. In practice, we operated from a Rigid Inflatable Boat (RIB) which was deployed from the oceanographic vessel BELGICA. The BELGICA remained adrift at a distance of at least 2 nautical miles from the RIB during the measurements.

3.2.2. Acoustic measurement equipment

For the underwater noise measurements we used two calibrated Brüel & Kjær hydrophones type 8104, simultaneously deployed at different depths. These hydrophones are suitable for underwater noise measurements between 0.1 Hz to 80 kHz, and according to the calibration curves at frequencies of up to 120 kHz with higher measuring uncertainty. Only the results of the noise measurements of the hydrophone positioned at 15 m depth is reported. The hydrophone positioned at 10 m depth was used for making control measurements. A study of the T_0 situation at the Thornton sandbank (Henriet *et al.*, 2006) had demonstrated that the underwater noise at 10 and 15 m depth did not differ significantly.

For recording the underwater noise, we used a MARANTZ Solid State Recorder PMD671 operating with a sampling rate of 44,100 Hz. The noise was recorded in WAVE format (.wav) on Compact Flash cards of 2 GB (Sandisk Ultra II). A Brüel & Kjær Nexus 2692-0S4 amplifier between

the hydrophones and the recorder allowed for correcting for the exact sensitivities of the hydrophones, and for the registration of a reference signal. The signal is amplified by the Nexus with 31.6 mV/Pa in the frequency range 10 Hz to 22.4 kHz. The Nexus generates a reference signal of 1.44 Vp (= 1 V RMS) at 159 Hz. This reference signal was recorded at each channel at the beginning and at the end of each measurement. All equipment was powered by batteries.

3.2.3. Recording position and depth

The position of the measurement platform was registered automatically at regular intervals of one or a few seconds by a GARMIN GPSMAP 60 Cx. Depth soundings were made at the beginning and at the end of each underwater noise measurement using a hand-held system (SPEEDTECH; 400 kHz). We did not make depth soundings during the measurements, given the possible interference with noise recordings.

3.2.4. Recording environmental variables

As underwater noise varies according to weather conditions, we described the environmental conditions for each of the measurements: general weather conditions, wind speed, wind direction and sea state. Environmental variables were recorded on board the BELGICA. Given the use of a RIB, campaigns were only organized if the foreseen sea state was 3 or less, and with a foreseen wind force of 3 Bft or less.

3.2.5. Registration of AIS data

Noise originating from ships constitutes an important part of the current background underwater noise level in seas and oceans. To avoid that such noise has a determining influence on our recordings, we only performed measurements for the T_0 surveys when no ships were visible in the immediate vicinity of the measurements. To assess the presence of ships in a wider surrounding during the measurements, we also inspected Automatic Identification System (AIS) data from an area of 5 nautical miles (NM) around the site where the underwater noise was measured. An AIS system on board ships sends information (such as name of the ship, type of ship, size, call sign, position, speed, heading, ...) at transmission intervals ranging from 6 minutes for static ships, to 2 seconds for ships with a speed of 23 kts or more, or 14 kts or more when changing course. AIS systems are required on board of most ships, and from the 1st of July 2008 onwards on all ships larger than 300 GT. An analysis of the AIS data allows for the possible indication of interference of noise generated by ships with the background noise measurements. Given the distance of noise measurements from construction works during the T_1 monitoring, AIS data during T_1 are less important, although they were still inspected. The AIS receiver present on the roof of MUMM Ostend's offices (COMAR SLR-500) was used to register AIS data. This receiver covers the whole of Belgian waters and slightly beyond. The system records most AIS signals; some though may be lost at the furthest distance from Ostend, and during periods with a very high number of signals emitted.

3.2.6. Measurements

For each recording the RIB was put at drift at a predefined position, with the engine shut off. For each monitoring campaign (T_0 , T_1 , different wind farm areas), at least 3 measurements at different positions were made. The target length of each recording was around 20 minutes. Especially during construction works, the length of recordings could be lower. This is due to the fact that the monitoring platform is at drift during the measurements, and is not supposed to interfere with the vessels or platforms active at the construction site. The clock of the recorder was synchronized beforehand with the GPS-time (UTC). Specific events possibly influencing underwater noise, such as the passing of a ship or an activity at the wind farm site, were registered (place, time) and described. Unless technically not possible, hydrophones were put at depths of 10 and 15 m.

Noise at frequencies higher than 22.4 kHz cannot be measured with the equipment described here. However, propagation loss is frequency dependent; high frequency noise is attenuated more than low frequency noise (Fisher & Simmons, 1977; Thiele, 2002). At a distance of hundreds of meters to some km from the source, high frequency noise is attenuated completely, while low frequency noise can travel up to tens and even hundreds of kms.

3.2.7. Analysis of the recordings

After the transfer from the CF cards to a PC, the recorded data were processed in a similar way as described by Henriët *et al.* (2006). This includes a spectral analysis of the signal in the form of a third octave band spectrum of the underwater sound pressure level. The spectra were obtained using a routine built on the software programme MATLAB, and according to the norm IEC1260. As a general basis for the analysis, extracts of 500 s of every recording were used, while also shorter sections were chosen for analysis of specific events, such as during construction. Only a selection of the analyses is presented here.

The level of the reference signal generated by the amplifier is set at $1.44 V_p (= 1 V_{rms})$ at a frequency of 159 Hz. As the signal is amplified by $31.6 mV Pa^{-1}$, the dB value of the reference signal can be calculated as:

$$dB \text{ reference signal} = 20 * \log\left(\frac{P_1}{P_{refwater}}\right) \text{ in which:}$$

$$P_1 = \frac{1V}{31.6 mV / Pa} = 31.646 Pa \text{ and } P_{refwater} = 1 \mu Pa$$

which results in a value of 150 dB for the reference signal.

3.3. Underwater noise measurements at the Thornton Bank site

3.3.1. Overview of measurements

In the framework of the monitoring of the effects of the construction and exploitation of the offshore windfarm at the Thornton Bank, measurements were made of the underwater noise during the construction phase (T₁). These activities are very diverse and involve various types of vessels, dredgers, jacked-up pontoons and other workboats. An activity potentially generating a high level of underwater noise is the laying of the scour protection around the windmill foundations. Although the aim was to organize a campaign during that activity, this was not possible in 2008 due to the rapidly changing planning of this activity, and the limited availability of the BELGICA or alternative research platforms. Measurements during this activity are planned in 2009.

During 2008, the following campaigns were organized:

- BELGICA campaign 2008/16, 4 July 2008
- BELGICA campaign 2008/20, 10 September 2008.

Other campaigns were planned but could not take place due to technical problems or adverse meteorological conditions. In order to assess the possibility of additional noise produced by other shipping activities in and near the windfarm zone, the AIS data collected in a zone with a radius of 5 NM around the position of the D3 foundation were investigated.

3.3.1.1. 4 July 2008

The activities on site on 4 July 2008 were limited (figure 1). At foundation D3 pontoon PAULINE was present, next to two towing vessels: VIKING and AMSTELSTROOM. A platform was moored next to foundation D5. The AIS data revealed the presence of MSC RHONE and the JACOB MEINDERT in the vicinity of the windfarm zone.



Figure 1. On site at the Thorntonbank on 4 July 2008 (Photo: MUMM / RBINS).

Two underwater noise recordings of approximately 10 minutes were made, and one of approximately 20 minutes (table 1). The track of the RIB during and between the recordings is presented in figure 2. The wind was blowing from a south-westerly direction with a force of 3 to 4 Bft; the sea state was 2.

Table 1

Underwater noise recordings made on 4 July 2008 (BELGICA campaign 2008/16); time in UTC

File name	Start	End	Wind speed (Bft)	Wind direction	Sea state
Tho_01.wav	6:38:11	6:48:25	3-4	SW	2
Tho_03.wav	6:58:46	7:11:50	3-4	SW	2
Tho_04.wav	7:20:42	7:42:44	3-4	SW	2

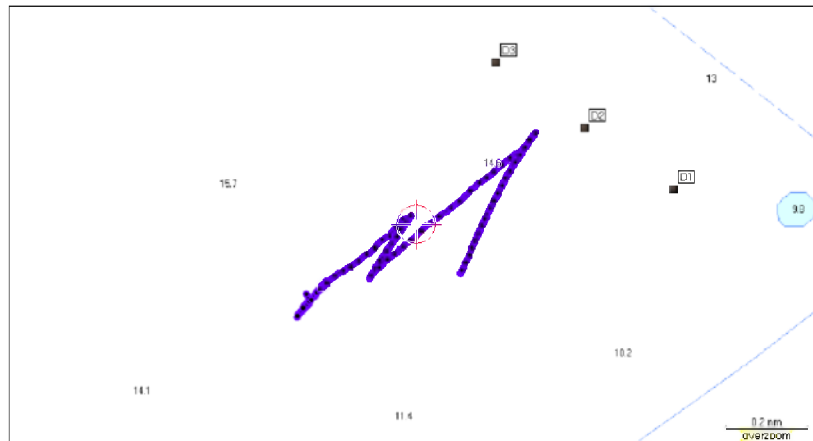


Figure 2. Track of the RIB during and between the underwater noise recordings on 4 July; the position of the foundations D1 to D3 is indicated on the map.

3.3.1.2. 10 September 2008

On 10 September 2008 BARGE 28 (cable work) was present close to foundation D1, as well as the NEPTUNE MARINER. An image of the activities the day before is given for illustration in figure 3. Besides these two vessels, the AIS data indicated the presence of the vessels MTS VAILANT, CLEMENTINE, SEA CRUISER 1 and (evidently) BNS BELGICA in or around the windfarm concession area.



Figure 3. Image of the activity at the Thorntonbank windfarm site on 9 September 2008, showing the cable barge which was also present on 10 September, when underwater noise measurements were made (photo MUMM / RBINS).

Measurements were made simultaneously under water (by MUMM) and above water (by C-Power), but this report only concerns these under water. Table 2 provides the basic information of the measurements; the track of the RIB during and between the recordings is presented in figure 4.

Table 2

Noise measurements made on 10 September 2008 (BELGICA campaign 2008/20) under water (UW) and above water (ATM), time in UTC

File name UW	Start UW	Start ATM	End UW	End ATM	Wind speed (Bft)	Wind direction	Sea state
Tho_05.wav	10:22:00	10:34:30	10:46:00	10:55:00	2-3	SW	1-2
Tho_06.wav	11:07:00	11:08:00	11:28:00	11:28:00	2-3	SW	1-2
Tho_07.wav	11:38:00	11:39:00	11:58:00	11:58:00	2-3	SW	1-2

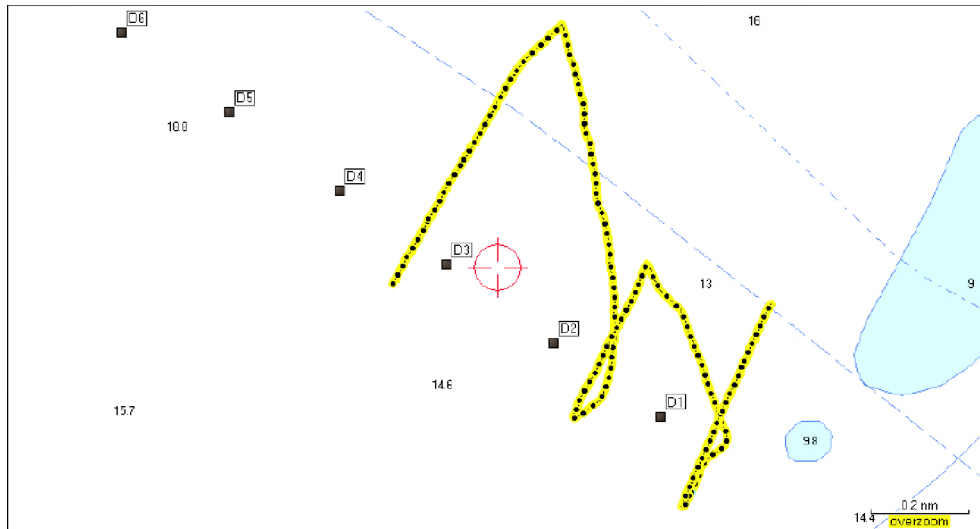


Figure 4. Track of the RIB during and between the underwater noise recordings on 10 September; the position of the foundations D1 to D6 is indicated on the map.

3.3.2. Results of the underwater noise measurements

In this section the raw data are presented together with the analyses. Figures 5 to 7 present a screenshot of the raw data of representative recordings made on 4 July and 10 September. The reference signal can be seen as a bar at the beginning and end of each recording. A rapid visual examination of these records indicates a relatively weak background noise level and discrete events with higher noise levels that can be attributed to the construction activities.

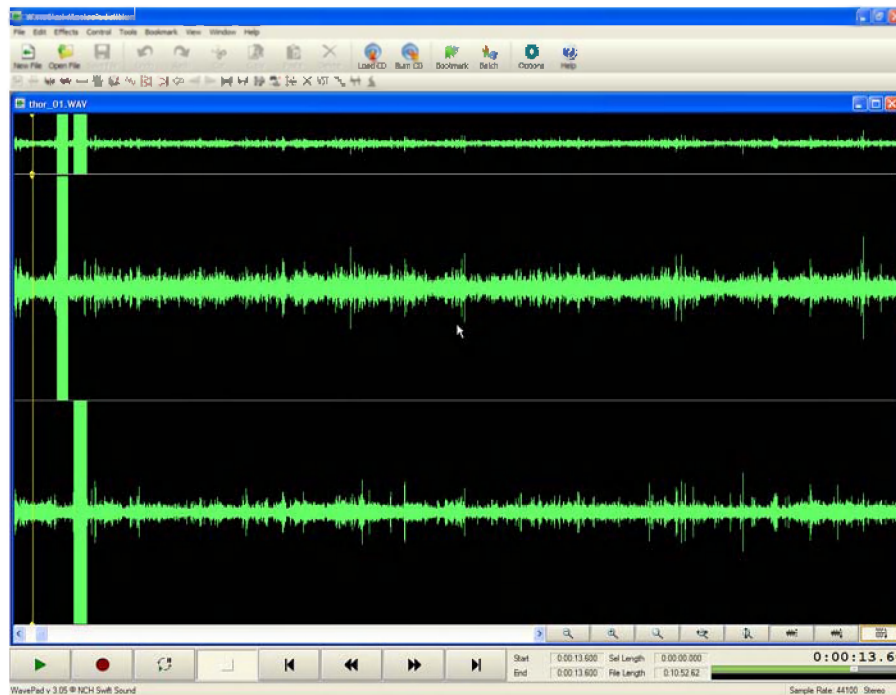


Figure 5. Raw data file Thor_01.wav, 4 July 2008. Middle graph: underwater noise level, upper hydrophone; lower graph: underwater noise level, lower hydrophone; the top graph is the sum of the two other graphs.

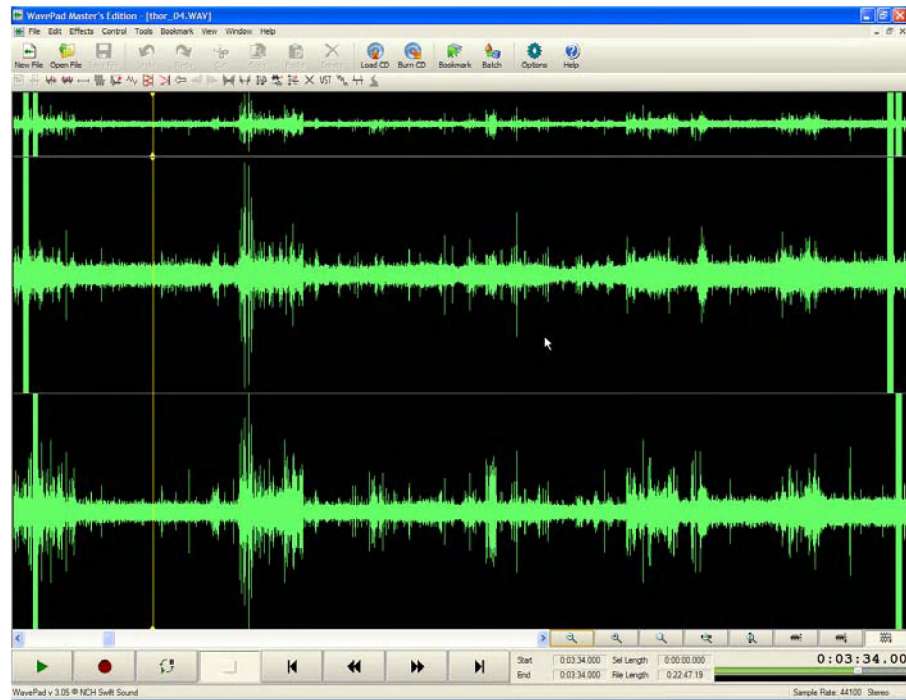


Figure 6. Raw data file Thor_04.wav, 4 July 2008. Middle graph: underwater noise level, upper hydrophone; lower graph: underwater noise level, lower hydrophone; the top graph is the sum of the two other graphs.

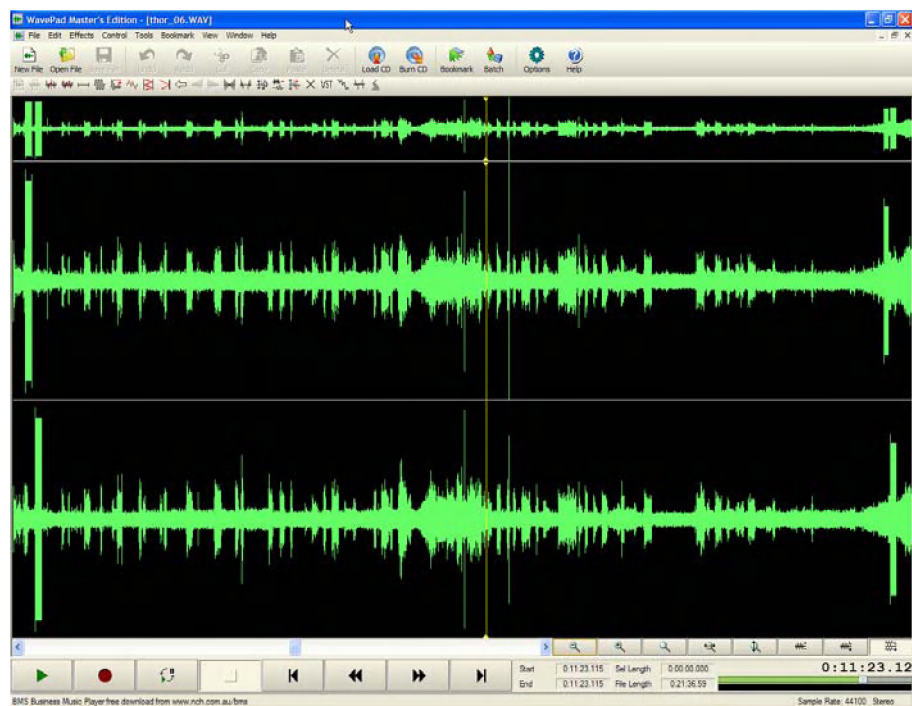


Figure 7. Raw data file Thor_06.wav, 10 September 2008. Middle graph: underwater noise level, upper hydrophone; lower graph: underwater noise level, lower hydrophone; the top graph is the sum of the two other graphs.

A number of spectral analyses are presented in figures 8 to 13. They indicate underwater noise levels (received levels) as measured – no effort was made to try to estimate the noise level at the source, given the relatively low increases in underwater noise. The measured noise level never exceeded the 150 dB reference level. A peak in underwater noise is observed below 1 kHz, as usual with noise generated by larger ships (OSPAR, 2009).

Figures 8 and 9 present the noise levels and the spectral analysis of a 500s segment of the second recording taken on 10 September 2008. Figure 9 indicates slightly higher underwater noise levels between 60 Hz and 2 kHz compared to the background noise levels measured by Henriët *et al.* (2006) (see figure 14).

Figure 10 is a section of 1.5 seconds of a recording made on 4 July (after 359 seconds into file Thor_04), and displays noise generated at the construction site. From the AIS record it appears that no other vessels were in the vicinity. The analysis (figure 11) indicates a noise level of nearly 120 dB (re 1 μ Pa) at frequencies between 100 Hz and 2 kHz.

Figures 12 and 13 display a section of 11 seconds of a recording made on 10 September 2008 (after 290 seconds into the file Thor_06). The activity recorded is a maneuver of a tugboat and a barge in the vicinity of foundation D1. The spectral analysis indicates an amplitude of 110 to 115 dB between 50 Hz and 1 kHz. During this measurement, a merchant ship was present at around 5 NM from the measurement site, as indicated by the AIS data.

Slight differences were identified between the recorded signals of hydrophone 1 and 2. This can be attributed to the complex sound propagation in this shallow area, with the presence of an irregular underwater topography. While it is known that the stratification of water masses can be responsible for such differences, no stratification occurs in this part of the North Sea. This was confirmed by data obtained with a CTD probe (measurement of temperature and salinity at different depths).

In comparison to the T_0 situation presented in the report prepared by Henriët *et al.* (2006) (example presented in figure 14), our measurements reveal a slightly higher underwater noise level, with peaks that can be attributed to the activities of the vessels. At frequencies higher than 2 to 5 kHz, the signal is similar to the T_0 situation.

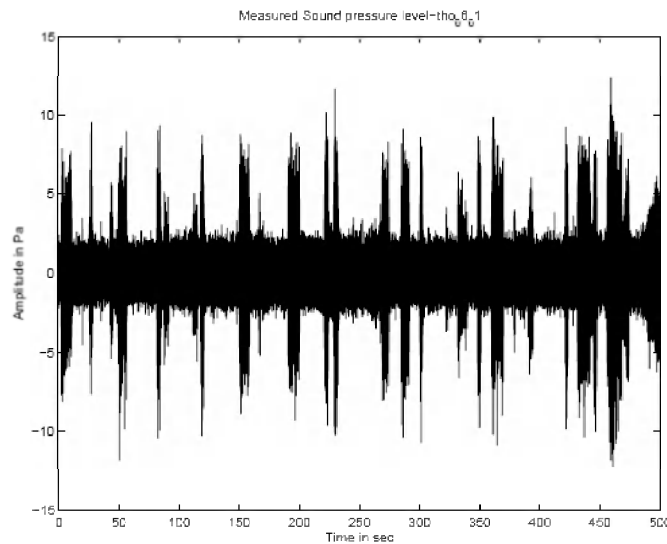


Figure 8. Amplitude (SPL – Sound Pressure Level) of a section of 500 s from the recording Tho_06_01 made on 10 September 2008.

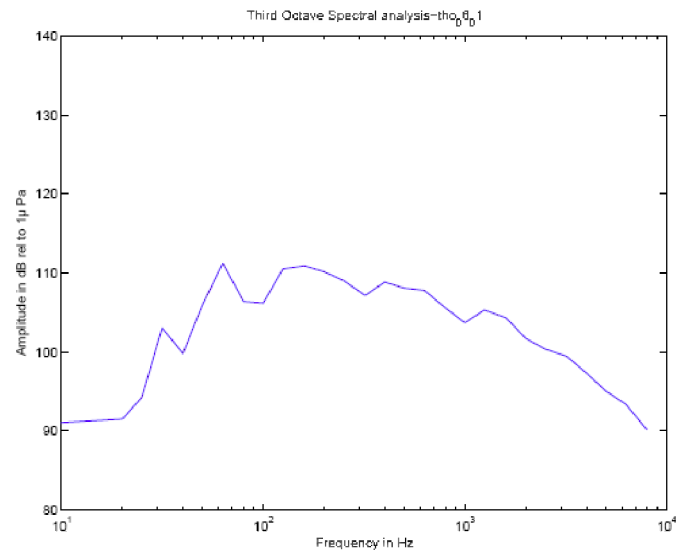


Figure 9. 1/3 Octave spectrum of the section of 500s from the recording Tho_06_01 made on 10 September 2008 (see figure 8).

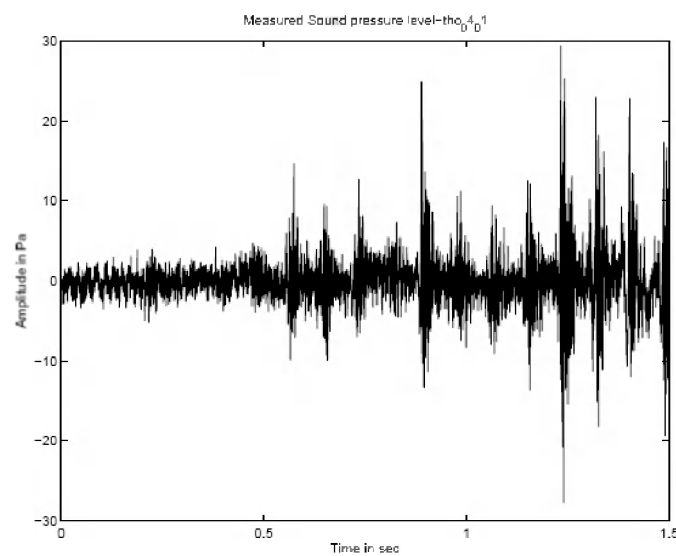


Figure 10. Amplitude (SPL – Sound Pressure Level) of a section of 1.5 seconds from the recording Tho_04_01 made on 4 July 2008.

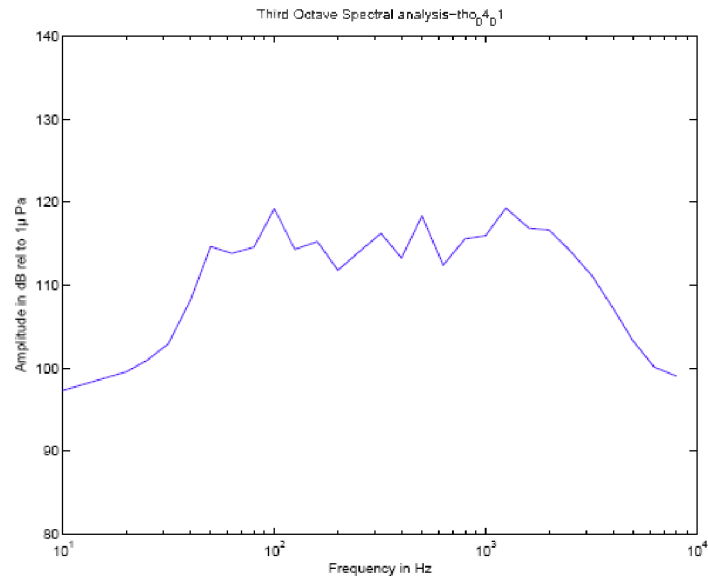


Figure 11. 1/3 Octave spectrum of the section of 1.5 seconds from the recording Tho_04_01 made on 4 July 2008 (see figure 10).

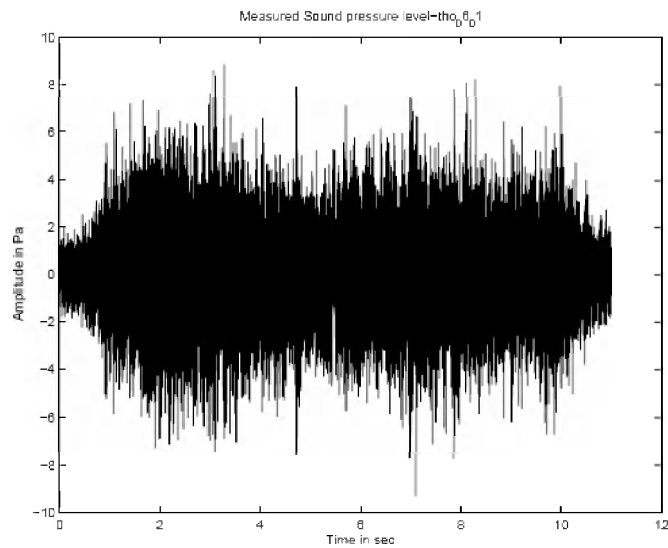


Figure 12. Amplitude (SPL – Sound Pressure Level) of a section of 11 seconds from the recording Tho_06_01 made on 10 September 2008.

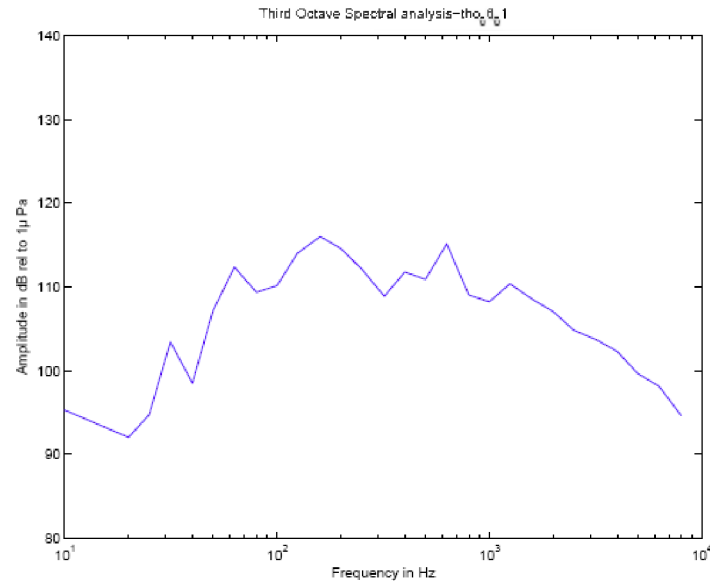


Figure 13. 1/3 Octave spectrum of the section of 11 seconds from the recording Tho_06_01 made on 10 September 2008 (see figure 12).

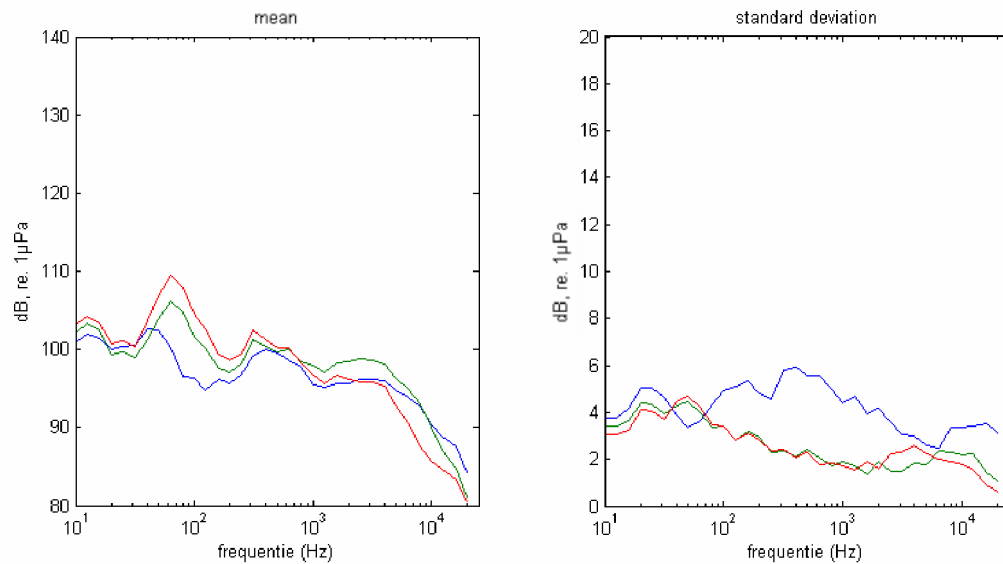


Figure 14. Left graph: example of the background underwater noise level at the Thorntonbank site, as measured by Henriët et al. (2006) using similar equipment as the equipment used during the monitoring described here, and in similar weather conditions. Three hydrophones were used at different depths: 1.5 m (blue), 8.5 m (green), and 16.5 m (red). Standard deviations are presented in the right graph.

3.4. Underwater noise measurements at the Blighbank site

3.4.1. Overview of measurements

In the framework of the monitoring of the effects of the construction and exploitation of offshore windfarms on the Blighbank, measurements were made of the underwater sound/noise level at this location before the start of the construction works (T_0). Underwater noise recordings were made at three locations within the future windpark area. In order to identify variations in the underwater noise

levels due to water depth and current, recordings were made at low and at high tide in similar meteorological conditions.

Table 3 presents an overview of the measurements that were made on site on 3 July 2008, and includes the most relevant meteorological conditions. Measurements 1 to 3 and 7 were made at low tide, measurements 4 to 6 at high tide. Figure 15 presents the track of the survey platform (RIB) during and between the noise measurements. Noise measurement 7 (TEST_BEL, table 3) was made with the BELGICA approaching the measurement platform from approximately 1.5 NM to 0.1 NM.

Table 3

Underwater noise measurements made during the BELGICA campaign 2008/16 at the Blighbank. Time in UTC: 3 July 2008

File name	Position name	Start	End	Wind speed (Bft)	Wind direction	Sea state
BLI_01	BW-EAST	6:40:35	7:01:44	3-4	SW	1-2
BLI_02	BW-IN	7:24:35	7:45:12	3-4	SW	1-2
BLI_03	BW-WEST	8:02:15	8:23:01	3-4	SW	1-2
BLI04	BW-WEST	12:17:55	12:39:21	3	SW	1-2
BLI_05	BW-IN	12:51:59	13:12:47	3	SW	1-2
BLI_06	BW-EAST	13:27:09	13:47:40	3	SW	1-2
TEST_BEL	-	8:31:00	8:43:00	3-4	SW	1-2

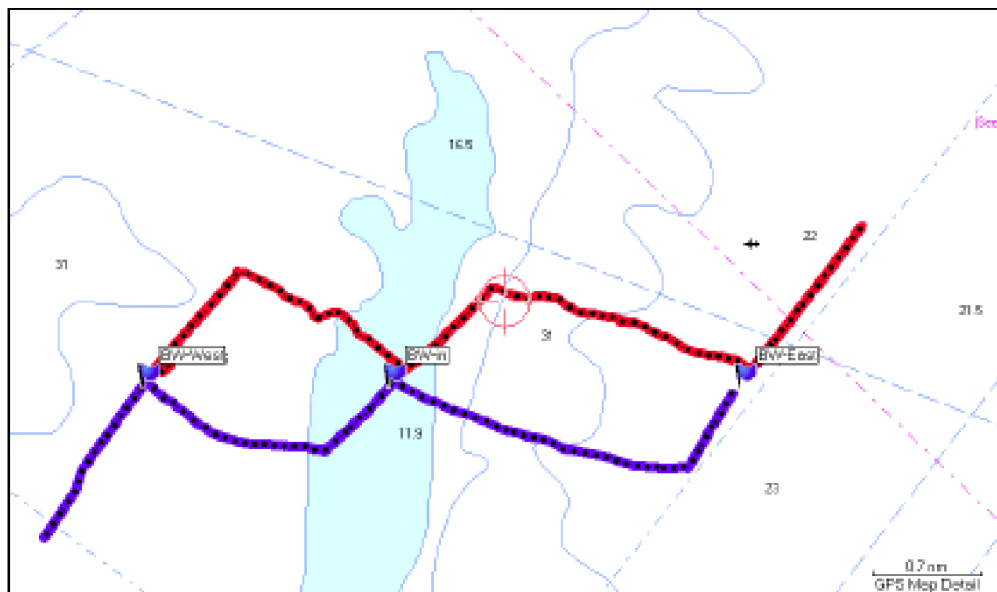


Figure 15. Track of the RIB during and between the noise measurements on the Bligh Bank on 3 July 2008. Blue lines correspond to measurements (files) 1 to 3, the red lines indicate measurements (files) 4 to 6.

In order to take noise produced in the zone by other maritime activity into account, Marine Automatic ID System (AIS) data were collected in a circle of 5 NM radius centered on the construction zone.

The presence of the following vessels was identified in the AIS data: INTERBALLAST I, ABEL TASMAN, UNION DIAMOND, CELANDINE, VLAANDEREN XXI, HYDRA and ARCO HUMBER. The latter vessel was present in the vicinity from 08:05h to 8:50h at a distance ranging from 5.5 NM to a minimum of 2 NM at 08:18h.

3.4.2. Results of the underwater noise measurements

Figures 16 to 18 present screen shots of the raw data of three of the measurements. The reference signal can be seen as a bar at the beginning and the end of each recording.

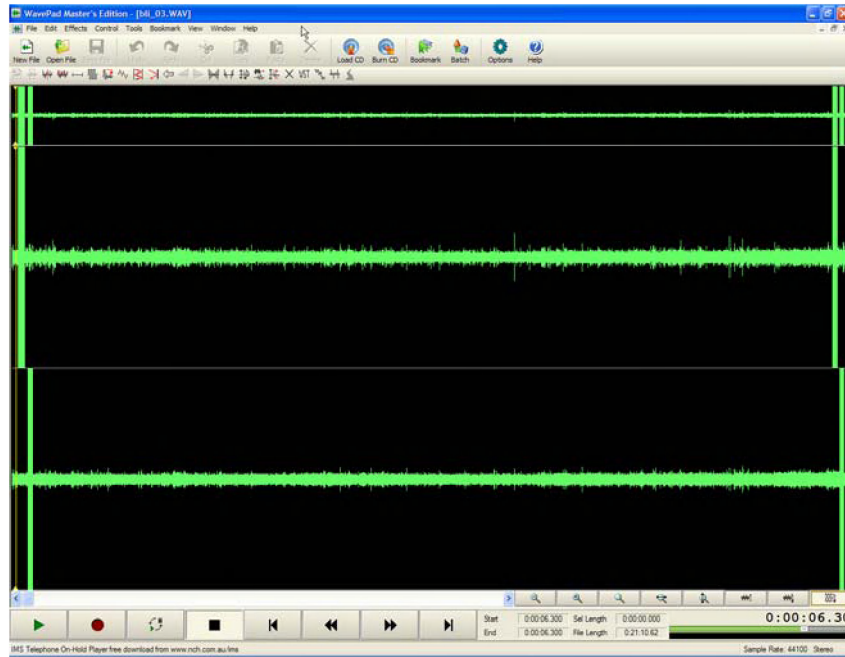


Figure 16. Raw data file Bli_03.wav, 3 July 2008. Middle graph: underwater noise level, upper hydrophone; lower graph: underwater noise level, lower hydrophone; the top graph is the sum of the two other graphs.

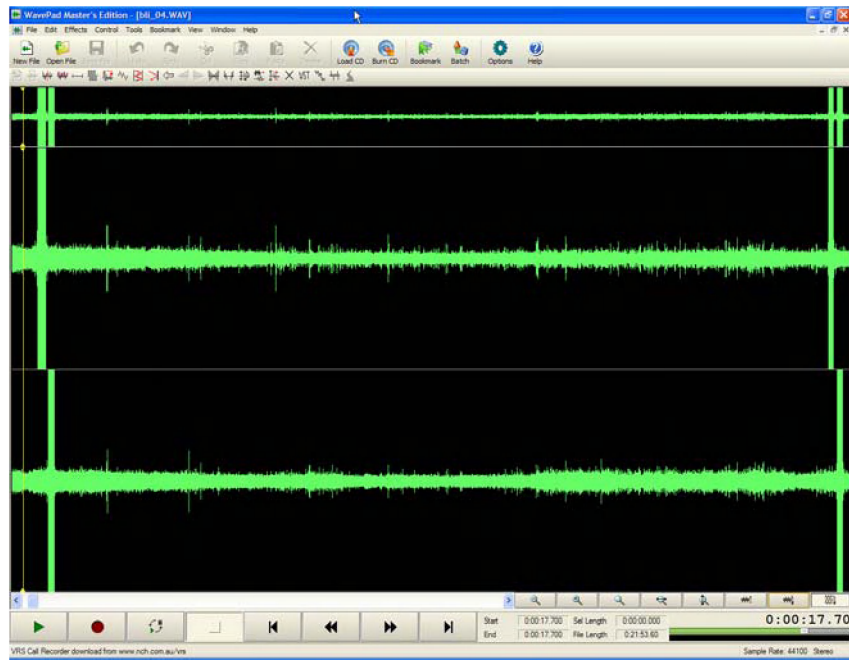


Figure 17. Raw data file Bli_04.wav, 3 July 2008. Middle graph: underwater noise level, upper hydrophone; lower graph: underwater noise level, lower hydrophone; the top graph is the sum of the two other graphs.

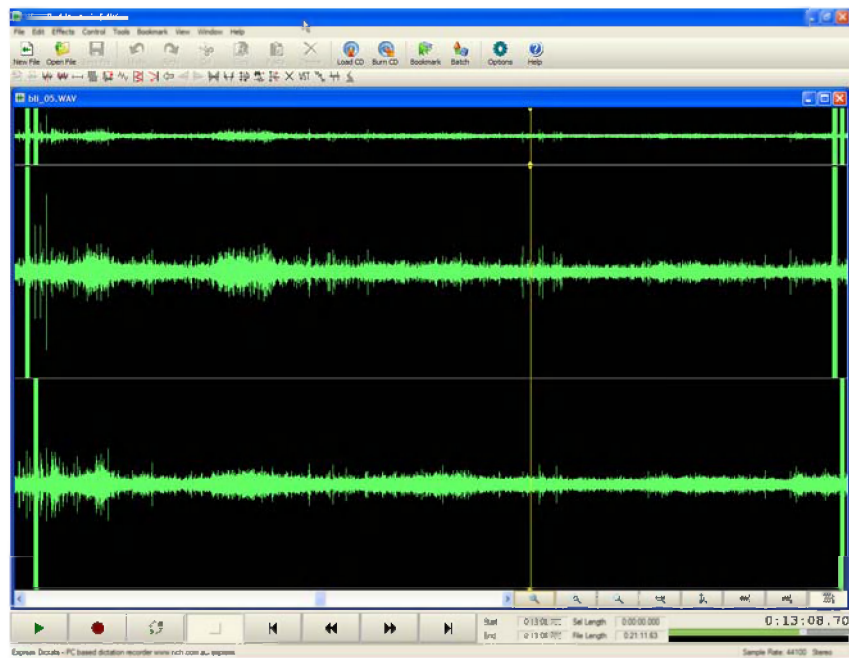


Figure 18. Raw data file Bli_05.wav, 3 July 2008. Middle graph: underwater noise level, upper hydrophone; lower graph: underwater noise level, lower hydrophone; the top graph is the sum of the two other graphs.

No difference was observed between noise levels recorded at low (figure 16) and high (figure 17 and 18) tide. The recorded background level is lower than the level recorded during the construction works at the Thornton Bank, although it still contains noise originating from shipping.

Figures 19 to 22 show the amplitude of the noise in the selected time intervals, and the respective results of the spectral analyses. They show slight variations, probably due to the irregular noise generated by distant shipping. Figure 20, presenting an analysis of a 500s segment of the record Bli_03_01 (figure 19), shows an amplitude of approximately 95 dB between 10 Hz and 2 kHz, without clear peaks.

In figure 22, a peak can be distinguished at 100 Hz. It can be attributed to propulsion/machinery noise. The range of noise produced by ships can be situated predominantly between 10 Hz to 30 kHz; peaks in noise are usually observed at frequencies below 1 kHz (OSPAR, 2009). The AIS data at that moment indicate the presence of two vessels at a distance of approximately 5 NM: the VLAANDEREN XXI and the CELANDINE.

Similar to the measurements with the CTD probe at the Thornton Bank, no water stratification, potentially affecting sound propagation, could be demonstrated. Small differences observed between the two hydrophones could be due to the topography.

In comparison to the T_0 situation at the Thorntonbank, presented in the report prepared by Henriët *et al.* (2006) (example presented in figure 14), our measurements reveal a similar level, although a peak at 1 kHz is not always present in the recordings at the Bligh Bank.

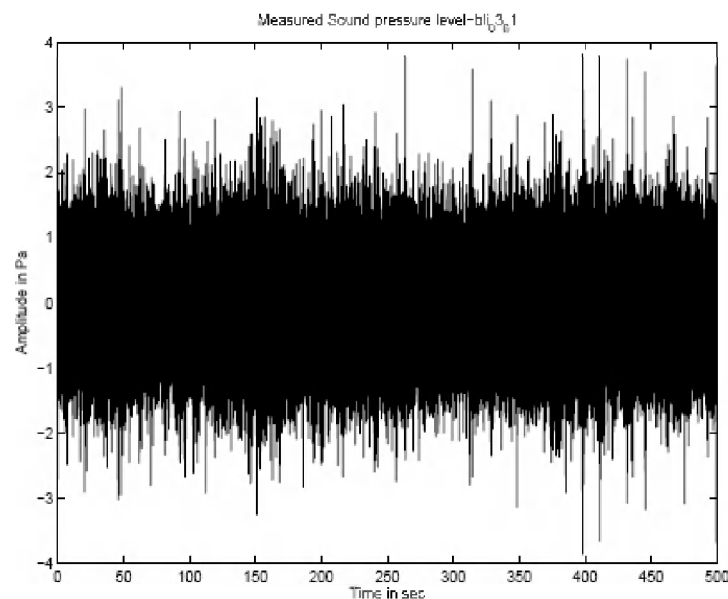


Figure 19. Amplitude (SPL – Sound Pressure Level) of a section of 500 s from the recording Bli_03_01 made on 3 July 2008.

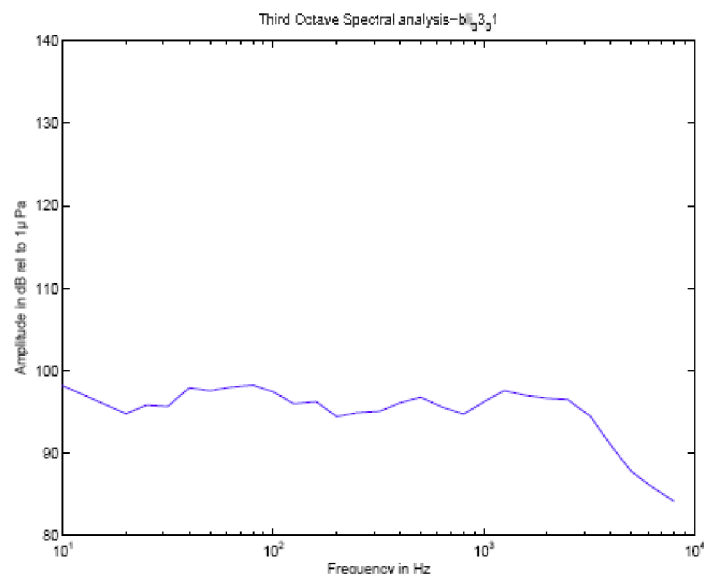


Figure 20. 1/3 Octave spectrum of a section of 500 s from the recording Bli_03_01 made on 3 July 2008 (see figure 19)

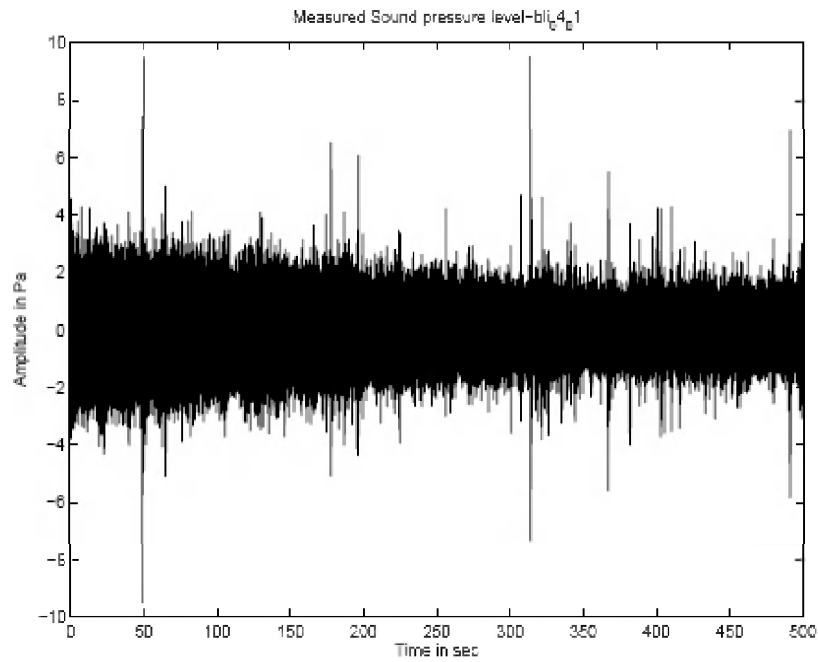


Figure 21. Amplitude (SPL – Sound Pressure Level) of a section of 500 s from the recording Bli_04_01 made on 3 July 2008.

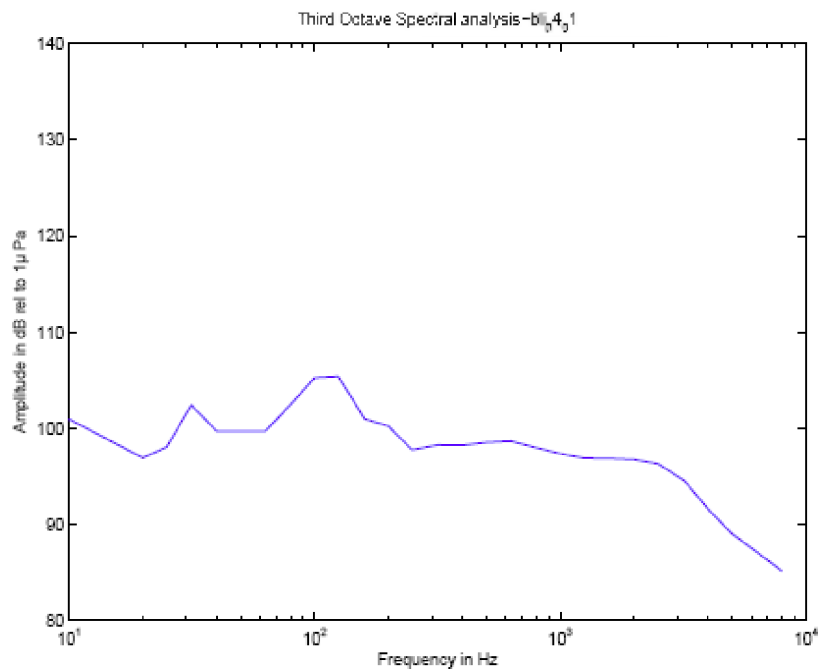


Figure 22. 1/3 Octave spectrum of a section of 500 s from the recording Bli_04_01 made on 3 July 2008 (see figure 21).

3.5. Discussion

3.5.1. Underwater noise levels (T_1) at the Thornton Bank

The recorded average sound pressure level at 50 Hz to 3 kHz is 5 to 25 dB (re 1 μ Pa) higher than the noise levels recorded at T_0 during similar meteorological conditions (Henriet *et al.*, 2006). The increase in noise level is relatively minor, and is consistent with the noise levels generated by normal ship traffic.

3.5.2. Underwater noise levels (T_0) at the Bligh Bank

The results of the measurements of T_0 at the Bligh Bank windfarm area indicate that the average background sound pressure level in that environment lies around 95 to 100 dB (re 1 μ Pa) between 10 Hz to 2 kHz during weather conditions with wind speeds of 2 to 3 Bft and a sea state of 1 to 2. Noise levels during high and low tide did not differ significantly. Some of the recordings indicate the distant presence of ships. These underwater noise levels can be considered as the background noise level (T_0) in this area. Future underwater noise measurements during the construction and exploitation of the windfarm should be put against those values.

The results concur with the T_0 measurements performed during 2005 and 2006 at the Thornton Bank windfarm area (figure 14). A difference is that additional background noise at the Thorntonbank site, possibly originating from the Interconnector and/or Zeepipe pipelines, apparently did not show up in the measurements at the more distant and deeper location of the Bligh Bank site. It would be useful to characterize the underwater noise possibly generated by the Interconnector and/or Zeepipe pipelines.

During the limited number of underwater noise recordings, the additional noise originating from the construction activities at the Thornton Bank site, about 15 km away, apparently only contributed for a minor part to the background noise at the Bligh Bank, and this additional noise could not be discriminated from background noise and distant shipping noise.

3.6. Conclusions

3.6.1. Underwater noise levels at the Thornton Bank during construction works

The increase in underwater noise levels recorded during the monitoring campaigns in 2008 was minor, and can be compared to general shipping noise, as temporarily present over a large part of the Belgian marine waters, and especially near ports and shipping lanes. Future underwater noise monitoring activities will focus on those activities of which the noise characteristics are less well known and/or are suspected to cause significant increases in underwater noise levels. Examples are the dumping of scour protection and cable laying. Measuring noise generated by a variety of types of activities will be beneficial to our knowledge in underwater noise.

Besides the need to fine-tune the recording methodology, it proved very difficult to synchronize the monitoring campaigns with relevant, selected construction activities, due to repeated postponing of the construction works in the course of 2008. The fact that adverse weather conditions make underwater noise recordings not feasible with our current setup, places additional constraints on this monitoring, and calls for a maximal flexibility in planning and resource mobilization.

3.6.2. Background underwater noise level at the Bligh Bank

The background underwater noise level recorded at the Bligh Bank area was similar to the background noise level recorded at the Thornton Bank site. Differences can be linked to slight differences in weather conditions at the time of the monitoring campaigns, differences in the site itself, differences linked to the season and water temperatures, differences in human-generated noise

during the respective campaigns (e.g. shipping) and to a combination thereof. Also the larger distance to the noise-generating gas pipelines, which run through the Thornton Bank, can have an influence. The level measured should be used as the background level for future monitoring of underwater noise during the construction and the operational phases of the windfarm project. The location of monitoring stations should be appropriately adapted in the future, for instance to measure point sources, such as originating from pile driving activities.

The variations observed between the T_0 at the Thornton Bank and the T_0 at the Bligh Bank, likely due to the proximity of pipelines at the former site, indicate that it is useful and necessary for underwater noise monitoring to establish T_0 values for each site separately.

3.7. Acknowledgements

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