THE EFFECT OF SIMULATED SEAL SCARER SOUNDS ON SEALS

Technical Report from DCE – Danish Centre for Environment and Energy No. 108 2017

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Data sheet

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Abstract:	Seal scarers are used to deter seals from fishing gear, but also at underwater construction sites, in order to protect the seals against potentially injuring noise exposure. A study on the effectiveness of seal scarers was conducted on Anholt. Seals were exposed to seal scarer sounds at reduced sound pressure levels. Contradictory to expectations, results show that seals were observed closer to the loudspeaker when sound was played, compared to baseline and significantly more seals were observed just after sound was played compared to just before. Hence, the reduced sound source appeared to attract the seals instead of deterring them.
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Summary

To test the effect of seal scarer noise on seals, we conducted an experimental study at the island of Anholt in Kattegat, Denmark, in September 2015. Seals were exposed to noise simulating that of a seal scarer, but with reduced source level. Reduced sound source level was chosen since experiments were placed inside the Natura 2000 site appointed to protect harbour and grey seals.

We show results from 13 conducted sound trials, where sound with a source level of 165 dB re 1µPa pp at 12 kHz were played in random intervals for 20 minutes. Baseline observations of seals were made at a minimum of 30 minutes prior to exposure trials and 40 minutes after the exposures. Sound exposures were conducted with a minimum of two hours interval between onset and no more than three sound exposures were made per day.

Observations / tracking of seals was achieved with a theodolite, a precision instrument for measuring angles in the horizontal and vertical planes. The theodolite can very precisely position an animal at sea and distances to the underwater loudspeaker can subsequently be calculated.

Results show that seals were observed at closer distances to the loudspeaker when sound was on compared to when sound was off. Significantly more seals were observed just after sound was played compared to just before. Hence, the reduced sound source appeared to attract the seals instead of deterring them.

Sammenfatning

For at undersøge effektiviteten af sælskræmmere blev et studie gennemført på Anholt, i september 2015. Spættede sæler blev eksponeret til undervandslyd, der simulerede lyden fra en sælskræmmer, men ved reduceret lydtryk. Lydtrykket var reduceret i forhold til en rigtig sælskræmmer fordi forsøget foregik inde i et Natura2000 område udpeget for grå- og spættede sæler.

Der blev gennemført 13 eksponeringer med et 12 kHz signal; kildestyrke 165 dB re 1µPa pp, og afspillet med randomiserede intervaller over en periode på 20 minutter. De uforstyrrede sæler blev observeret gennem minimum 30 minutter forud for lydeksponeringen og efterfølgende minimum 40 minutter efter lyden blev slukket. Der var altid mindst to timer mellem eksponeringer og aldrig mere end tre eksponeringer per dag.

Sælernes position og dermed afstand til undervandshøjttaleren blev bestemt med en teodolit, som er et præcisionsinstrument til bestemmelse af sigtevinkler i det vandrette og lodrette plan.

Resultaterne viste at sæler blev observeret tættere på højttaleren når lyden var tændt end inden lydeksponeringen. Signifikant flere sæler blev observeret i tidsrummet efter lyden blev tændt, i forhold til inden. Dette viser at sælskræmmerlyde med reduceret kildestyrke tilsyneladende virker tiltrækkende, snarere end afskrækkende på sæler.

1 Background

This study was commissioned by Energinet.dk to evaluate the effectiveness of seal scarers as a mitigation tool for seals during construction of offshore wind farms, in order to protect the seals from exposure to noise levels capable of inflicting hearing damage. The aim of this report is to show the results of the experimental study conducted at the island of Anholt in September 2015, where seals were exposed to sounds simulating a seal scarer at a reduced source level.

Seal scarers or seal scrammers are devices designed to deter seals from fishing gear and aquaculture installations to avoid depredation on fish. They are often referred to as acoustic deterrent devices (ADD's), together with for example acoustic alarms (pingers) used to deter harbour porpoises from gill nets. As the seal scarers are significantly more powerful than porpoise pingers, they are often also referred to as acoustic harassment devices (AHD's).

In addition to their primary purpose in relation to fisheries and aquaculture, seal scarers are also extensively used to deter marine mammals from loud and potentially dangerous sound sources, such as pile driving or underwater explosions and are sometimes in this context referred to as acoustic mitigation devices (AMD's). Mitigation is achieved by deploying an AHD prior to the main activity (pile driving, explosion etc.) such that marine mammals are deterred out to safe distances before the main event occurs.

The efficacy of these devices is, however, not well known. Some field studies have examined the effects of seal scarers on seals, but most of these have focused on keeping seals out of a fishery or foraging site, where the animals have strong incentive to be and tolerate noise (e.g. Yurk and Trites 2000, Graham et al. 2009, Götz and Janik 2014). Only very few studies have aimed directly at quantifying the deterrence distance of the AHD's in the field (Jacobs and Terhune 2002, Götz and Janik 2010, Hall et al. 2014). These studies report very different reaction distances (anywhere from 50 m to more than 1000 m), reflecting mainly the use of different devices and different source levels, making comparison very difficult (see review by Mikkelsen et al. 2015).

2 Experimental setup

2.1 Location

The study was conducted at Anholt's northeastern tip (Totten, 56° 44,25'N, 11° 39,03'E) in the period 1st – 20th of September 2015. The island of Anholt is located in the middle of Kattegat in Danish waters (Figure 2.1). The north-eastern tip of Anholt holds a significant seal population with approx. 1000 harbour seals and a few grey seals. The area around Totten is designated as a seal reserve and there is no admittance in the area. Furthermore, the waters north of Anholt are designated as a Natura2000 area for seals (**Figure 2.1**).

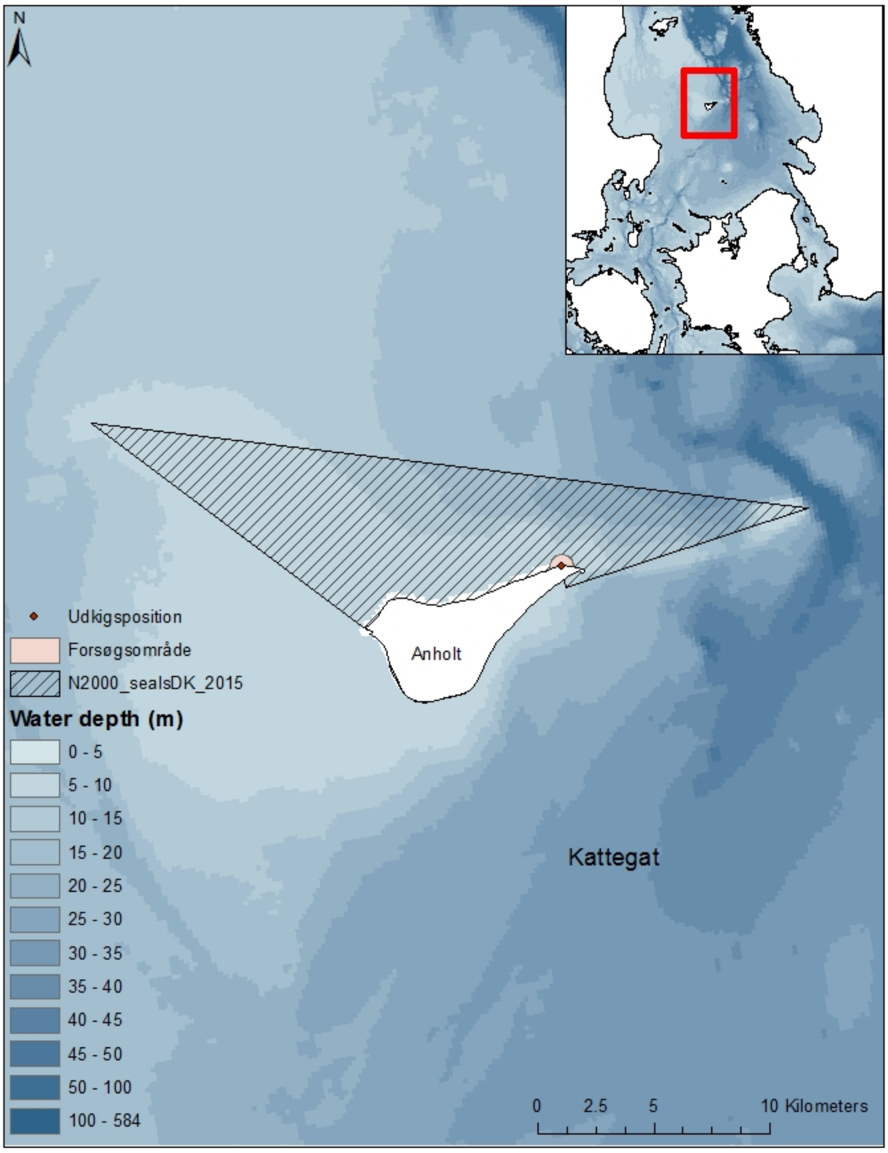

Figure 2.1. Study area at Anholt. The Natura2000 area is designated for both harbour and grey seals.

Seal observations were conducted from the lighthouse, which is located on the northern coast just outside the seal sanctuary (Figure 2.1). The lighthouse is located right next to Fyrgården, where we were lodged (Figure 2.2) and the proximity to the study site helped us to keep constant track of wind and ocean condition.

Figure 2.2. Fyrgården and the lighthouse at the northern tip of Anholt.

The height of the lighthouse allowed us to make observations 40 meters above sea level which provided a very good overview of the waters west of Totten, which is an area where many seals pass on their way back and forth to the haul out site. The position of the lighthouse to the north and hence the study site, meant that the area was relatively sheltered from wind from the south-west, which is the predominant wind direction. The coast is heavily exposed to northerly winds, however, and this was the reason for a several day long break in observations about half way through the field period.

Figure 2.3. View from the lighthouse towards the seal reserve "Totten". The experimental area with the underwater loudspeaker was located outside the picture to the left.

2.2 Location of seals with theodolite

The observations of seals were conducted with a theodolite and associated software Cyclopes. A theodolite is a precision instrument for measuring angles in the horizontal and vertical planes. Cyclopes is a software package designed for tracking whales with theodolite and was easily adapted to the task of locating seals. Calibration of the setup requires that the accurate position and height above sea level of the theodolite is known, as well as the true compass bearing to a reference site. When working at sea, the sea level and hence, the height of the theodolite, will change continuously, so the tide must be monitored by tracking the sea surface at regular intervals, by means of a tide pole. The basis for positioning of an item is based on simple trigonometry. The declination of the theodolite (angle below horizontal) when the instrument points to an object, allows for calculation of the vertical distance from the observation position to the object to be calculated and when also the compass bearing is known, the geographic coordinates of the seal can be determined.

2.3 Tracking protocol

The tracking was conducted from the lighthouse top approx. 40 m above sea level. The setup required a firm mounting for the theodolite, to obtain the exact same position of the instrument every day. This was secured by a flat base made out of wooden planks with three holes, one for each leg of the tripod of the theodolite. All equipment was taken in at night and set up again the next morning. The theodolite was connected to a computer station, to run the associated software Cyclopes.

Two observers were in position at all times during tracking, both equipped with binoculars. This allowed both observers to scan the area, as well as locating seals with the theodolite whenever they were spotted. A protocol of how to scan the area was established and involved scanning the area in three horizontal bands to cover the entire survey area over a period of approx. 2 minutes. A third person was stationed by the computer, categorizing the observations as they came in and taking notes. Hence, three people were required for the observations and a fourth person on standby allowed rotation between the posts every 20-30 min to prevent fatigue and keep observers alert.

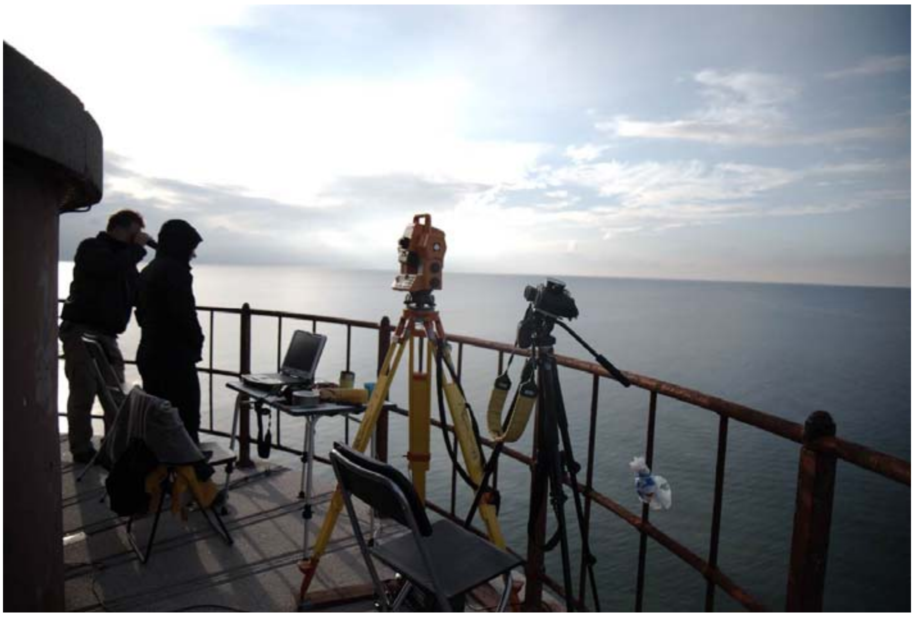

Figure 2.4. Setup in the lighthouse with the theodolite (centre), observation stations with binoculars and a small table with a computer connected to the theodolite.

Before every trial, a 30 minute baseline observation period was conducted. Trials lasted 20 minutes, followed by minimum 40 minutes post-exposure observation after each trial. Initially the trials were conducted as “blind” trials, where a pseudo-random schedule determined whether sound was played or not, to make the observations unbiased by observers expectations on responses. Later on, when the effect on the animals became evident, and it was established that the risk of a bias in the observers distribution of effort was unlikely, every trial was conducted with sound exposure to maximize data collection effort and after it. A minimum of two hours were set from the onset of one trial to the next and a maximum of three trials per day with sound was allowed.

2.4 Acoustic signal

The acoustic signal was a 12 kHz pure tone with a source level of 165 dB re 1μPa pp transmitted from a LL9162 underwater loudspeaker (Lubell Labs, Whitehall, Ohio) with a transmitting sensitivity of 168 dB re 1μPa/1V. The loudspeaker was placed approx. 1.5 meters above sea bottom. The maximal source level of the system was relatively low in comparison to the commercial AHDs (e.g. Lofitech 189 dB re 1μPa peak-to-peak). The visual detection range of seals was limited to 500-1000 m (depending on environmental conditions) and the reaction threshold of the animals to the sound source needed to be within visual range which this setup allowed us using this source level. Furthermore, as the experiments were conducted immediately outside a seal sanctuary and inside a Natura2000 area, a reduced source level was required in order to minimize the impact on seals inside the reserve. The Lubell speaker was set to transmit at 12 kHz, as this is within the frequency range used by most commercial AHD's (10-14 kHz) and because of reasonable omnidirectional transmission characteristics at this frequency (figure 2.5).

A computer with a custom-made program created in Labview (National Instruments, Austin, Texas) program generated a randomized signal (sampling rate 44100 samples/s, stimulus duration 0.5 sec, pause intervals of 600-9000 ms mimicking the behaviour of a Lofitech seal scarer) for a period of 20 minutes. The signal was amplified by a 12 V car amplifier (Earthquake 1000 W) and connected to the loudspeaker through a 300 m impedance matched cable. The system was powered by a 12V car battery.

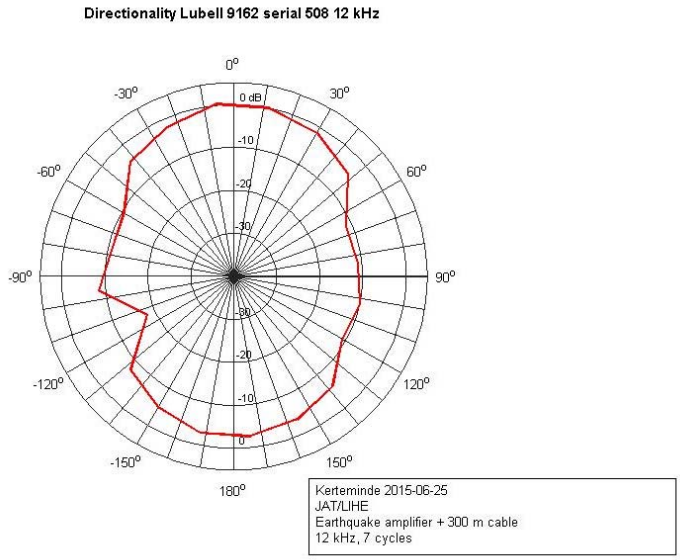

Figure 2.5. Directionality in the horizontal plane of the Lubell loudspeaker at 12 kHz, as measured in a calibration tank in Kerteminde. Received levels were recorded with a calibrated Reson TC4014 hydrophone positioned 0.75 m from the speaker and 0.75 m from the wall of the tank.

2.5 Acoustic monitoring

To monitor the sound transmission and assess possible effects of directionality on the exposure levels of seals, we recorded received levels of the emitted sound at four positions around the speaker with SoundTraps (Ocean Instruments, Auckland New Zealand). Three soundtraps were deployed at an approx. 200m distance from the speaker to the east, west and north of the loudspeaker, respectively. A fourth SoundTrap was deployed 100m to the north. All stations including the loudspeaker had an orange buoy as a surface marker. Two additional dummy stations with surface buoys but without instruments were deployed to provide additional aids for orientation when observing seals and especially to assist in communicating seal positions to other observers.

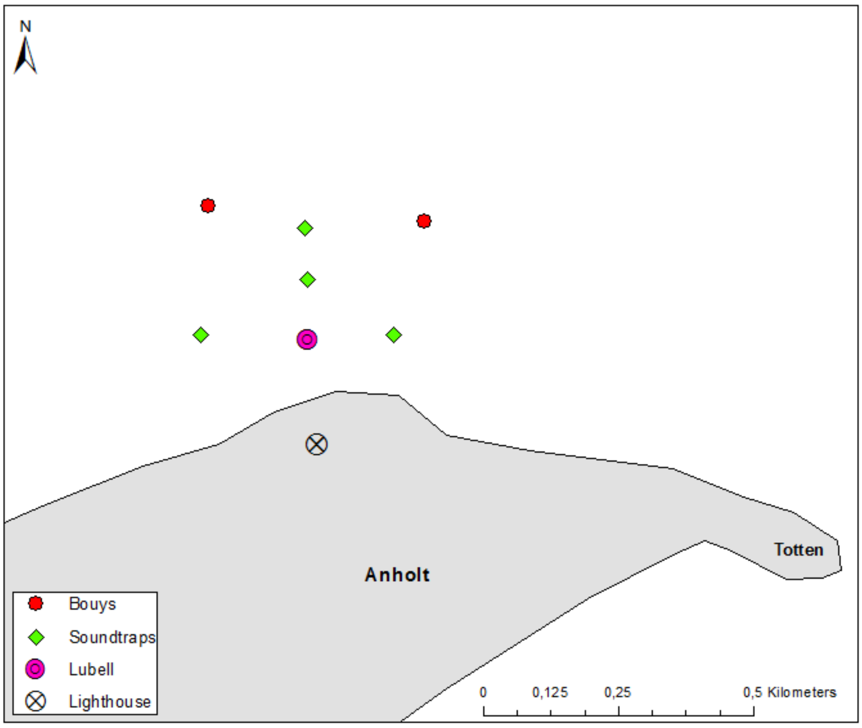

Figure 2.6. Equipment deployed in the study site. All stations were marked with a red surface buoy.

3 Results

The table below lists the activities day by day. A "trial" indicates that a playback was conducted either as a true playback with sound or a “sham-exposure”, where no sound was presented, unbeknownst to the observers. Five days into the study period a strong gale from north damaged the loudspeaker setup and the cable. The following days were spend recovering, repairing, testing and redeploying the equipment, which therefore reduced the number of days for which data could be collected.

Tabel 3.1. Activity schedule during the 20 days field period, the number of conducted trials and of these the amount conducted with sound.

Date	Activity	Number of trials	With sound
01-09-2015	Arrival and unpacking	-	-
02-09-2015	Setup of equipment	-	-
03-09-2015	Deployment and testing of equipment	-	-
04-09-2015	Observations and trials	3	2
05-09-2015	No observations due to bad weather	-	-
06-09-2015	No observations due to bad weather	-	-
07-09-2015	No observations due to bad weather	-	-
08-09-2015	No observations due to bad weather	-	-
09-09-2015	Retrieve, repair and test broken equipment and SoundTraps	-	-
10-09-2015	Re-deployment of loudspeaker setup and SoundTraps	-	-
11-09-2015	Observations and trials	4	1
12-09-2015	Observations and trials	3	2
13-09-2015	No observations due to bad weather	-	-
14-09-2015	No observations due to bad weather	-	-
15-09-2015	Observations and trials	3	1
16-09-2015	Observations and trials	3	3
17-09-2015	Observations and trials	2	2
18-09-2015	No observations due to bad weather	-	-
19-09-2015	Observations and trials. Retrieving equipment and packing	2	2
20-09-2015	Departure from Anholt		
Total		20	13

3.1 Observations

In total 2090 point observations of seals were made over the seven days where observations were possible. The figures below show an overview of the total amount of observations that was made with and without sound. The total observation time without sound was considerably larger than the observation time with sound; therefore many more observations are seen in Figure 3.1 than in Figure 3.2. It appears that more seals were observed in the lower right part of the study site. This reflects that many seals came swimming from the haul-out site at Totten, east of the experimental area.

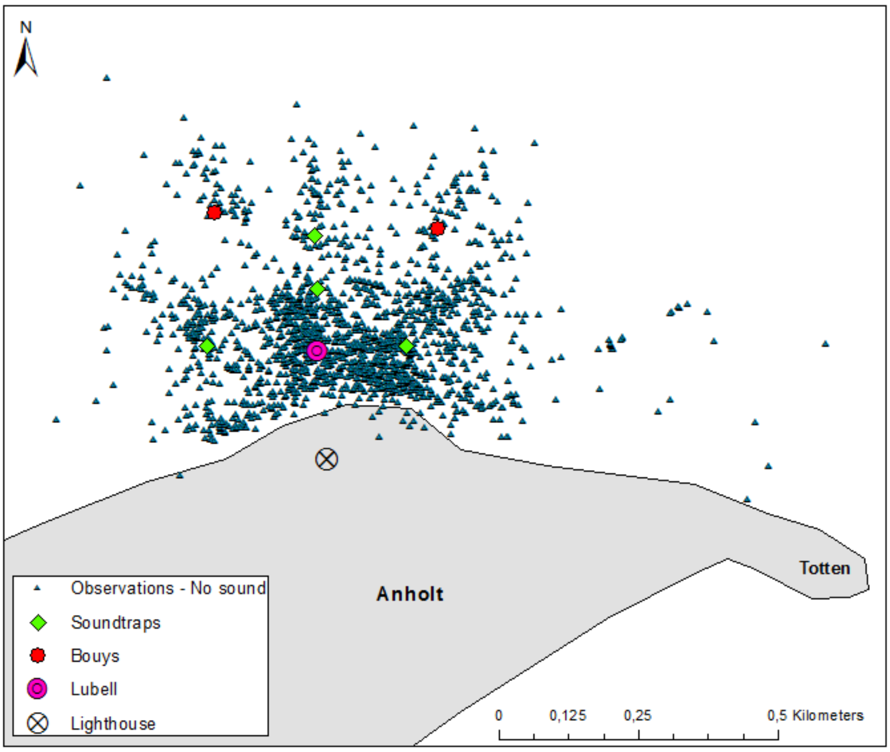

Figure 3.1. The total amount of seal observations of seals when no sound was played. Every dot indicates a spotting made with the theodolite. Sound recordings were made at the stations indicated by green. The loudspeaker was located at the large pink circle (Lubell). Dummy buoys without equipment were located at the points indicated by red dots.

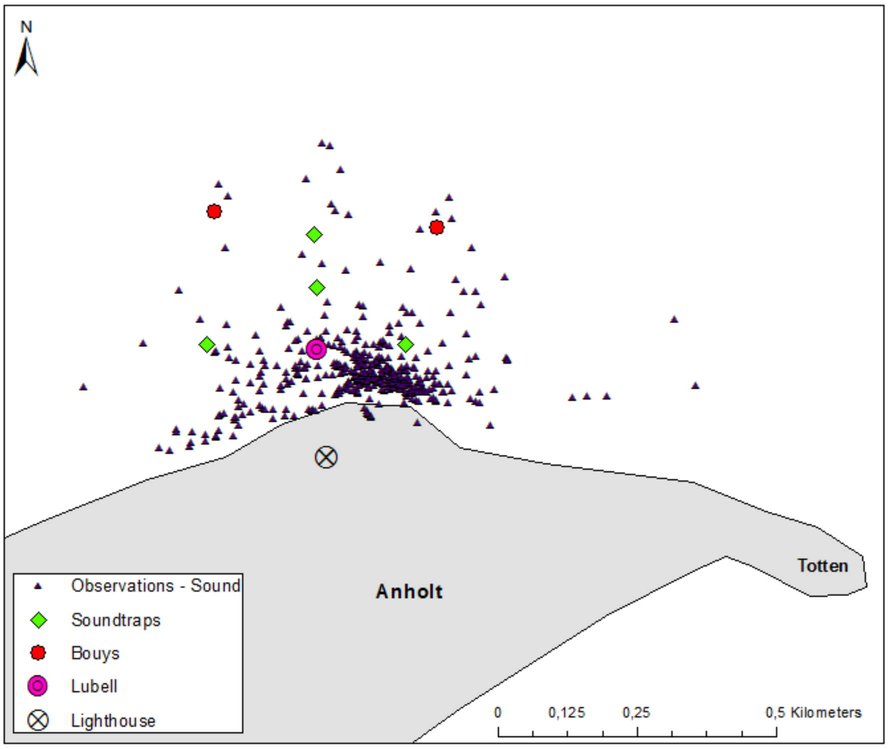

Figure 3.2. Total amount of seal observations when sound was played. Every dot indicates a spotting made with the theodolite. Sound recordings were made at the stations indicated by green. The loudspeaker was located at the large pink circle (Lubell). Dummy buoys without equipment were located at the points indicated by red.

During some of the sound trials, seals were observed very close to the loudspeaker (Figure 3.3).

Figure 3.3. Photo taken during a sound trial. Three seals (black dots) can be seen simultaneously within tens of meters from the loudspeaker (the orange buoy).

3.2 Distribution of observations

Figure 3.4 provides an overview of the observations made at different distances from the loudspeaker. The top three graphs show the number of observations grouped in 50 m distance intervals during the entire survey time, when sound was off and when the sound was on. The graphs illustrate that in the first 50 m around the loudspeaker approx. 150 seals were observed in total (figure 3.4a). Approx. 400 seals were observed between 50 and 100 m from the loudspeaker and so forth. The next two graphs are divided into observations made when no sound was on (sham exposure, figure 3.4b) and when sound was playing (figure 3.4c). It can be seen that more seals were observed closer to the speaker (50-200m) during sound on trials, compared to without sound. To be able to compare the distributions of observations with and without sound better, the observations were normalized. By creating new bins based on 5% percentiles rather than equal distance ranges bins (figure 3.4d), the two can be compared directly. It is seen that at distances between 50 and 200 m, fewer observations were made when no sound was on (figure 3.4e) and more observations were made at the further distances compared to “All observations”. Oppositely, when sound was on (figure 3.4f), more observations were made in the bins closer to the loudspeaker, between 50 and 200 m and fewer further away.

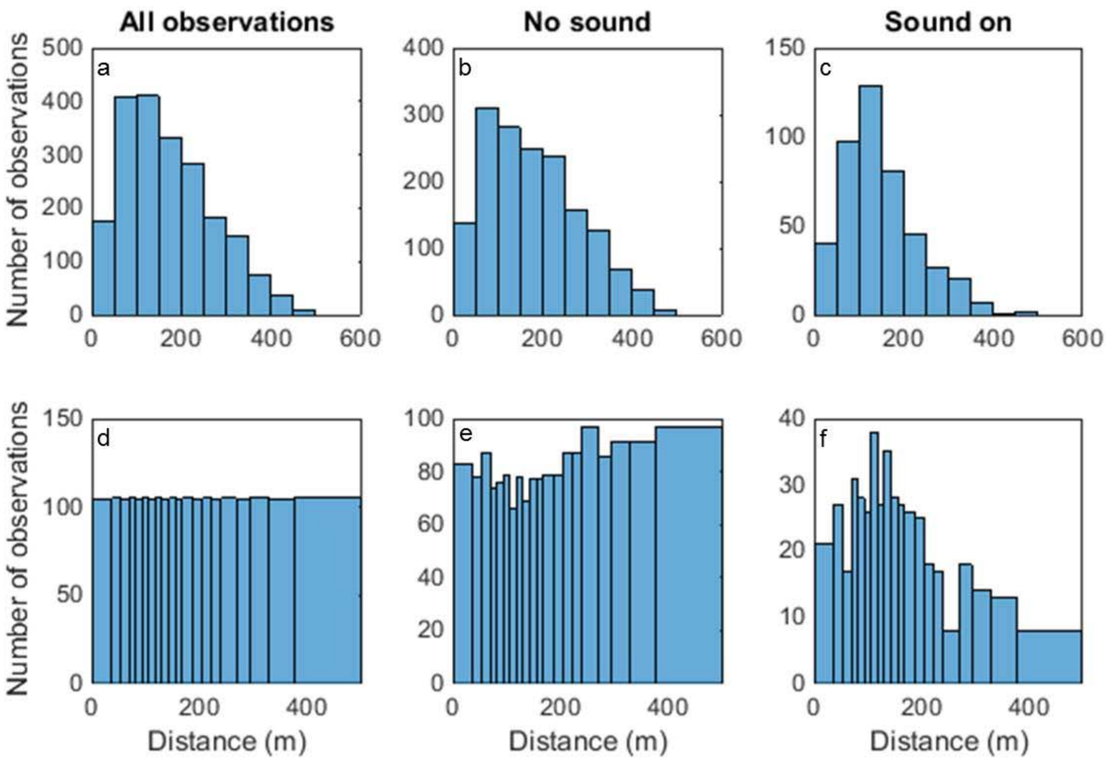

Figure 3.4. Top: The number of observations made in every 50 m distances to the loudspeaker (a), the number of observations when no sound was played (b) and when sound was played (c). Bottom: Normalised levels of observations. Bin intervals determined based on 5% percentiles, i.e. each bin in (d) contains 5% of the observations. Same bin intervals applied to the data with the two scenarios no sound (e) and sound (f). Note that axes differ among plots.

A clear difference appears in the distribution of normalised levels of observations when sound is off or on respectively. Another way of visualising the distribution of the normalised data is to plot the sighting probability per bin (Figure 3.5), where we have calculated the probability of a sighting as the different distances relative to all the observations made in the three different scenarios. The probability of observation is constant at 5% for all observations combined, which is a consequence of normalising into 5% percentile bins, as described above. The probability of seeing a seal increased for distances up to 200 m when sound was on, unlike the situation without sound, where it decreased. The fact that much fewer observations were made at distances further away than 200 m when sound was on may reflect that during sound trials where many seals were observed, we prioritized to track the seals closest to the sound source, in cases when there were too many simultaneous sightings.

The difference in distribution of the two data sets sound versus no sound was highly significant (Kolomorogov-Smirnov, $D = 0.20$, $p < 0.001$). Hence, more seals were seen at closer distances when sound was on compared to when sound was off.

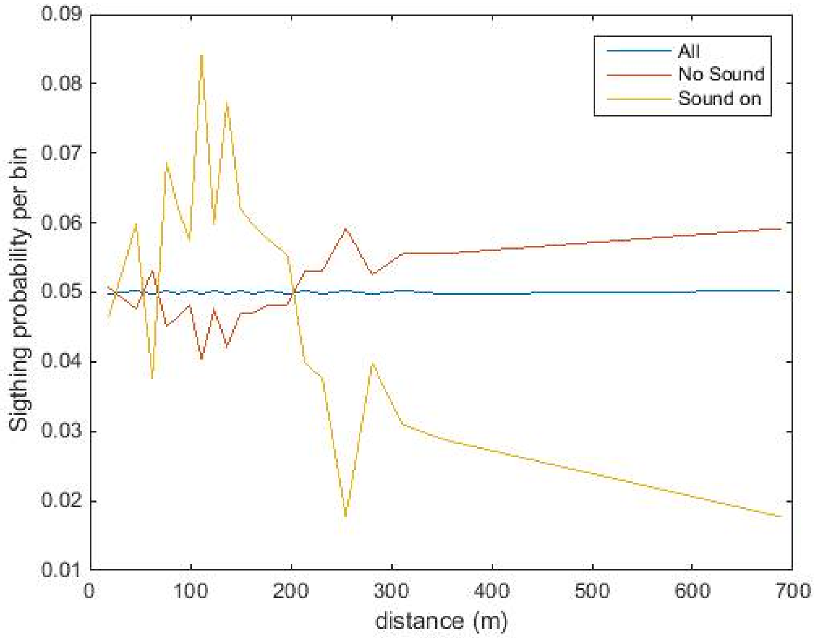

Figure 3.5. Sighting rates under the two conditions sound on and sound off, compared to the overall, normalized sighting probability.

3.3 Sound exposures

The following figure 3.6 illustrates at which distances observations were made 20 minutes prior to sound exposure; during the 20 minutes of sound exposure; and 20 minutes after exposure. Some of the graphs show an obvious attraction of the seals towards the loudspeaker. Trial 24 illustrates a clear example of this. Prior to sound exposure no observations were made at all. Halfway into the trial seals showed up and kept within 300 m distance even after exposure. It is, however, also obvious that the amount of seals occurring in the area varied greatly among trials. Some of the graphs show only very few seal observations both, before, during and after sound exposure.

Figure 3.7 illustrates the observations made before, during and after the "sham" exposures. A "sham" meant that a regular trial was conducted according to the observation protocol, but no sound was played from the speaker, unbeknownst to the observers.

To test if the general visual impression of seals being attracted to the study area during sound exposures holds true, we made a pairwise test of the number of observations made in the three 20 minutes scenarios against each other, before versus during exposure, during versus after exposure and before versus after exposure. The test statistics can be seen in Table 3.2. We found a significant difference between number of seals observed before the sound was turned on and after it was turned off, i.e. between the baseline and the post-exposure periods. Hence, significantly more observations were made after the sound was turned on compared to before sound exposure. The reason why we did not find a significant difference between before versus during sound exposure, even with a large difference in mean, is probably the large variation in the data, which is obvious from the large variation in the amount of observations as seen in fig. 3.6.

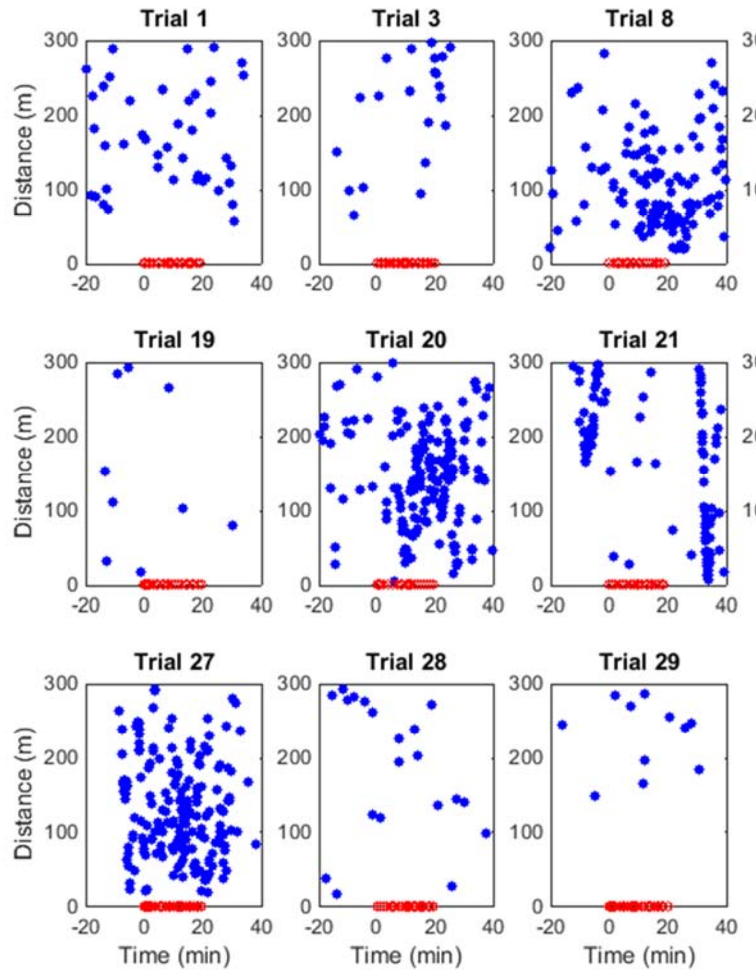

Figure 3.6. The number of seal observations made 20 minutes prior to sound exposure, 20 minutes during exposure and 20 minutes after exposure. Every blue dot marks an observation. Red dots indicate sound exposures.

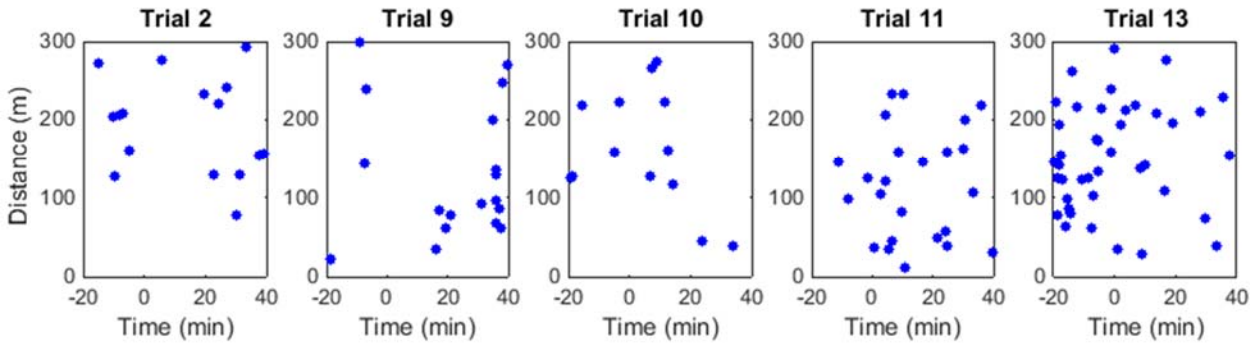

Figure 3.7. The number of seal observations made 20 minutes prior to “sham” exposure (no sound trials), 20 minutes during “sham” exposure and 20 minutes after. Every blue dot marks an observation.

Table 3.1. Results from the pairwise t-test conducted on the amount of observations made before versus during exposure, during versus after exposure and before versus after exposure. Asterisks indicate significance.

	Before	During	After
Mean	18,308	32	34,154
T-test	**Mean Diff**	**t**	**p**
Before vs. During	13.69	-1,545	0.148
Before vs. After	15.85	-2,518	0,027*
During vs. After	2.15	-0,321	0,754

To test for a difference in the distances of the observations, we pooled all the distances together for each of the three scenarios, before, during and after. To remove the skewness and make the data normally distributed, we made a square root transformation. To test for difference in means we applied an ANOVA and to test which groups was different from each other a Turkey's post hoc test was used. The results are shown in Table 3.3.

We found a significant difference in the distances observed between the three groups (ANOVA, $p < 0.001$). From the post hoc test we see that the distances observed before sound was played is significantly higher than both during sound (Turkeys, $p < 0.001$) and after sound (Turkey, $p < 0.001$) was played. Hence, seals were observed closer to the loudspeaker during and after exposure compared to before exposure.

Table 3.2. Test statistics from the ANOVA and following Turkey's post hoc test between the group distances of seal observations before, during and after sound exposure.

ANOVA	**Df**	**Sum Sq**	**F**	**p**
Group	2	1241	40.32	<0.001
Turkey post hoc	**Diff**	**Lower**	**Upper**	**p**
Before vs. After	2.57	1.83	3.31	<0.001
During vs. After	-0.02	-0.65	0.61	1.00
During vs. Before	-2.59	-3.34	-1.84	<0.001

To test if there was a significant difference between the 13 different exposures, we applied the ANOVA test again, but with exposure as an additional factor. As can be seen in table 3.4 below, there was no difference between exposures.

Table 3.3. Test statistics from the ANOVA, using both the group distances of seal observations before, during and after sound exposure and the 13 exposures as factors.

ANOVA	**Df**	**Sum Sq**	**F**	**p**
Group	2	1241	40.32	<0.001
Exposure	1	18.6	1.21	0.27

4 Discussion

This study demonstrated that the number of seals closer to the loudspeaker was higher during sound exposure trials compared to baseline observations before the sound was turned on. We tested if more (or less) seals were observed before, during or after sound trials and found that significantly more seals were spotted in the first 20 minutes following sound exposure compared to the 20 minutes before sound exposure. The seals were also observed significantly closer to the loudspeaker during the 20 minutes of sound exposure and 20 minutes afterwards, compared to the baseline immediately before sound exposure. It thus appears that seals were attracted to the sound rather than being deterred from it.

We had several observations within 50 m of the loudspeaker during playback. Seals were observed at some instances to be less than 20 m away from the loudspeaker during sound trials. When seals were observed they had their heads above water and thus were not exposed to the sound, but none of the seals were observed to swim with their heads constantly above water, hence, these seals must have been exposed more than once to the sound at very close distances. Most of the seals, however, were found between 50 and 200 m from the loudspeaker.

It should be noted, that not all observations were possible to record with the theodolite. At some occasions, many seals were spotted simultaneously, which meant that it was impossible to record all of them. However, we presume that this loss of observations was spread out equally across all distances to the loudspeaker. It is obvious from the observational data, that fewer seals were tracked further away. During sound trials it was a conscious choice to track the seals that was closest to the loudspeaker if several seals were seen simultaneously, to get an estimate of the reaction distance. Still, during the "sham" exposures (sound trials without sound), no bias was found in the observations, supporting the assumption that there was no bias caused by unconscious expectations by the observers.

The aim of the experiment was to determine a deterrence distance of the seal scarer signal, but this is obviously difficult to do from the results, as the sound had the opposite effect of what was expected. A 12 kHz signal with a source level of 165 dB re 1 µPa pp was thus not sufficient to scare the seals out to any significant distance. This result can be compared to the rather mixed results from other, previous studies on the effect of seal scarers on seals in the wild. Götz and Janik (2010) found a deterrence range of 40-60 m, when emitting sounds from different seal scarer devices (Lofitech, Airmar dB II plus, Ace-Aquatech) towards grey seals, with a source level of 172 dB re. 1 µPa rms . Jacobs and Terhune (2002) found no significant reaction towards a seal scarer (Airmar db II plus) with source level of 178-179 dB re 1 µPa pp. Most seals were observed around 200m from the seal scarer, but a few were observed approx. 45 m away. At the opposite end of the spectrum, Hall et al. (2014) found reaction distances between 350 and 1000 m when exposing GPS-tagged harbour seals to a Lofitech seal scarer with source level of 189 dB re 1 µPa rms. It is difficult to compare these studies directly with the study presented here, as they differ with respect to method, context and sound types / levels (see also review by Mikkelsen et al. 2015). However, the source level used by Hall et al.

(2014) was obviously much higher explaining the much larger reaction distances, but the method (GPS) used was also more sensitive in detecting reactions from the individual seals. The other two studies reveal much shorter reaction distances, which is more in line with the results found here, also because they used much lower source levels. However, none of these studies described the attraction of seals towards the sound source as seen here. There is, however, a potential bias in the observations due to the fact that seals could not be followed under water. Kvadsheim et al. (2010) thus showed that hooded seals exposed to a very powerful sonar signal spent more time in the surface than during baseline observations, meaning that the seals were much more visible. There is no doubt that the seals reacted to the sound. They spent more time with their head high out of the water and oriented themselves towards the location of the speaker, as if trying to visually identify the source of the sound. The very large increase in seals, gradually over the duration of some sound exposures is not consistent with this explanation as the only explanation. If this effect was the predominant explanation behind the increased number of observations one would expect that the number of seals increased dramatically by the time the first few signals were played and then followed by a gradual disappearance of seals from the area. The picture was the opposite, with a gradual increase in numbers and decrease in distance to the loudspeaker, consistent with an attraction to the source. This is in line with other studies from Sweden, testing the deterrence effect of AHD on seal behaviour around fishing gear, and more specifically the so-called dinner-bell theory. This theory stipulates that seals learn to associate AHD sounds with areas with fishing nets, i.e. favourable feeding areas (Königson et al. 2007) and thus actively seek locations where seal scarers are deployed. Such a dinner bell effect is unlikely to have played a role in the results presented here, however as there was no food reward associated with the sound. In four out of five occasions in the study of Königson et al. (2007), seals approached the AHD when tested at a site without any fishery. This was however, in an area where AHDs were commonly used, and seals were used to associate AHD sounds with food. This is unlikely to be the case around Anholt, but more likely a sign of curiosity. This is supported by the observation that seals appeared to gradually move closer to the loudspeaker over the course of each playback session.

5 Conclusion

The goal of this study was to determine the deterrence distance of simulated seal scarer (AHD) sound on seals around the island of Anholt in Kattegat, Denmark. The results were contradictory to expectations, in the sense that seals were not deterred by the sound. Rather it appeared that the sound elicited a curiosity in the seals and that they gradually moved closer to the loudspeaker during sound exposures, as seals in the study area in general were found closer to the loudspeaker when the sound was on compared to when the sound was off. Thus, significantly more seals were observed just after sound trials compared to before and seals were observed closer during and after sound trails compared to before.

This type of experiment has never been attempted on seals before. As stated in the beginning, only very few field studies have tested the effect of seals scarers on seals, that was not related to a fishery and foraging site. Based on the results obtained here, it is obvious that a source level of 165 dB re 1 µPa pp is not high enough to scare seals away. This has important implications for the use of seal scarers as mitigation devices in connection to for example pile driving and underwater explosions, where the aim of the seal scarer is to deter animals out to safe distances before the potentially injuring noise exposure occurs. Although the seals appeared to spend more time in the surface, which also provides protection against loud noise and to a lesser degree blast injury from explosions, the mere fact that they remained close to the sound source would also mean that the risk of unintentional exposure to dangerous noise levels is present in a real pile driving or during an underwater explosion. This result is in stark contrast to the situation for harbour porpoises, which although they have a hearing sensitivity comparable to harbour seals in the frequency range of the seal scarer, display a much stronger and negative reaction to the seal scarer sounds (Hermannsen et al. 2017). This means that the current seal scarers may not be ideal as mitigation devices in situations where both harbour seals and harbour porpoises are present, as the levels needed to deter seals may lead to unwanted large exclusion zones for harbour porpoises. See also (Mikkelsen et al. 2017).

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THE EFFECT OF SIMULATED SEAL SCARER SOUNDS ON SEALS

Seal scarers are used to deter seals from fishing gear, but also at underwater construction sites, in order to protect the seals against potentially injuring noise exposure. A study on the effectiveness of seal scarers was conducted on Anholt. Seals were exposed to seal scarer sounds at reduced sound pressure levels. Contradictory to expectations, results show that seals were observed closer to the loudspeaker when sound was played, compared to baseline and significantly more seals were observed just after sound was played compared to just before. Hence, the reduced sound source appeared to attract the seals instead of deterring them.

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