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Report

Testing the hypothetical reasons for inappropriate responses to the candidate mechanisms for the unexplained seal deaths

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1 Executive Summary

The primary aim of this investigation was to establish whether the acoustic properties of ducted propellers had an attractive quality to seals. Ducted propellers were identified as a candidate, causal mechanism for the unexplained seal deaths in Onoufriou & Thompson (2014). However, the means by which a seal would come into contact with a propeller remain unclear. The hydrodynamic qualities of a ducted propeller mean that seals must be voluntarily swimming to within a few metres for an unavoidable collision to occur.

Sound exposure experiments were carried out on both harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) in both wild and captive situations. Target seals were exposed to recordings of ducted propellers, open propellers and harbour seal mating calls.

In the wild, seal responses were monitored with active sonar to detect any approach to the sound source. In the captive trials seals choice of feeding location and behaviour close to and remote from the sound source were monitored using video recordings.

No response was detected by any seal to the exposures. In the wild, no seals approached the speaker and with the captive seals the primary drivers appeared to be feeding rather than exploration of the sound producing device. Even with the removal of the feeding stimulus, no behavioural response as a direct result of sound exposures was observed.

If ducted propellers are a cause of the spiral injuries in seals then the results of this study would suggest the manner by which the interaction occurs is not the result of an acoustic attraction. The stranding of a grey seal test-subject with spiral lesions two days after release from the captive facility indicates either (a) at least one individual was susceptible to the attractive qualities of ducted propellers and those qualities were not replicated in this experiment, or (b) that acoustic signals are not involved in attracting seals to the mechanism causing the spiral lacerations.

2 Introduction

It was argued in Thompson *et al*., (2015) and in Onoufriou & Thompson (2014) that interactions between seals and ducted propulsion systems on medium to large vessels could be the primary cause of the spiral lesions (Onoufriou & Thompson, 2014). However, these are still relatively rare events and both the geographical and temporal distribution of spiral lesion carcasses suggest that this is not a simple random process whereby any seal has a set probability of being hit by any vessel it comes close to. In such circumstances the carcasses might be expected to represent a random sample of the age, sex and species structure at any particular site but in practice there appears to be strong species, sex, age and geographical selectivity.

Patterns of flow around ducted propellers (Onoufriou & Thompson, 2014) clearly show that there is no appreciable acceleration of flow into the duct at ranges of more than a few metres, i.e. at ranges equivalent to 1-2 propeller diameters from the nozzle. Although the flow pattern immediately in front of the propeller duct may be complex, the average rate of flow will fall off approximately in proportion to the square of distance from the duct. This suggests that a conscious seal would not be sucked into the device from a great distance and would therefore have to voluntarily approach to within 2-3 metres for a fatal interaction to occur.

It is not known what would cause seals to approach spinning propellers. To date only two plausible mechanisms of attraction have been proposed; concentration of food close to the vessel could attract seals and lead to them inadvertently approaching too close to the propeller, or some form of inappropriate attraction to the acoustic signal from the propeller itself may be operating.

Fish are known to aggregate under both moving and stationary vessels in deep water (Røstad *et al.*, 2006) but there is no published information on aggregations around vessels in shallow water. The prey concentration hypothesis requires that prey aggregate close to ships and that seals are aware of and can exploit such aggregations. The distribution of seal carcasses in south-east Scotland described in Thompson *et al*., (2015) shows very clear temporal and spatial segregation of strandings of the two species. In summer when the strandings in St Andrews Bay and the Tay and Eden estuaries are almost exclusively harbour seals, the local harbour seal population is greatly outnumbered by the local grey seal population at nearby haul-out sites. This strongly suggests that the mechanism is highly selective and it seems unlikely that food concentrations attractive to harbour seals would be ignored by the more numerous grey seals.

In fact, given that hearing will be the primary sensory modality that seals use to locate such vessels at long range it is likely that acoustic attraction would, to some extent, be involved in both scenarios. Ducted propellers of the size required to inflict such injuries are likely to produce extremely loud, broadband noises so any approach would entail swimming up a noise gradient and involve closely approaching an unpleasantly and possibly painfully loud sound source.

Here a report on work to investigate seal responses to propeller noise is presented. Behavioural response trials have been carried out on both captive and wild grey and harbour seals to ascertain whether the acoustic signal of ducted propellers acts as an attractive mechanism.

3 Acoustic response field trials

In July 2013 a series of behavioural response trials were carried out with wild, free ranging harbour seals to assess their response to a range of visual and acoustic signals. The seals' responses were monitored using a combination of visual and sonar observations.

3.1 Methods

Wild, free ranging adult and juvenile harbour seals were exposed to sequences of sounds as they swam around coastal sites in the Sound of Sleet and Kyle of Lochalsh, on the west coast of Scotland (Figure 1). Five study sites were chosen based on their relatively high abundance of seals. Four locations contained both juvenile and adult harbour seals and one location at the south end of the tidal narrows at Kyle Rhea contained only juveniles.

Four sound treatments were tested at each site: 1) ducted propeller sounds, 2) open propeller sounds, 3) conspecific calls, and 4) a period of silence as a control. Ducted propeller sounds were recorded from a large tug boat (450 tonne, 34m vessel with twin azimuth thrusters) and open propeller sounds were recorded from a fisheries patrol boat (1385 tonne, 73m vessel with variable pitch twin screw propellers) using an HTI-96-MIN hydrophone (High Tech Inc.) and a Tascam DR-40 LINEAR PCM digital recorder. Both vessels were recorded making a series of fast and slow passes and turning manoeuvres. The conspecific calls were recordings of adult male harbour seals display calling during the breeding season. These calls comprised a gradually increasing rhythmic pumping noise lasting 8s to 10s that merged into a white noise roar lasting a further 8s to 10s followed by one to four loud crashing sounds. The total call lasted 16 to 20s and was repeated at approximately one minute intervals. A single sequence comprised 30 minute blocks of the three sounds and the control silence with a 5 minute silence period between each treatment. Each sequence therefore lasted 140 minutes.

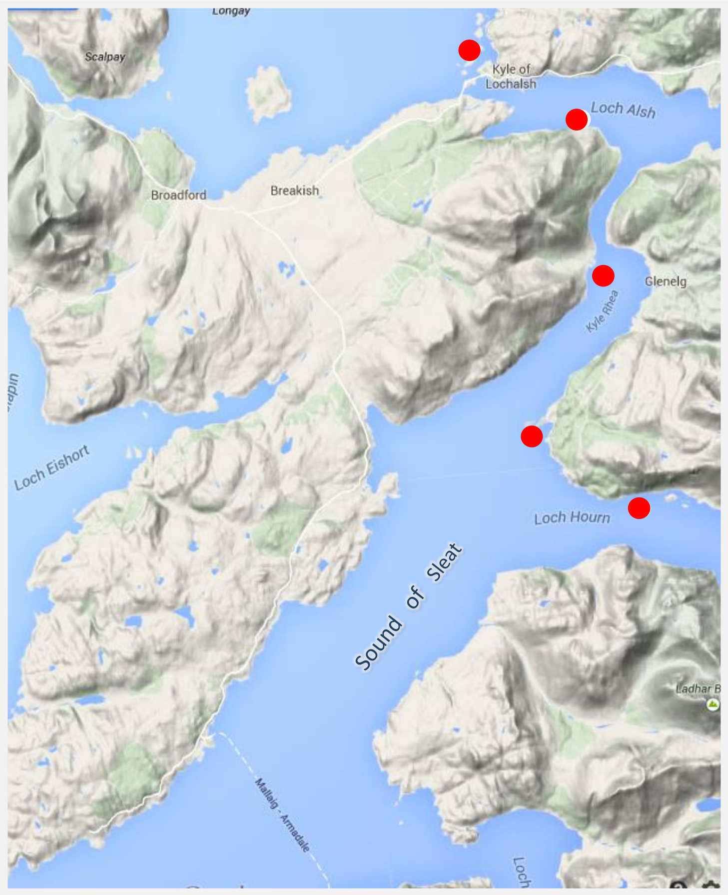
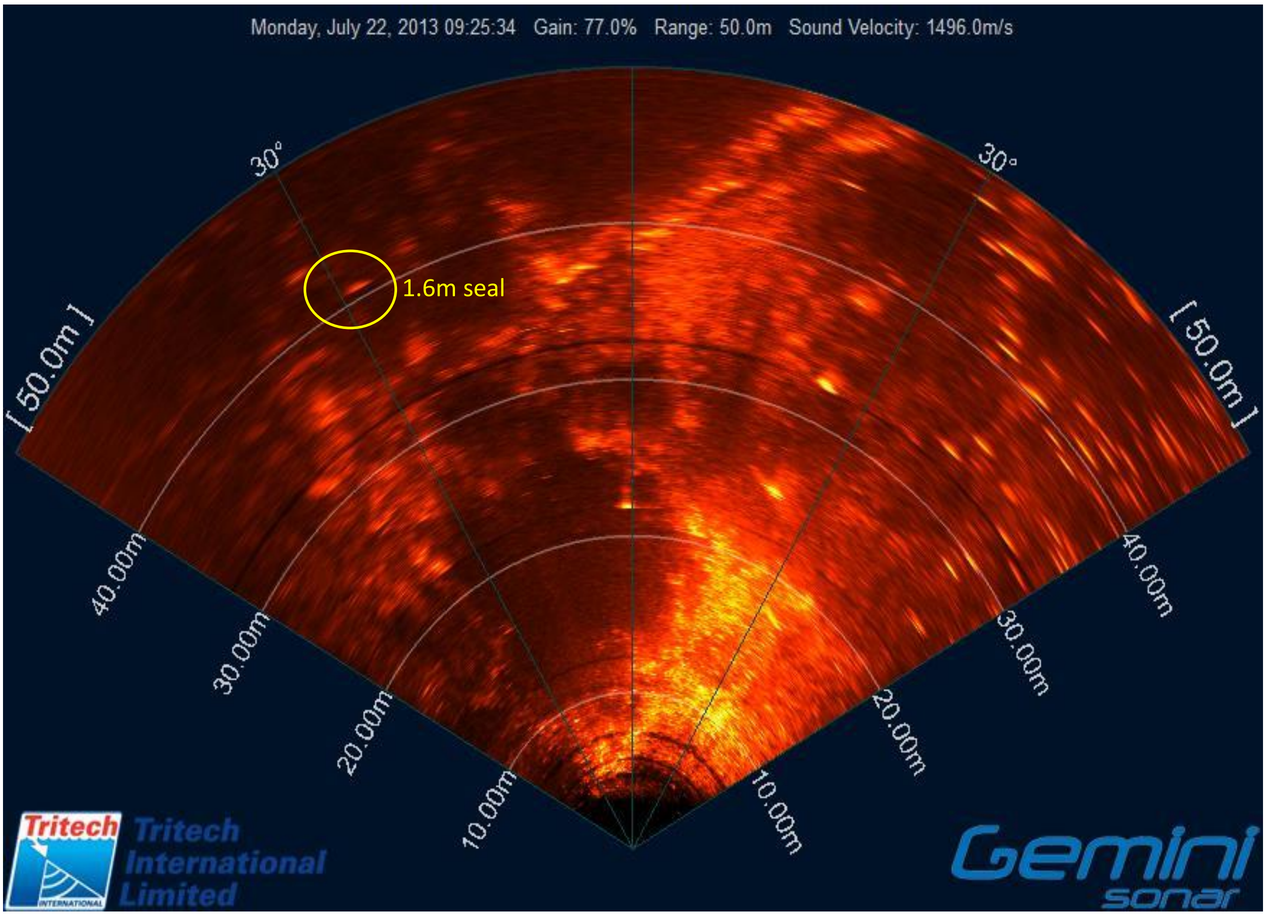


Figure 1: Locations of study sites

The acoustic signals were transmitted through a J11 speaker (30 Hz – 10 kHz; > 160 dB re 1µPa Peak) suspended 2 metres below a small inflatable dinghy that was moored in water approximately 10m deep. The speaker was driven by a 1000w 12v power amplifier (Sony XM2200GTX) and signals were played from the Tascam DR40 solid state recorder operated manually from the dinghy.

An observation vessel, in this case a 6m RHIB, was moored 20m from the playback vessel. Distance was maintained by tying the boats together with a 20m line that was kept taught by allowing the playback vessel to drift with wind or current. Underwater seal activity in the vicinity of the speaker was recorded using a TriTech GEMINI 720i multi-beam sonar system. This provided reasonably good resolution imagery of the water in a 120^{o} arc out to a range of 50m. The vertical beam width was approximately 20^{o} so that the image at a range of 20m represented all objects within a depth range of approximately 0.5 to 4m.

The sonar was tested by pointing the beam towards a group of foraging seals in a fast moving tidal stream. Surface seal movement was visually determined by two independent observers, while a third party confirmed this movement on the sonar image (Figure 2). In most cases the seal sonar image was very faint at the surface but became more visible as soon as the seal dived. A combination of the size and movement pattern relative to background scatter meant that seals were readily identifiable, allowing identification of any seals that approached to within 50 metres of the sonar across the entire 120° field of view.



Monday, July 22, 2013 09:25:34 Gain: 77.0% Range: 50.0m Sound Velocity: 1496.0m/s

Figure 2. Screen-shot of a sonar image showing a seal detected at >40m range. Size and movement was used to differentiate seals from fish and flotsam. Approximate seal length is given.

At each site the sonar boat was anchored and the playback boat was tied to it so that it drifted under the influence of the current or wind to a range of 20m from the sonar. Set up took approximately 20 minutes and then the sequence of sounds and control period was played twice i.e. two iterations of each treatment group lasting 280 minutes in total.

Seals were observed swimming around the study areas prior to each set of exposures. At four sites some individuals were hauled out when the playback vessels arrived. The playback vessels were set up at a sufficient distance to avoid causing the hauled-out animals to startle and enter the water. All seals at the study site were clearly aware of the presence of the vessels and the observers. Visual awareness of the set-up was assumed not to be confounding as any seal approaching a vessel with an operating propeller would also, presumably, be visually and acoustically aware of its presence.

3.2 Results of trials in the wild

No seals were observed to react to the sound exposures either by directly approaching or by swimming away from the speaker. Observations of seals at the surface outside the range of the sonar also showed no sign of obvious movement either towards or away from the playback vessel. Seals in each case continued to move around and through the area but did not appear to pay any attention to the observers. However, by the end of each session, all animals had left the study area.

4 Captive animal trials

4.1 Captive behavioural response trials

Behavioural response trials were carried out with captive grey and harbour seals at the SMRU captive seal facility in February and March 2014, using the same suite of acoustic signals as used for the wild trials described above.

4.2 Methods

Six juvenile grey seals (3 male and 3 female) were caught on the breeding site at the Isle of May in December 2013 and transported to the facility at St Andrews. Seals were held in a secure compound with free access to two circular sea water tanks, 3.5 and 5m diameter and 2.5m deep. Once acclimatised to the facility seals were introduced to a test tank that consisted of a 40m x 6m x 2.5m (length:width:depth) pool. A graphic of the experimental layout can be seen in Figure 3.

Two automatic feeding devices were placed at the corners furthest from a haul-out chamber. Each feeder consisted of an aluminium box with an access port approximately 2m under water. A motorised belt, loaded with fish at intervals of approximately 50cm, delivered the fish to the underwater access port.

In each trial the belt was loaded with 2 kg of sprat. The belt speeds on the feeders were set to a constant value to provide an equal food delivery rate for each trial.

The haul-out chamber had a square breathing hole which could be opened and closed from the surface to control the seals' access to an underwater cage. The cage had a gate which could be opened and closed from the surface to control access to the rest of the pool. Aluminium panels were placed over the surface of the pool to restrict surface access; the seals therefore were only able to surface at the breathing hole. A subsurface vertical panel ran along the length of the centre line of the pool with a gap in the centre that gave the seal access to the feeders. This arrangement ensured that irrespective of its behaviour in the vicinity of the breathing chamber, a seal would have to pass through a narrow gap that was equidistant from the two feeders.

An underwater speaker housed in a plastic box and a dummy speaker in an identical box, were placed at opposite ends of the pool on the opposite side of the sub-surface panels, but close to the feeders (Figure 3). A dummy speaker was used to ensure any reaction to the acoustic signal was caused by the sound and not the presence of the device itself. The seals' behaviour was monitored using 8 live camera feeds (Figure 4) overlooking the dummy speaker, the real speaker and the two feeders and inside the haul-out chamber. All camera feeds were monitored and recorded by an observer in a separate room to the operator of the sound source.

Two additional observers were positioned at ground level on the pool edge to record any movements outside the visual scope of the cameras.

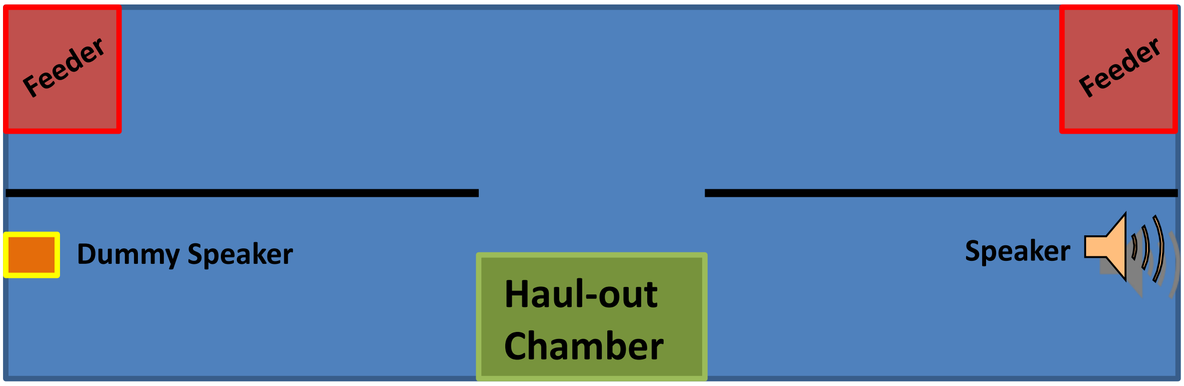


Figure 3. Experimental set-up for final playback trials. The haul-out chamber consisted of a sub-surface cage which could be opened and closed to provide selective access to the rest of the pool. The black lines indicate the panels which restricted direct access to the feeder ensuring a firm choice had to be made. Surface panels prevented surfacing in any location other than the haul-out chamber to ensure all discrete dives could be recorded.

The playback system consisted of a Lubell 9484 piezoelectric underwater loudspeaker (200Hz – 20kHz). The playback files were played from a Tascam DR40 solid state recorder via a 1000w 12v power amplifier (Sony XM2200GTX). A maximum broadband source level of 147db re 1uPa at 1m from the speaker was used to ensure the potential for temporary threshold shift was limited. The output from the speaker was calibrated before the experiment to set the source levels. Across a 54 minute trial period (average time of trial given average dive time of approximately 3 minutes), this maximum source level would produce a maximum cumulative exposure level of 183 dB re 1uPa if the animal spent the entire trial period only 1m from the sound source (Kastak *et al.*, 2005). In practice no seal spent more than 2 minutes at the feeder on any dive, so cumulative exposure levels were well below this level.

Each individual was introduced to the set-up and allowed to explore the pool before the trial period began. During this introduction period the pool contained all of the experimental apparatus.

Figure 4. Example of a feeder approach (left) and an exploratory dive around a camera (right).

Once an individual was settled into the set-up the first signal (chosen at random) was initiated only once a dive had begun. A dive was defined by any sub-surface behaviour lasting longer than 20 seconds. Any sub-surface period lasting for less than 20 seconds resulted in the same signal being used on the next dive, i.e. the signal was halted on surfacing and then re-started when the animal submerged again.

Each signal dive was followed by a silent control dive. The signal was halted when the seal surfaced at the end of a dive, and the next signal or silent control was initiated when the seal submerged at the start of the next dive. Each trial lasted 36 dives with 6 blocks of 6 dives (3 sound exposures and 3 silent controls). Signals were played in random order within each block.

Camera set-ups allowed observation of approaches to feeders and speakers while pool observers could discern near-surface movements. Continual qualitative records with associated times were kept for all movements during dives which could be cross-referenced to time-stamped video images.

- Animals were scored for response based on proximity to the speakers and behaviour around the feeders.
- A non-response was classified as any dive in which the animal either did not use the feeder or did not swim to within ~2 metres of the speakers.
- Positive feeding response was scored as any observed feeding event or attempted feeding event at a depleted feeder.
- Positive reaction to the sound source was scored for every direct approach to the speaker to within 2 metres.
- Positive reaction to the dummy speaker was similarly scored as any direct approach.
- A score of 1 was allocated for swimming directly towards the speakers while a score of 2 was allocated for any “close exploration” to the speakers i.e. touching their muzzle or flippers to the surface panels immediately below.

4.3 Results

A total of 540 dives were recorded from five seals; one seal did not leave the haul-out chamber during any trials and so no dives were recorded.

Throughout the trials no reactions to the acoustic signals were observed. In all cases animals began feeding, depleted both feeders of fish and then began to explore the rest of the experimental set-up. There was no evidence to suggest preferential use of the feeder associated with the speaker or the dummy speaker.

There was no evidence to suggest preferential exploration of either the speaker or dummy speaker, over the remainder of the experimental set-up. While two animals were observed touching their muzzles to the surface panels immediately below the speaker this was also seen at the dummy speaker and this behaviour always occurred during dives where the same behaviour was seen in other parts of the pool which had no visual or acoustic stimuli associated with them. The same behaviour was seen to occur during exposures of different sounds (including the control treatment) so no response to any specific acoustic cue was evident.

5 Discussion

The apparent lack of response to any of the acoustic signals by any of the seals tested in both the wild and captive situations suggests that an inappropriate response to noise is unlikely to be the main reason of attraction to the causal mechanism.

The absence of a reaction to the sound exposures may indeed be a result of playing signals which are of no attractive interest to a seal. Given the relatively rare nature of spiral seal strandings, as demonstrated by the sporadic nature of the reported cases, the propellers involved with the interactions may have a specific acoustic property that was not represented by the sound source being played. Further acoustic trials would be necessary with a wider array of ducted propeller sounds to ascertain whether this is the reason or whether acoustic attraction is not the cause of these interactions.

The absence of a response to conspecific calls by adult and juvenile harbour seals is puzzling. Male harbour seal vocalisations have been shown to attract other competing male seals during the breeding season and are thought to attract breeding females. No such responses were observed during playbacks that were timed to coincide with the expected peak in mating activity.

One of the grey seals involved in the captive playback experiments was found dead with characteristic spiral lacerations only two days after release from the SMRU facility. This seal did not respond to any of the acoustic signals during the play backs. This strongly suggests that whatever the attraction is, it was not clearly replicated in these experiments or that the context in which the stimulus is played was somehow negating its attractive properties.

This case was of particular interest because it provided a unique opportunity to pinpoint a time of death with greater accuracy than any previous cases and coincided with a period of low ship activity. Only one candidate vessel which could have been involved in an interaction was identified (see Jones *et al*., 2015) and this vessel was tracked by AIS passing several kilometres offshore. No other vessels were recorded in the vicinity. If this vessel was involved and if its acoustic signal was the primary attraction leading to a fatal interaction it poses the following questions:

- Why was this response not observed in the captive trials which involved this individual?
- Is the acoustic signal different enough between vessel types to elicit different responses?

Clearly it could be that the signals used or the context in which they were presented were incorrect and failed to elicit a response. However, given the apparent absence of reaction to any of the signals played to the seals it must be concluded that an inappropriate positive response to an acoustic signal is unlikely to explain why seals would swim directly towards such devices.

6 References

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