RESEARCH PROJECT: "BEHAVIOURAL RESPONSE OF AUSTRALIAN HUMPBACK WHALES TO SEISMIC SURVEYS (BRAHSS)"

Submission to: Senate Standing Committees on Environment and Communications, inquiry into the Impact of Seismic Testing on Fisheries and the Marine Environment.

Summary

1. BRAHSS was a research project aimed at understanding the behavioural response of humpback whales migrating along the Australian coasts to various sizes of seismic air gun arrays, including a full commercial array.
2. Short-term changes in behaviour of migrating humpback whales exposed to seismic air guns were found. These were changes in dive behaviour, movement behaviour (making less progress southwards) and social behaviour (less likely to socialise), though no abnormal behaviours were observed.
3. Changes in movement behaviour resulted in groups avoiding approaching the seismic array. This was more likely to occur if groups were within 3 km from the array and exposed to received levels over 140 dB re 1 μPa^2.s (SEL: Sound Exposure Level).
4. This tendency to avoidance suggests that the use of ramp-up or soft start to manage impacts on the whales, is likely to be effective. Ramp-up involves a gradual increase in sound level over 20 to 30 min with the intention of allowing the whales to move out of the way before the highest noise levels are reached.
5. Simulations using information determined in the experiments indicated that changes in movement behaviour will likely result in migrating groups experiencing a small delay in returning to the feeding groups.
6. This delay, however, is unlikely to have significant energetic consequences on migrating whales exposed to a single seismic survey, and therefore unlikely to have a significant impact on the population.
7. For simulated surveys carried out in an area where groups were not migrating (e.g. resting area), the whales were more likely to respond to the seismic array as well as experience a longer migratory delay. This was deemed to have the potential for population-level consequences, though this needs to be tested in a realistic scenario.

Background

Although there has been concern for decades about the potential impact of seismic exploration on whales, much of the research concerning behavioural disturbance in particular was anecdotal or observational. BRAHSS was a research project involving four major experiments from 2010 to 2015 with humpback whales migrating southwards along the Australian coastline. It aimed to understand how the whales responded to seismic air gun surveys and to provide the information that will allow these surveys to be conducted efficiently with minimal impact on whales. It was designed as a behavioural response study to determine how whales changed behaviour when exposed to seismic surveys as well as what longer term biological effect this might have. It also aimed to determine the effectiveness of ramp-up or soft start used at the start of surveys as a mitigation measure. Ramp-up involves a gradual increase in sound level over 20 to 30 min with the intention of allowing the whales to move out of the way before the highest noise levels are reached. Procedures to ensure that whale hearing is not affected by seismic operations were established by the "EPBC Act Policy

Statement 2.1 - Interaction between offshore seismic exploration and whales: Industry guidelines" (Department of the Environment, Water, Heritage and the Arts, 2008).

BRAHSS remains the largest and most comprehensive controlled research study of the effects of seismic surveys on whales ever conducted. It was a collaboration between scientists from the Universities of Queensland, Sydney and Newcastle, Curtin University, the Defence Science and Technology Group, Blue Planet Marine, and the Australian Antarctic Division.

Total funding was about $12M provided by the Joint Industry Programme on E&P Sound and Marine Life (JIP) and by the United States Bureau of Ocean Energy Management (BOEM). JIP is funded by a consortium of oil and gas companies with independent scientific advisers and project assessment. BOEM is the U.S. Government agency that manages offshore energy including minimising environmental impact. Strict protocols were established by the BRAHSS research team to ensure that the funders and other interested parties had no influence on the research or the publication of the results.

The whales most likely to be exposed to seismic surveys are humpback whales off the east and west coasts of Australia and southern right whales off the southern coast. Humpback whales migrate along the east and west coasts of Australia between their tropical winter breeding grounds and the summer polar feeding grounds. The humpback whales off each coast are separate populations. Off the east coast, they have been increasing at more than 10.5% per year for decades (as of the latest surveys) with broadly similar rates off the west coast. They can be considered robust and healthy stocks, with current numbers off each coast in the range 30,000 to 40,000 individuals. Worldwide, humpback whales are classified as "least concern" by the IUCN (International Union for Conservation of Nature). The population off the west coast has been exposed to seismic surveys for many years while the east coast population has had little exposure.

BRAHSS Experiments

Experimental trials involved a single air gun (20 cubic inch or in^3), a small clustered array (up to 440 in^3), and a full commercial array (3130 in^3). All sources were towed at a speed of 4 knots (7.4 km/h) with air guns firing at 11 s intervals, typical of a seismic survey. Observations of whale behaviour were conducted for three types of trials were conducted: trials with air guns operating ('active' for response to the array), trials with the air guns towed but not operating ('control' for response to the ship) and in the absence of any vessel ('baseline' for normal behaviour). More than 300 whale groups were studied, roughly distributed between the three types of trials. Migrating whales normally show a wide range of behaviours, many of which can be related to breeding behaviour, so it is necessary to conduct the 'control' and 'baseline' studies to separate behaviours in response to the air gun array, from any response to the ship, and from their normal behaviour.

Migrating groups (female with her calf, female-calf pairs being escorted by one or more males, single whales, adult pairs or groups of more than two adults) were exposed to one of these sources as they migrated southwards along the Australian coastline, from breeding grounds in the Great Barrier Reef, towards feeding grounds in the Antarctic. In addition to array capacity, other variables tested included tow path direction (across the migratory path or directly into the migratory path). Many of these groups were carrying out typical breeding behaviours including singing (males), socialising with conspecifics, and using social signals such as surface slapping to mediate group-group interactions. The most common group consisted of a female and her calf. The study consisted of a series of trials, each one involving a one or two focal groups of whales as they migrated along the coastline (tracked

from land). Group responses were quantified as significant changes in dive behaviour, movement behaviour, and/or social behaviour.

Behavioural response of migrating humpback whale groups to seismic air guns

Humpback whales were found to respond to the various air gun arrays by changing their migration movement pattern, diving pattern (Dunlop et al. 2015, 2016, 2017a, 2917b, 2018), and social behaviour (Dunlop et al. in review). No 'abnormal' behaviour was observed (e.g. groups turning and migrating in the opposite direction, groups ceasing to migrate or moving at high speed, abnormally high or low rates of surface behaviours, cessation of breeding interactions etc.). The responses that were observed, were, to some extent, dependent on social cohort. Females with calfs tended to respond at a greater magnitude (for some response variables) compared to other cohorts (Dunlop et al. 2018). The most consistent responses were changes in movement behaviour, where groups responded by changing their net speed (progress) south. This resulted in groups making slower progress southwards for a period of time before returning to normal migratory behaviour. While these changes occurred during the 'active' trials with the air guns firing, they were also evident during the 'control' trials, when a ship towed air guns through the study site but the air guns were not operated. Changes in behaviour during 'control' trials, however, were of a lesser extent when compared to the larger capacity active sources. In other words, migrating groups also responded to the presence of the vessel and not just the air guns.

These movement responses resulted in the group deviating away from the source vessel and were considered to be an avoidance reaction to the source and/or vessel. Therefore this metric (the amount by which a group deviated away from the source vessel) was used within a dose-response framework. Simply put, a dose-response framework quantifies the magnitude of the change in group behaviour (in this case, deviation away from the source) as a function of 'dose' (for example, how loud the air gun sounds were at the whales). In theory, as the received level or loudness of the air gun signal at the group increases, the group should deviate away from the source to a greater degree.

During the trials, humpback whale groups were at varying distances from the source vessels, ranging from <1 to >10 km. In most cases, the whale groups were north of the source vessel and moving south and the vessel was moving north, so that the distance between the source and the group (proximity) decreased until the vessel passed by the group, and/or the group deviated away from the source. Received levels of the air guns at the group were therefore also highly variable, with the maximum received Sound Exposure Levels (SELs) during the trials ranging, for example, from 115 to 170 dB re 1 μPa^2.s for the full commercial array. (Note that SELs are different to the more commonly used Sound Pressure Levels which are related to the sound intensity level. Due to the very short duration and impulsive nature of the air gun sounds, SPLs are not considered appropriate measures as they do not provide a realistic assessment of how 'loud' the air guns are perceived by the whales. The perception of loudness of such very short sounds is better captured by SELs which are a measure of the total energy in the impulse.) Results showed that both the loudness (received level) of the air gun sound and the distance between the whales and air guns (proximity) affected the whales' behaviour. Whales were more likely to deviate away from the source when it was BOTH within 3 km AND the received SEL was more than 140 dB re 1 μPa^2.s (Dunlop et al., 2017, 2018). If groups were more than 3 km from the source, they were unlikely to deviate away even if the received level was greater than 140 dB re 1 μPa^2.s. This demonstrates that behavioural responses are not just determined by how loud a sound is, but also the context in which it is produced.

Biological consequences of exposure of migrating humpback whale groups to a seismic survey

The BRAHSS controlled experiments provided an understanding the detailed, individual responses which can then be generalised to any scenario of migrating humpback whales exposed to seismic surveys which may run for days or weeks. In addition, the results also provide behavioural information needed to infer the biological consequences in terms of if and how changes in group behaviour potentially relate to population-level consequences such as affected survival or reproduction. To do this, further work was carried out that simulated the interaction between migrating whale groups and a full commercial seismic survey (using an agent-based modelling approach; see details below). The results of these simulations were then assessed for longer term population-level impacts using the Population Consequences of Disturbance (PCoD) model framework.

The agent-based model (ABM) was used to simulate migrating groups moving through a full commercial seismic survey. The simulated seismic survey area was 60 km north/south by 75 km west/east out to the continental shelf and lasted for 10 days and 17 hrs. The simulated commercial air gun array travelled at a speed of 4 knots, with transects running in a west-east direction across the migration path. Agents (simulated migrating humpback whale groups) were parameterised based on the BRAHSS results (i.e. were programmed to respond to the seismic vessel in the same way as the real whales did during BRAHSS), and from this, the probability of response of a migrating group within the population was estimated as well as the cost of the response in terms of a delay in migration to the feeding grounds. Results found a low response probability for both female-calf agents as well as well as all other group compositions, and further simulations found that even those that 'responded' were delayed by less than one day in their return to the Antarctic.

The PCOD framework is a simple four-step process, moving from changes in individual behaviour and/or physiology, to a change in individual health, vital rates (e.g. birth rate, death rate, breeding rate), and finally to population-level effects (altered rates of increase or decline). For eastern Australian humpback whales migrating southwards from their breeding grounds to their feeding grounds, lactating females were considered to be the most vulnerable (in terms of energetic costs) and the most likely cohort to influence any change in population growth due to future breeding success. If lactating females are significantly delayed in their return to the feeding grounds, the loss of blubber may mean they are in poor condition and unlikely to breed (fall pregnant) the following year (from other data we know that some females are breeding annually). This would lower the calving rate for the population and therefore lower the population growth rate. However, using the PCOD framework with an energetic model for lactating humpback whales, there was no evidence that the delay found in the ABM model had any significant effect on the body condition of lactating females. It was therefore unlikely to cause any significant population consequence.

However, ABM results suggested that the most important factor in dictating the group's response probability, as well as the cost in terms in migratory delay, was the time the group spent in the survey zone. The entire ABM/PCOD analysis was then repeated for groups in a 'resting' area – where the time they spent in the seismic survey zone was increased. Here, groups were more likely to respond and the cost of response, in terms of migratory delay, also increased. Again, according to the energetic model, this was unlikely to have any significant impact on lactating female body condition. However, if exposure to seismic air guns caused the calf to stop nursing, this could have the potential for significant negative impacts on calf survival and if a significant number of calves are affected, population-level consequences.

Although this modelling was conducted using the best available data, uncertainty remains around how much exposure to seismic surveys females with calves can withstand before there are impacts. For instance, while we have good data on the behavioural response of migrating humpbacks, we lack data on their responses to seismic surveys in breeding and resting areas. We also lack detailed data for the energetics modelling for lactating females, and the response of nursing females to seismic air gun sounds. More studies on this are required.

Caveats

1. BRAHSS results found that groups also responded to the presence of the vessel (without air guns turned on). All group responses therefore cannot be attributed solely to exposure to the seismic array.
2. This work was carried out on one (robust and healthy) population, in one species (humpback whales) and in one context (migrating towards the feeding grounds from the breeding grounds and showing some breeding behaviour). Significantly more work is required to determine the extent that the results, at this stage, can be applied to humpback whales in other contexts, to other populations (that are not as robust), and to other species. More studies are required to fill these data gaps.
3. The responses of groups to the continuous commercial survey, the migratory energetics of these groups, and other parameters of the PCOD model are simulated using the best available data. Further work is required to ground truth these models.
4. Simulations (ABM and PCOD) concentrated on changes in movement behaviour which led to a migratory delay in returning to the feeding grounds. The potential impact of changes in social behaviour has not been investigated.

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