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4aAB5. Behavioral responses of humpback whales to seismic air guns

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A study of the response of humpback whales to seismic air guns is being conducted in Australian waters and two of four major experiments have been completed. It aims to assess the impact of seismic surveys on the whales and the effectiveness of ramp-up in mitigation. In separate trials, whales were exposed to a 20 cu in air gun, ramp-up in level from 20 cu in to 440 cu in with an air gun array, and a 'hard start' of 140 cu in. Whales were tracked using theodolites on high points ashore and behavioral observations were made from these points and from three small vessels and the source vessel. Vocalising whales were tracked with an array of hydrophones. DATGs were attached to some whales. Observations were made before, during and after exposure. Trials exposing whales to air gun treatments were balanced by controls without air guns firing. Characterization of the sound field throughout the area and the exposure at each whale were determined from propagation measurements and recordings on the hydrophone array and several moored acoustic recording systems.

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INTRODUCTION

The concern about the effects of noise of human activities on marine mammals has led many nations to regulate activities to minimize the impacts of the noise. Such regulation involves some limitations on the activities, such as shutting down of the source or changing to lower power if a marine mammal comes within a specified distance of the noise source. In spite of substantial research over the last decade or so, there still remain significant limitations in the scientific knowledge upon which these measured are based and thus uncertainty about their effectiveness. Managing this uncertainty usually results in greater limitations on activities than might be the case with better knowledge, without necessarily providing adequate protection of whales. There is a need to improve our knowledge to allow human activities at sea to continue without significant impact on marine mammals. Just what is "significant impact" is not readily definable but an expert working group has expressed this in terms of the longer term biological effects such as effects on the life functions (such as feeding, breeding), vital rates (e.g. birth rate) and ultimately, the health of the population (The National Research Council, 2005).

Behavioral reactions of marine mammals to noise are difficult to manage because reactions can occur at low received noise levels and thus at large distances from high level sources. In studies of the behavioral effects of noise, it is difficult to separate responses to the noise exposure from normal behavior, and difficult to interpret the results in terms of the biological significance. A range of variables other than the characteristics of the received noise may influence behavioral responses, and these influences need to be taken into account in studies of impacts and in developing management tools. For example, the response may be influenced by how close the source is, the direction the source is moving, the animal's behavioral state, social interaction with other animals and the ambient noise.

This paper discusses a behavioral response study of humpback whales to seismic air guns. The project, known as BRAHSS (Behavioral Response of Australian Humpback whales to Seismic Surveys), it aims to assess the impact of seismic air gun arrays on the whales and the effectiveness of ramp-up as a mitigation measure. Ramp-up is widely used at the start of surveys and involves the step by step increase in the source level, usually starting with one small air gun and increasing until the full array is operating. It is intended to alert the whales to the presence of the noise source with the idea that the whales will move away before the full radiated level is reached, but little is known of its effectiveness. The broad aim of the project is to provide results that will reduce the uncertainty in evaluating the impacts on whales of noise to from human activities.

PROJECT DETAILS

BRAHSS involves four major experiments. Two have been completed off the east coast of Australia and the remaining two will be conducted this year and in 2014 off the west coast. Humpback whales migrate along these coastlines between the feeding grounds in the Southern Ocean and the breeding grounds in tropical waters of the continental shelf, the populations of the two coasts being largely separate (Chittleborough, 1965; Dawbin, 1966). The experiments are timed to coincide with the southbound migration away from the breeding grounds, and at the experimental sites, whales still show breeding behavior. Observations and measurements include a wide range of variables likely to affect the response of the whales.

The behavior, population dynamics and acoustic behavior of these two populations of humpback whales has been studied extensively for decades. This information provides a good background understanding of the environment and their normal behavior to give context to any observed reactions. A large amount of information about the whales' basic biology is also available from the studies at the whaling stations from 1952 – 1962 (Chittleborough, 1965). This information will be useful in inferring longer term biological effects of noise exposure.

The first two experiments have been completed off Peregian Beach, about 130 km north of Brisbane on the east coast. The remaining two experiments will be off the west coast.

Exposure Treatments

A range of air gun array sizes are being used in the project, from a single 20 cu in air gun to a full commercial seismic array (several thousand cubic inches). Such a range of exposures helps avoid pseudoreplication in the nature of the stimulus (where we decrease the risk that behaviours observed are only in response to one particular size or type of air gun array) and also allows us to understand how whales react to the components of ramp-up. In the first experiment, a 20 cu in air gun was used and towed in two directions, one across the migration (directly offshore) and one against the direction of the migration (running parallel to the coastline). Since the whale paths show significant meandering, the actual source path relative to the whale paths varied significantly. The second experiment used a small air gun array towed across the migration. The construction of the small array allowed for two different treatments: “ramp-up” and “hard start”. Ramp-up consisted of four stages (three steps) from 20 cu in to a total of 440 cu in with a nominal 6 dB increase in each step. Hard start consisted of stage 3 of the ramp-up (140 cu in), nominally 12 dB in level above that of the 20 cu in air gun. The third experiment (the first off the west coast) will use repeat aspects of the second experiment to compare reactions between the two populations. The final experiment, off the west coast will use a full seismic array, including ramp-up.

Experimental design

The experimental design followed the “before, during and after” (BDA) method in which the treatment (noise exposure or control) occurred only in the “during” phase”. Each phase lasted 1 h (except for ramp-up for which the treatment lasted only 30 min). Observations of whale behavior were conducted for all phases, thus allowing a comparison between the phases. The air gun was towed for the “during” phase but the vessel and array were effectively stationary during the “before” and “after” phases. “Exposure” experiments (air guns firing) consisted of 20 cu in, ramp up or hard start. In control treatments, the air guns were towed in the “during” phase, but not operating. There were also observations of groups when the source vessel was absent to provide a control for the presence of the vessel. The number of controls were planned to equal the number of treatments with the air guns operating.

A power analysis of previous playback experiments at the east coast site was used to estimate the sample size required (Dunlop, 2013).

Observations

Whale behavior and movements were tracked from land with five theodolite stations at two high points ashore, positioned about 12 km apart. Focal follow observations, in which the same whale group was followed and all behaviors noted as it passed through the study area, were made from the theodolite stations. Additional focal follow observations were made from three small boats. Data were recorded on computer using VADAR software (specially developed for the project by Kniest, 2011). DTAGs, which record the acoustic field, depth, roll, pitch and heading (Johnson and Tyack, 2001) were deployed on a small number of focal group whales. Vocalizing whales were tracked using an array of five hydrophones arranged in a T-shape, the separation of pairs varying from 660 to 870 m. Acoustic data were transmitted back to a base station ashore and source positions calculated using ISHMAEL (Mellinger, 2001). VADAR produced almost real-time track plots annotated with behavior from the visual and acoustic data. Observations were also made of whale movements and behavior from the source vessel.

Four CMST-DSTO sea noise loggers were deployed throughout the study region over the period of the experiments to record the signals from the air gun array, whale vocalisations and ambient sea noise. Positions were changed during the experiments to provide adequate coverage of the area and to provide propagation measurements along many paths. Two drifting buoys with a vertical array of four hydrophones were deployed near focal whale groups to sample the vertical acoustic field.

Analysis

Statistical analysis involves generalized linear mixed models (GLMM) incorporating fixed effects, covariates and random effects. Behavioural response variables from the focal follow data include course travelled, speed, dive profile, surface behaviours, and vocalization parameters. Fixed effects (those which are determined by the experimenter), include exposure (exposed/non-exposed), treatment (single air gun, multiple air guns, ramp-up, full array and controls), tow-path, experimental period (before, during and after exposure), and social context (group composition, group social behaviour, nearest singing whale and nearest neighbour). Covariates (other variables that might affect the results) including array proximity, array movement relative to the whale, received level, and background noise, will be incorporated as additive and/or interactive effects.

Random effects are those where the levels of the effects are assumed to be randomly selected from an infinite population of possible effects, in this case, the selection of test groups from a large population. Fixed effects will be introduced and removed (depending on their significance in influencing the response) and generated models will be compared using likelihood ratio tests and AIC (Akaike Information Criterion) scores to assess which model best explains the data. The aim is to identify the main factors affecting responses.

RESULTS

The first two experiments were completed successfully and more than 140 focal follows were obtained exceeding the target sample size, each with a large number of observations leading to almost 200,000 lines of data. The processing of the data into a form suitable for analysis is now largely complete for both experiments. This has involved the reconciliation of between platforms, stringent quality control and the generation of meaningful metrics of behaviour. We are now moving into the statistical modelling stage and some preliminary modelling has been done to check the integrity of the processed data.

Acoustic propagation measurements showed patches where the propagation was anomalous, showing a much larger decrease in level with increasing distance than observed over the rest of the area. These would have significantly affected sound exposure at whales over or beyond the patches relative to the air guns. Consequently, a sea bed survey was conducted in the second experiment in 2011 revealing exposed rock in the patches of anomalous propagation loss.

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