Effects of Disturbance on Populations of Marine Mammals

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LONG-TERM GOALS

Our long-term goal is to develop transferable models of the population-level effects of anthropogenic and natural disturbances on marine mammals. Disturbances can affect the physiology or behavior of animals, which in turn may lead to changes in demographic rates and viability. Population-level effects of disturbance also may cascade among species. However, it has proven difficult to identify and model the mechanisms by which individual-level responses to disturbance might propagate to the population level. A clear, quantitative understanding of such mechanisms will inform assessment of trade-offs among potential responses of species to environmental changes and diverse human activities.

OBJECTIVES

Translate conceptual models of effects of disturbance on behavior or physiology, health, vital rates, and population dynamics into quantitative models for different taxa.

Prioritize data collection for estimation of population-level effects of different types of disturbance on marine mammals with different life-history attributes.

Examine the extent to which collection of high-priority data currently is feasible in terms of time, money, and technology.

Examine inferences about effects of disturbance on individuals and populations that can be drawn on the basis of limited empirical information or with expert elicitation.

Compare inferences about population-level effects of disturbance that are based on extensive empirical data to those based on expert elicitation.

APPROACH

Most of the work was conducted by a multidisciplinary group of approximately 15 individuals, many of whom participated in an earlier phase of the work. The group held about two face-to-face workshops of three days each per year. Meetings were held in locations that minimized travel time and expenses for the greatest proportion of participants and maximized opportunities to interact with other parties interested in the work and its applications. Project oversight was provided by a five-member steering committee [Dan Costa (University of California, Santa Cruz), Erica Fleishman, John Harwood (University of St. Andrews), Scott Kraus (New England Aquarium), and Mike Weise (Office of Naval Research)].

WORK COMPLETED

The working group met from 28–30 September 2015 at the Brookfield Zoo in Chicago, Illinois. At their home institutions, group members modeled the population-level effects of disturbances on southern (*Mirounga leonina*) and northern (*M. angustirostris*) elephant seals, coastal populations of bottlenose dolphins (*Tursiops* spp.), North Atlantic right whales (*Eubalaena glacialis*), and Blainville's beaked whales (*Mesoplodon densirostris*).

Effects of disturbance on bottlenose dolphins in Sarasota Bay. This work is ongoing. We are running mark-recapture models that estimate survival and reproduction as a function of health (body mass index and white blood cell count) and a separate model of direct relations between demographic rates and prey availability, contaminant load, sea surface temperature, and intensity of recreational and commercial fishing. Quarterly mark-resight data are available for 336 individuals from May 1992 – April 2010. Data are classified on the basis of whether animals were seen during standard or non-standard surveys, which improves estimates of detection probability. Data also extend beyond the standard survey area, improving estimates of movement probabilities. Such improvements increase the precision of survival and reproduction estimates.

We developed methods for monitoring whether human activities affect the physiology or behavior of marine mammals and, if so, whether those effects may lead to changes in survival and reproduction. We suggested four sequential steps in designing and implementing such a monitoring program. The first step is development of a theory of change: a mechanistic hypothesis that outlines why a given activity might be expected to have one or more measurable effects on individuals or populations, and ideally the magnitude and timing of the effects. The second step, definition of biologically meaningful effects, facilitates the development of a monitoring program that can detect the associated effect sizes and confidence intervals. The third step, strategic selection of response variables for monitoring, ultimately allows inference to whether observed changes in the status of individuals or populations are attributable to a given activity. Visual observations, passive acoustic data, tagging data, and direct physical measurements all can provide data relevant to testing hypotheses about individual-level and population-level effects of human activities. The fourth step is specification of the temporal sequence of monitoring. These methods also can be used to monitor individual- and population-level responses to other types of environmental change. This work is in revision with *Marine Mammal Science*.

We explored how the group's conceptual models on population-level responses to sound might be represented as integral projection models. These models include both a set of statistical distributions that describe variability in fitness-related traits within a population and a set of stochastic kernels (loosely, mathematical functions) for projecting these distributions between time steps. IPMs are usually constructed by fitting regression models to at least two estimates of the state and fate of individuals in a given population. We aim to project the effects of behavioral and physiological responses to disturbance on population dynamics with regression analysis, computer simulation, and biological inference. A manuscript on this work is in preparation.

RESULTS

Assessment of uncertainty in physiological studies of northern elephant seals. There may be a correlation between the percentage of lipid mass and the probability of survival in northern elephant seals. Measurement error in adult female lipid mass and pup wean mass did not affect the estimated function between maternal lipid mass and pup wean mass. The function between pup wean mass and pup survival also was unaffected. There was a small change in reproductive rate as a function of maternal lipid mass. Process error is unavoidable in many cases in which the ultimate goal is to understand the probability of decline. In most cases, ignoring uncertainty will lead to relatively estimates of probability of decline that are relatively low.

Estimation of lipid mass for northern elephant seals. Fat mass and body condition can also link foraging success with demographic rates. Maternal fat mass in elephant seals is correlated reproductive rate and pup survival, but sources of uncertainty in the two fat-mass estimation methods (labeled water and truncated cones) had not previously been quantified. On land, seals are elliptical rather than circular, and skin may account for a high proportion of what is often defined as blubber. Also, blubber extends past the neck-to-pelvis region, and comparisons of new and old ultrasound instrumentation indicated previous measurements of sculp thickness may have been biased low. A modified cones method can isolate blubber from non-blubber adipose tissue and separate fat into skin, blubber, and core compartments. Estimates of adipose tissue and fat that are based on tritiated water may be biased high during the early molt. The modified cones method allows for more-accurate quantification of the various tissue masses and may be transferrable to other species.

State-space modeling of bottlenose dolphin behavior. We fit a simulation model of bottlenose dolphin behavior to data from Doubtful Sound, New Zealand. The simulation model initially was built to inform management of interactions between bottlenose dolphins and boats in the Moray Firth. In this case, data were collected during scan-samples of focal groups of dolphins from 2000 through 2002. Every 15 min, observers assigned the behavior of the group to one of four categories (travelling, foraging, resting, socializing). The respiration rate of a focal individual was recorded during each scan sample. The model-generated predicted activity budgets for animals in Doubtful Sound were not biologically realistic. Data from group follows likely are insufficient to reliably infer motivational states and health of individuals. Successful parameterization required information on the spatial distribution of behaviors and the health of individuals (i.e., respiration rate). Telemetry data may be more useful for this purpose because they can provide information on behavioral state, movement, responses to sound or other disturbances, and potentially on direct measures of health.

Population-level effects of mid-frequency active sonar on Blainville's beaked whales. We developed and published the first empirical risk function that combined passive acoustic detection data and empirical Navy sonar data to estimate the probability that Blainville's beaked whale will be disturbed by mid-frequency active sonar exercises over an full year. We estimated the probability that an individual whale might change its behavior (stop foraging) as a function of the received level of sonar. The function predicted a 0.5 probability of disturbance at a received level of 150dBrms re mPa (confidence interval: 144 to 155) This is 15dB lower than the level used historically by the US Navy in their risk assessments but 10 dB higher than the current 140 dB step-function (i.e., assumption that a response is certain above 140 dB).

Expert elicitation on movements of North Atlantic right whales. Gaps in knowledge of right whales' movements through the mid-Atlantic limit informed management of stressors. We elicited estimates of the relative abundance of adult right whales in the mid-Atlantic during four months, representing each season, from ten experts. For each month-sex combination, we merged the ten experts' answers into one distribution. The estimated modes of relative abundances of both sexes were highest in January and April and lowest in July and October. In some cases, our elicitation results were consistent with the results of studies based on sightings data. However, these studies generally did not adjust for sampling effort, which was low and likely variable. Our results supplement the results of these studies and will increase the accuracy of priors in complementary Bayesian models of right whale abundances and movements.

Population-level effects of sound on North Atlantic right whales. We led an expert workshop in developing a conceptual model of potential mechanisms by which right whales might respond to sound. The group also documented, for each class of response or mechanism, existing data that might inform models, strength of evidence, major uncertainties, options for testing hypothesized relations, and feasibility and priority for testing. The group identified three priorities. First, support remaining processing and cleaning of data from Cape Cod Bay. This might allow tests of hypothesized relations between sound and commensal food-finding and mate finding. Second, consider an expert elicitation on whether masking of sound is related to the probability of ship strike. Third, parameterize models or submodels addressing chronic stress. There are multiple ways to address the third priority, including continued analysis of empirical data; conducting comparative studies in different habitats of the species, on different populations, or on different types of samples (e.g., blubber, feces, blow); conducting an expert elicitation that would focus on whether stress affects the response, or magnitude or duration of response, to sound sources; and conducting a rigorous assessment of evidence and uncertainty. An elicitation would aim to parameterize a chronic stress or stress–population effects model, whereas the latter assessment would better characterize what is known and the associated level of confidence.

IMPACT/APPLICATIONS

Multiple public and private sectors wish to understand whether observed changes in animals' behavior or physiology affect probabilities of persistence. Subsistence hunters also wish to understand whether short-term changes in behavior may affect long-term spatial distributions of animals. The concept that behavioral responses to disturbance are not necessarily surrogate measures of population-level responses is widely understood. However, without tractable methods for quantifying population-level effects, most sectors will be restricted to estimating exposure of individual animals to disturbances or changes in habitat quantity or quality. Thus, improved understanding of transfer functions might help to guide research and management, and to project how marine mammals will respond to alternative scenarios of human activities, from those that produce sound to climate change to changes in human density and distributions.

RELATED PROJECTS

The following projects supported models of effects of disturbance on individual species: N000141110433 and N000141210213 to Diane Claridge, N000141310134 to Dan Costa, N000141210389 to Scott Kraus, N0001413WX20616 / N0001412WX20919 to David Moretti, and N000141210286 to Len Thomas.

Fleishman is leading a project on cumulative effects of underwater anthropogenic sound on marine mammals for BP Exploration. The project has developed both quantitative and qualitative methods for assessing the aggregated sounds of multiple sources received by a given species during a defined time period in a defined location. The ONR-sponsored project is highly complementary because it quantifies mechanisms by which responses to sound or other disturbances may affect survival, reproduction, and population viability.

D. Costa, L. Schwarz, and R. Wells received support from the Joint Industry Programme to develop a bioenergetic model to estimate population-level responses to disturbance. They are focusing on sperm, blue, and humpback whales, bottlenose dolphins, elephant seals, and California sea lions.

D. Moretti received support from the Office of Naval Research to model the population-level effects of acoustic disturbance on Cuvier's beaked whale (*Ziphius cavirostris*) in southern California.

PUBLICATIONS

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