

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 is conducted by a multidisciplinary group of approximately 15 individuals, many of whom participated in an earlier phase of the work. The group holds about two face-to-face workshops of three days each per year. Meetings are held in locations that minimize travel time and expenses for

the greatest proportion of participants and maximize opportunities to interact with other parties interested in the work and its application. Project oversight is 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 convened 21–23 January 2013 at Mote Marine Laboratory in Sarasota, Florida. A meeting is planned for 16–18 October 2013 at the New England Aquarium in Boston, Massachusetts. At their home institutions, subsets of the working group are modeling the population-level effects of disturbances on five marine-mammal taxa: southern elephant seals (*Mirounga leonina*), northern elephant seals (*Mirounga angustirostris*), coastal populations of bottlenose dolphins (*Tursiops* spp.), North Atlantic right whales (*Eubalaena glacialis*), and Blainville's beaked whales (*Mesoplodon densirostris*). The following studies are ongoing.

We are comparing estimates of fat generated with truncated cones versus labeled water while quantifying uncertainty in both methods for northern and southern elephant seals and Sarasota Bay bottlenose dolphins. Incorporation of uncertainty is necessary before using fat or percentage of fat as the measure of health linking behavioral and physiological changes and vital rates.

We are defining the functional relation between maternal health and pup survival in southern elephant seals. First, we will model the relation between maternal lipid mass and pup wean mass. Second, we will model the relation between pup wean mass and first- and second-year survival. We developed a multi-event, multi-state Bayesian model based on the standard Cormack-Jolly-Seber model to determine the relation between pup wean mass and survival. We are linking results to complementary models of the relation between foraging and health.

We are defining the functional relation between health and survival, and between health and reproductive rate, in northern elephant seals. Since 2004, at least 40 female northern elephant seals have been captured each year and fitted with transmitters. The females were weighed, some aspects of their morphology were measured, and ultrasound was used to determine fat mass before and after a foraging trip. Data also were collected on mass and morphology of their pups. On the basis of these data, we are examining the relation between foraging success of mothers and whether they produce a pup (reproductive rate). It may be possible to relate rates of survival of adult females to their foraging success.

We are testing whether different methods for identifying drift dives and estimating drift rates yield equivalent results. We are subsampling time depth recorder (TDR) data on northern elephant seals so sampling intervals for northern and southern elephant seals are comparable and then examining the subsampled data with methods used to identify drift dives of southern elephant seals. The results will be compared to those from analysis of the full set of TDR data on northern elephant seals with methods used to identify drift dives of that species. If results are different, we will analyze the full set of TDR data on northern elephant seals with methods for identification of drift dives of southern elephant seals. Work will elucidate whether differences are driven by sampling interval or the method for identifying drift dives.

We are analyzing population-level effects of disturbance on bottlenose dolphins in Sarasota Bay. We will use a Bayesian individual-based mark-resight analysis to correlate survival and reproduction with measures of health. Potential health metrics are body mass index, percent lipid in blubber, blubber thickness, total mass standardized by length and age, white blood cell count, and respiration rates. The individual-based model accounts for repeated measures of health of the same animal. Reproductive parameters will include probability of producing a calf and duration of mother-calf association. A separate analysis will correlate health metrics with probability of carrying a calf to term when pregnancy status is confirmed during health assessments.

We are modeling the population-level effects of sonar on Blainville's beaked whales in the Bahamas. We are using an energetics model to estimate the number of foraging dives lost in response to exposure to sonar as a proxy for overall energy loss. We will apply the model to a population of sonar-exposed animals at the Atlantic Test and Evaluation Center (AUTEK) weapons range. We also will apply the model to a separate population of animals in the Northwest Providence Channel off Abaco. The latter population rarely is exposed to sonar.

We are examining whether photographic observations of individual North Atlantic right whales, and measures of health derived from those photographs, allow reliable estimates of individual-level and population-level health in the period between observations. We are fitting a multi-state mark recapture model to 30 years of photographs. Four variables associated with health are estimated from the photographs: body condition, skin condition, cyamid infestation around the blowholes, and presence of rake marks forward of the blowholes. We developed a process model that links these observations to the true, but unknown, health of individual animals. The model estimates monthly health of individuals and population segments. We are comparing model results to the number of calves produced annually to determine the model's ability to reproduce known periods of poor population-level health.

We convened an expert elicitation to assess whether the Right Whale Ship Strike Reduction Rule has affected the probability of persistence of right whales. The two-part workshop was held on 13 and 14 November, 2012 during the annual meeting of the North Atlantic Right Whale Consortium in New Bedford, Massachusetts. We also aimed to examine the type and strength of inferences that expert elicitation can contribute to assessments of the population-level effects of disturbance on marine mammals.

We are eliciting experts' knowledge about the timing of peak abundance of North Atlantic right whales in the southeastern United States, the timing of departure from both the southeastern United States and the greater Gulf of Maine to the mid-Atlantic (i.e., the timing of right whales' northward and southward migrations), the timing of peak abundance of right whales in the mid-Atlantic, and the activities of right whales in the mid-Atlantic. Knowledge of right whales' movements within and through the mid-Atlantic region largely is uninformed. Right whales are difficult to detect because they are migrating through the region. A modest amount of information has been generated by opportunistic sightings, some systematic surveys, and satellite telemetry data from a small number of animals. The relative lack of information on use of the mid-Atlantic region by right whales complicates management planning and action. These facts motivated the elicitation.

RESULTS

We found a positive, although highly variable, relation between maternal lipid mass and pup wean mass in southern elephant seals. Pup separation, maternal experience (i.e., whether a female previously

reproduced), and crowding may reduce the strength of the relation. The relation between pup wean mass and pup survival was quadratic, and pups with a wean mass near 160 kg had the highest probability of surviving their first year. The relation between maternal lipid mass and pup survival was not particularly strong, although pup survival increased slightly as maternal lipid mass increased from about 120 to 180 kg.

A state-space model that estimates movement, health, and survival for North Atlantic right whales indicated that photographic observations of body condition, skin condition, cyamid infestation on the blowholes, and rake marks measured the true underlying health. The resulting time series of individual health highlighted both baseline variations in health status and potential effects of anthropogenic stressors on the health and, ultimately, the survival of individuals.

The workshop we held at the North Atlantic Right Whale Consortium meeting illustrated the feasibility of conducting a formal expert elicitation on population-level effects of disturbance on marine mammals. To the best of our knowledge, such an elicitation has not previously been conducted for marine species. We demonstrated that after a short training session, a diverse group of experts could estimate parameters that are directly relevant to rigorous scientific analyses. Given that expert elicitation has a strong conceptual basis and results from elicitations in various disciplines have been independently verified, the method contributes to generation of the best science available for decision-making.

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 support models of effects of disturbance on individual species. N000141110433 and N000141210213 to Diane Claridge. Assessing beaked whale reproduction and stress response relative to sonar activity and Population consequences of acoustic disturbance of Blainville's beaked whales at the Atlantic Undersea Test and Evaluation Center. N000141310134 to Dan Costa. Development of the PCAD model to assess biological significance of acoustic disturbance. N000141210389 to Scott Kraus. The population consequences of disturbance model application to north Atlantic right whales (*Eubalaena glacialis*). N0001413WX20616 / N0001412WX20919 to David Moretti. The effects of behavioral change in response to acoustic disturbance on the health of the population of Blainville's beaked whales in the Tongue of the Ocean. N000141210286 to Len Thomas. Statistical tools for fitting models of the population consequences of acoustic disturbance to data from marine mammal populations.

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 quantitative method models the sound field from multiple sources and simulates movement of a population through it. The qualitative method uses expert knowledge to assess responses of individuals and populations to sound sources and identify potential mechanisms. 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.

PUBLICATIONS

- Schick, R.S., S.D. Kraus, R.M. Rolland, A.R. Knowlton, P.K. Hamilton, H.M. Pettis, R.D. Kenney, and J.S. Clark. 2013. Using hierarchical Bayes to understand movement, health, and survival in the endangered North Atlantic right whale. *PLoS ONE* 8(6):e64166. doi: 10.1371/journal.pone.0064166 [published, refereed]
- Costa, D.P., L. Schwarz, R.S. Schick, L. New, L. Thomas, M.A. Hindell, C. McMahon, P.W. Robinson, S.S. Simmons, J. Harwood, and J.S. Clark. 2013. A bioenergetics approach to understanding the population consequences of disturbance: elephant seals as a model system. Proceedings of the conference on the effects of noise on aquatic life, Budapest. [in press]
- Fleishman, E., M. Burgman, M.C. Runge, R.S. Schick, and S. Kraus. 2013. Expert elicitation of population-level effects of disturbance. A bioenergetics approach to understanding the population consequences of disturbance: elephant seals as a model system. Proceedings of the conference on the effects of noise on aquatic life, Budapest. [in press]
- Harwood, J.S., S. King, C. Donovan, L. Thomas, R. Schick, C. Booth, D. Costa, E. Fleishman, S. Kraus, D. Lusseau, L. New, and L. Schwarz. 2013. Understanding the population-level consequences of acoustic disturbance (PCAD) for marine mammals. Proceedings of the conference on the effects of noise on aquatic life, Budapest. [in press]
- Schick, R.S., S.D. Kraus, R. Rolland, A. Knowlton, P. Hamilton, H. Pettis, R. Kenney, and J.S. Clark. 2013. Using effort, sightings, and body condition data to estimate survival and Robert health of individuals and the entire right whale population. Proceedings of the conference on the effects of noise on aquatic life, Budapest. [in press]