Development of the PCAD Model to Assess Biological Significance of Acoustic Disturbance

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LONG-TERM GOALS

Assessing the impact of disturbance events on cryptic or far-ranging marine mammal species is critically important to stakeholderswho must balance project objectives with the environmental impacts of proposed activities. In recent years, considerable scientific interest in this topic has led to key discoveries relating to species-specific sensitivities, behavioral responses, and the physics of disturbance; however, we still lack the ability to predict the effect of potential disturbance events on a population. To better inform stakeholdersabout the likely consequences of a specific proposed activity, the PCAD (Population Consequences of Acoustic Disturbance) working group established a conceptual framework detailing the impact of disturbance events and how the effects cascade from individuals altering their behavior all the way to population-level demographic effects. The PCAD working group then developed a more rigorous analytical approach (New et al. Accepted) . These methods require substantial pre-existing knowledge of foraging patterns, life-history schedules, and demographics. Therefore, it is essential to use well-studied species to validate the approach. This is best accomplished by selecting species that are as similar as possible to target species and are also extremely well-studied. We identified northern elephant seals and Atlantic bottlenose dolphins as the best species to parameterize the PCAD model. These species represent two life-history extremes (capital and income breeders), have clear taxonimic separation (pinnipeds and cetaceans), and both species have been studied intensively for several decades, providing unprecedented demographic data. These factors imply that they likely respond to disturbance in unique ways and by developing models for each system, we can effectively bound the input parameters (and expected outputs) for other species of interest. This will be an essential step to eventuallly apply the model to species for which much less is known.

In the current project, we are focusing on several key opportunities. First, the combination of remarkable demographic data with “health” or body conditon data will allow us for the first time to assess the effects of a disturbance event through all of the transfer functions of the PCAD model. This will be done with both simulated, natural, and experimental disturbance events, giving us the power to estimate the effects of proposed disturbance activities while bounding the estimates with real-world values. We will also be focusing on some of the mechanistic aspects of the PCAD model. For example, by investigating fine-scale energetics via accelerometry or the role of the stress response in long-term health and reproduction, we can begin developing tools that will enhance our confidence in the PCAD model for the data-limiting/cryptic species.

OBJECTIVES

While considerable progress has been made to quantify the transfer functions described above for southern elephant seals, our goals are to parameterize these models to make them applicable to other species and take the models one step further by simulating disturbances and quantifying how such disturbances may affect the population. Although this three-year project encompasses many aspects of the PCAD effort, we list only the objectvies we have worked on during this first year.

1. Determine the relationship between adult female foraging success (energy gain) and natality and pup wean mass. Define the function of pup wean mass to pup survival.
2. Examine how differences in the spatial distribution of a disturbance affects the population: given a marine mammal foraging distribution map, examine how disturbances in particular regions could be used to quantify the impact of a specific disturbance.
3. Organize and then incorporate Dr. Randy Wells' Sarasota Bay dolphin data set for analysis of an income breeding system
4. In addition to the proposed objectives, we completed a short study to validate our method for assessing body composition in the northern elephant seal. This enables us to quantify the uncertainty associated with female condition metrics (fat mass) that is a key link between disturbance events and demographic rates.

APPROACH

<u>Disturbance Simulation Study</u>
Using long-term empirical data we developed a complete PCAD model and application for northern elephant seals (Costa et al. In press). By creating a simulated disturbance and using existing tracking data to understand how seals use the region, we can make informed predictions of the impact a disturbance will have at the individual level (lipid gain) and population level (e.g. survival rate and reproductive rate). Specifically, we used the TOPP tracking dataset combined with the buoyancy-lipid analysis from 26 adult females (Schick et al. 2013) and demographic models to simulate the impact of disturbance, defined as a lack of foraging success within a 25 km and 100 km diameter region in both the main foraging and transiting areas of the post-molt migration. Using a bootstrapping approach, we simulated thousands of disturbances to achieve realistic error estimates on all results.

<u>Sarasota Bay Bottlenose Dolphin Analysis</u>
The first step to analyzing the bottlenose dolphin data is to create a mark-recapture model to estimate survival and reproductive rates. We will use a Cormack-Jolly-Seber model based on resights of animals both in and out of the main study area (Schwarz et al. 2013). The analysis will be limited to animals that are found within the main study area during at least 50% of the year (resident population). Given seasonal differences in calving, causes of mortality, and movement patterns, we will estimate demographic rates on a quarterly basis starting May 1, 1992 through April 30, 2010 (latest available data). Calves are considered dependent on their mothers until their association coefficient falls below 0.5. Another important aspect of this research is to find easy-to-measure physiological metrics that can be applied to dolphin populations where health assessments are not possible. Therefore, another initial

step is to investigate correlations between respiration rates and known mortalities to see if respiration rates can be used as a metric of health.

Body Composition Validation Study
Quantified uncertainty is becoming a standard metric provided to policy makers when deciding on protection levels for species (Regan et al. 2013). If physiological indicators are to become a part of models to predict the population outcome of disturbance, it is important to quantify the uncertainty in those metrics. In particular, fat mass of female elephant seals has become a critical foraging success metric linked to reproductive rate. Pups' wean mass is also a function of maternal condition, and wean mass affects pup survival (McMahon et al. 2000, Crocker et al. 2001). To better understand the uncertainty and validity in fat mass estimates, this study compared results of several different methods to estimate percent fat in elephant seals: elliptical truncated cones, circular truncated cones, and labeled water. We included use of two different ultrasound machines (with and without images), and quantified uncertainty in all techniques.

WORK COMPLETED

Disturbance Simulation Study
During the summer of 2013, we gathered the necessary behavioral and demographic data, completed all of the coding to extract the behavioral data and analyze the demographic data, ran all of the simulations, presented the work at the Aquatic Animals and Underwater Noise conference, and wrote a manuscript for publication. This effort was highly successful and has motivated us to continue this effort by analyzing all tracks for changes in lipid content over the migration, streamlining the analysis, and applying new questions/scenarios to the data.

Sarasota Bay Bottlenose Dolphin Analysis
The PIs on this grant met twice over the past year to discuss different approaches to this analysis. Resight codes were developed and modified to accommodate the dolphin data. Dr. Randy Wells has almost completed the task of coding the dolphin data for mark-resight analysis. Dr. Katie McHugh from the Sarasota Dolphin Research Program is leading efforts to correlate breathing rates with known mortalities.

Body Composition Validation Study
During the molt season (April – June 2013), 14 adult females were anaesthetized and standard morphmetric data (girths and lengths) as well as height and width measurements were taken at eight sites along the females' bodies (Slip et al. 1992, Webb et al. 1998). Blubber depth was also estimated using two ultrasound machines (one that stores images and one that does not), and all measurements were taken in triplicate. Ten of the 14 females were also injected with roughly 1.2 mCi tritiated water. Percent water from equilibrated tritium concentration was translated to percent fat and compared with morphometric results.

RESULTS

Disturbance Simulation Study
In our simulated 100 km diameter disturbance zone, 73% of the population was impacted for a mean of 6.4 days in the foraging area. In contrast, 100% of the population was impacted for a mean of 3.6 days when the disturbance area was placed in the transit area near the home colony. Although the foraging success (total lipid mass gain) for some seals was dramatically impacted, this caused only a small

decline in mean total lipid gain (none: 169.3 kg, transit: 169.3 kg, forage: 167.5 kg). This 2 kg difference was insufficient to cause a biologically meaningful decline in reproductive rate, pup wean mass, or pup survival.

Sarasota Bay Bottlenose Dolphin Analysis
No results yet to report.

Body Composition Validation Study
Overall, old morphometric methods (cicular cones with no ultrasound image) produces a roughly 10% higher estimate of blubber volume compared to newer methods (elliptical cones with ultrasound image). Percent lipid estimates were 40-50% higher using the truncated cones methods compared to estimates from labeled water, and estimates from truncated cones could be up to 250% higher. In general, uncertainty is higher for labeled water techniques compared to truncated cones techniques, and the results are consistent with an earlier study on juvenile northern elephant seals (J. Maresh, unpublished data).

The discrepancy between labeled water techniques and truncated cones techniques could be caused by bias in both techniques. For example, the relationship between total body water from labeled water techniques and percent fat is based on a small sample size using other pinniped species. In addition, current truncated cones methods include the dermis layer in the blubber depth and volume. New analyses of blubber tissue will verify if current estimates of blubber density and percent lipid in blubber do indeed include the dermis layer. We will continue to investigate additional methods for estimating percent lipid from labeled water.

IMPACT/APPLICATIONS

Disturbance Simulation Study
This study represents one of the first complete applications of the PCAD approach to quantify the likely impact of a disturbance. The results indicated that a large disturbance of long duration would have negligible impacts on demographic rates in northern elephant seals. This is due in large part to the vast foraging region exploited by this capital breeder. In contrast, a similar disturbance event would likely cause dramatic impacts to California sea lions that exhibit an income breeding strategy and smaller foraging areas. By leveraging the existing datasets of migratory tracks, daily at-sea foraging success estimates, and demographic parameters, we are now able to make specific predictions about the likely impact of proposed disturbance events on elephant seals and potentially provide useful information for similar species. This work has already been presented at the Aquatic Animals and Underwater Noise conference and has been submitted for publication (Costa et al. In press). This work paves the way for future analyses of both simulated and actual disturbance events.

Sarasota Bay Bottlenose Dolphin Analysis
Initial mark-recapture analysis will allow us to look at survival and reproductive rates as a function of age, sex, season, and year. Later analyses will expand to include demographic rates as a function of physiological condition, most from health assessments, such as body mass index, mass, maximum girth, white blood cell count, and the presence or absence of a post-nuchal depression. Connecting demographic rates to health indexes may allow us to analyze the effects of long-term non-lethal exposure to disturbance.

Body Composition Validation Study

Once results are finalized, uncertainty in lipid mass estimates will be incorporated into the PCAD functions defining the relationships between foraging behavior, adult female condition, and demographic rates. These new results will provide a more realistic understanding of our uncertainty in population-level effects of disturbance, which is an important aspect of species management and decision-making.

RELATED PROJECTS

Application of the PCAD Model to the California Gray Whale, Integration of Existing Data and Towards a Quantitative Assessment of Biological Significance of Acoustic Disturbance. Joint Award Shell Oil and ExxonMobil Oil Companies. Nov 1 2012-Sept 31 2013. $120,000.

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