Environmental Perturbations, Behavioral Change, and Population Response in a Long-Term Northern Elephant Seal Study

Daniel P. Costa
University of California, Santa Cruz
100 Shaffer Rd.
Santa Cruz, CA 95060
phone: (831) 459-2786 fax: (831) 459-3383 email: costa@biology.ucsc.edu

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www.topp.org

LONG-TERM GOALS

A major challenge in marine mammal conservation and management is to understand how behavioral responses affect populations. To address this challenge, the National Research Council established the Committee on Characterizing Biologically Significant Marine Mammal Behavior. This committee developed a framework for analyzing the population consequences of acoustic disturbance, or PCAD (NRC 2005). The PCAD framework defines a series of transfer functions which describe how behavioral responses to sound affect life functions, how life functions are linked to vital population rates, and how changes in vital rates cause population change (Fig. 1). The U.S. Navy included the PCAD framework in the U.S. Navy Living Marine Resource Sound Research Requirements, specifically within the "Response to Naval Sounds" requirement #5: *Determine biologically significant behavioral responses from Navy sound sources on individuals representing marine mammal species of concern with respect to ... determining long-term effects of behavioral responses and how individual vital rates may affect the population*. This requirement was given the highest priority under the Navy's requirements.

Implementing the concepts of transfer functions which link behavior to population change, however, requires substantial long-term data on individual animals and population size, and there are few marine mammal populations where quantifying the functions is plausible. Funding from this grant has allowed us to extend and improve a four-decade study of northern elephant seal populations in California, aiming specifically to quantify key linkages within the PCAD model. Since 1968, several thousand individual seals have been tagged and tracked for their lifetimes, and several hundred of those have been weighed or outfitted with telemetry devices in order to document pelagic foraging behavior and body condition. The study has spanned the Pacific Decadal Oscillation and several El Niño events and documented how such environmental fluctuations affect individuals and populations. Recent advances in telemetry and our understanding of foraging behavior and body condition allow us to extend this study into the future with improved methods, and with our current funding we have maintained and advanced a classic long-term study of a vertebrate population.

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OBJECTIVES

Specifically we have collected data to answer two general questions: 1) How closely coupled are short term changes in foraging behavior to adult fecundity and survival? and 2) Does this link vary with environmental perturbations such as the El Niño Southern Oscillation (ENSO) that are known to impact prey availability? Such data are essential for the population modeling effort currently underway by the PCAD Working Group organized by the Office of Naval Research.

These two questions translate into three hypotheses we are testing:

1) Adult survival fluctuates with ocean climate, with low survival in the year following ENSO events, and higher survival after non-ENSO years.
2) Oceanic climate cycles will impact foraging of pregnant females and weaning weight and survival of pups. Specifically, warming trends (ENSO and "sardine" regimes) will be associated with lowered weaning weights. Survival during the first year at sea will be positively correlated with weaning weight.
3) Population growth potential is limited by these ENSO and Decadal (PDO) impacts on foraging and thus animal condition.

APPROACH

These hypotheses will be tested with data gathered through five research activities, all conducted through an ENSO cycle at the Año Nuevo, California, northern elephant seal colony: 1) continue annual censuses of the breeding population; 2) measure adult female body condition; 3) weigh weaned pups to link female condition to reproductive output; 4) continue and expand tag re-sighting to refine survival estimates; 5) continue satellite tracking of adult females to map foraging. Lastly, we have expanded and coordinated resighting efforts at two additional elephant seal colonies in central California in order to examine migration between colonies and assess population trends at larger spatial scales.

We will use data collected from these activities, as well as the legacy data of the past 40 years, to parameterize a Bayesian hierarchical population model, then use elasticity analyses to evaluate the links from ocean conditions to adult survival, nursing resources, weanling size, juvenile survival, and population growth. The results will allow us to explore potential population responses to climatic and other perturbations by building demographic models.

El Niño conditions were present across the equatorial Pacific Ocean in mid-2009 which created increases in sea surface temperatures during the pupping/breeding winter season of 2009/2010. The opposite La Niña conditions persisted through the 2010/2011 winter. Although changes in sea surface temperature were relatively strong, they were short-lived for both years. This is a rare opportunity to extend a dataset that allows us to examine the foraging behavior and demographics of a marine mammal in response to fluctuating environmental conditions. In addition, the long-term seal database spans two prior strong ENSOs, in 1998-99 and 1982-83 (Fielder 2002). Moreover, our results on seals can be placed in a broader context thanks to the coordinating efforts of the Tagging Pacific Predators program (TOPP) which has assembled foraging data from several large marine vertebrates.

WORK COMPLETED

This report marks the conclusion of the work conducted under this grant. Previous reports document completed work prior to August 2013. For field work, only resights were conducted from August 2013 to January 2014.

Juvenile Resights

Resight effort of juveniles was a total of 68 days by 21 observers between August 31, 2013 and December 31, 2013. All observed elephant seals with unique identifying flipper tags or dye marks were recorded, but the majority of elephant seals observed during this time period were juveniles or sub adults.

Linking maternal condition to reproduction, pup wean mass, and pup survival

During the summer of 2013, we used long-term empirical data to develop 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. pup survival rate and reproductive rate). Relationships that define reproduction as a function of maternal condition, pup wean mass as a function of maternal condition, and pup survival as a function of wean mass are used to quantify how lost foraging opportunities affect populations. While a strong ENSO event would have provided valuable data on seals in poorer condition, the results of the field effort supported by ONR provided important increases in sample size for all three analyses mentioned above. In addition, a dedicated juvenile resight effort every fall reduced uncertainty in juvenile survival rate estimates. Results were presented at the 20th Biennial Conference on Marine Mammals, Dunedin, New Zealand, December 2013. A manuscript based on the findings is in prep.

RESULTS

Juvenile Resights

Resights of tagged elephant seals between August 31, 2013 and the end of December, 2013 yielded a total of 466 uniquely identifiable seals: 304 seals that had been tagged as pups at Año Nuevo and thus have age known, and 70 seals tagged as adults at Año Nuevo (and thus age is not known). The remaining 92 seals had tags that were clearly read but come from other colonies, so we have little information about the animals.

The majority of those seals (272 of 304 whose age is known) were juveniles < 4 yr old, including 113 in their first year (< 1 yr old), 98 in their second, 47 in their third, and 14 in their fourth year. These juveniles were seen on as many as 12 different days, but most (181 of 272) were seen on only 1-3 days.

Linking maternal condition to reproduction, pup wean mass, and pup survival

Sample size for the relationship between maternal condition and reproduction increased 57%, from 105 to 165 adult females. Sample size for the relationship between maternal condition and pup wean mass increased 33%, from 33 to 44 mom-pup pairs. Lastly, sample size for the relationship between pup wean mass and survival increased by 114%, from 376 to 804 pups with known wean date.

Pup wean mass depends on many factors other than maternal condition, so the relationship between maternal condition and pup wean mass is not particularly strong, but they are positively correlated with each other. While sample size was very high for estimating first year survival as a function of wean mass, uncertainty in first year survival estimates remained high, primarily due to low resight probabilities. The mean probability of producing a pup was 0.5 or lower at blubber volume change rates less than 0.17 L/day. While annual reproductive rates were high (near 1.0) until maternal condition was quite poor, low adult survival rates (near 0.8) indicate this population needs to maintain either constant immigration or reproductive rates near 1.0 to maintain stable population growth.

IMPACT/APPLICATIONS

Using environmental variability as a proxy for disturbance, the 2009/2010 El Niño provided a rare opportunity to examine how elephant seal foraging behavior and pup provisioning changes with a natural disturbance. We are in the process of statistically comparing the data obtained during the El Niño year to prior and subsequent years. Weaning weight and female morphometric data will be used to inform and parameterize our models of the susceptibility and impact of an acoustic disturbance on elephant seals. These results provide not only the short term response of elephant seals to a change in prey resources but will allow us to quantify how such a reduction impacts their subsequent reproduction and survival. Mark-resight analysis, particularly in relation to mass, will provide us with survival and reproductive rate estimates that can be investigated in the context of the PCOD model. These are all very difficult parameters to otherwise measure in other capital breeders such as mysticetes, and the results from our models may be used to estimate the impact of disturbance on species with similar life history strategies.

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.

Environmental perturbations, behavioral change, and population response in a long-term northern elephant seal study. ONR N00014-10-1-0356.

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