Impacts of Climate Change on Distribution and Behavior of Marine Mammals

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BACKGROUND: Recent climate change is predicted to have serious implications for marine ecosystems, including increased sea surface temperatures (SST), changing thermocline depths, decreased sea ice, and decreased ocean salinity [1,2,3]. These factors have the potential to dramatically alter distributions, migratory behavior and foraging ecology of pelagic species. High trophic-level species, such as pinnipeds and cetaceans, that are already under strain from habitat degradation and clashes with the fishery industry, may be vulnerable to changing climatic conditions because of their population size, low rates of reproduction, and highly migratory natures[3,4,5]. In particular, marine mammals may be influenced by bottom-up forcing mechanisms induced by climate change and over-fishing, causing trophic mismatches and altering essential interspecific interactions[3,4,5].

Recent research has shown that climate changes have affected species like narwhals, elephant seals, and Stellar sea lions by altering prey availability, foraging patterns, and maternal attendance[3,4,5]. These changes may reduce the ability of these species to survive and reproduce even in the short-term; however, little research has been conducted to address these possible effects. To complicate matters, research on many pinnipeds and cetaceans is scanty; we have little knowledge of their migratory and foraging habits[2,6,7]. Comparative baseline data on distribution and foraging behavior can be formed by integrating historical data from fishery observations with more recent data from satellite monitoring programs, such as TOPP, the Tagging of Pacific Pelagics Program[3,5,6]. Research in this area is increasing slowly, but adequate conservation measures cannot be implemented without a comparative baseline and accurate data on how changing climate is affecting distribution and foraging behavior.

RESEARCH: I will examine the impacts of climate change on target species of cetaceans and pinnipeds in the eastern North Pacific. I will use satellite tagging in conjunction with the TOPP Program, and/or the University of Washington's Polar Science Center (PSC). TOPP is integrating data collected on twenty target species, including pinnipeds and cetaceans, to identify relationships between complex behaviors and physical oceanography[6,7]. The PSC is researching changing arctic environments and the effects on arctic marine mammals[3,8]. My research will serve the dual purpose of tracking environmental changes in the oceanic water column using pinnipeds and cetaceans as autonomous ocean sensors and of providing data on the influence of climate-induced habitat change on the behavior and ecology of marine mammals.

Research questions:

- **Environmental variables:** Which environmental variables in marine ecosystems will correlate most closely with marine mammal migratory behavior, foraging ecology, survival and reproduction? How do changing oceanographic variables influence trophic interactions?
- **Foraging Ecology and Distribution:** Are climate-induced changes in environmental variables altering the distributions and migratory patterns of marine mammals? Which foraging and reproductive behaviors of marine mammals are most likely to be influenced by climate-induced habitat change? What are the implications of changing behavior on survival and reproduction?

Hypotheses:

- **Environmental variables:** Target species of cetaceans and pinnipeds will exhibit habitat affinity for oceanic water masses with specific physical characteristics (such as SST, thermocline depth, density, etc.). Furthermore, bottom-up forcing will alter distribution, foraging, and migratory

behavior of target species. Oceanographic data from cetacean and pinniped satellite tags will improve climate change modeling by providing data for areas that are inaccessible to other methods of data collection due to sea ice, depth, etc.

- **Foraging Ecology and Distribution:** Target species will display changes in distribution, migration, and foraging and reproductive behavior in response to changing climatic conditions. These behavioral changes will influence the ability of target species to survive and reproduce.

Methods:

- **Environmental variables:** Satellite tags will monitor oceanographic variables (SST, thermocline depths, salinity, etc.) and target species behavior and physiology (migration routes, foraging vectors, body temperature, dive depth and time, etc.). Principal component analysis (PCA) can reduce complex multidimensional data sets and Bayesian probability can be used to analyze data with a high degree of uncertainty; both may be used to determine the magnitude of oceanographic changes and evaluate how closely these changes are linked to changing climate. Comparisons with related studies will be conducted to determine short- and long-term trends.
- **Foraging Ecology and Distribution:** Foraging behaviors and distribution will be studied at both fine-scale and large-scale levels, using methods such as dive analysis, fractal analysis, and/or correlation analysis. Fisheries catch data will be analyzed to determine changes in prey distribution and availability and the links to changes in climate and bottom-up forcing mechanisms. Haul-outs of pinnipeds and observations of calves and calving grounds of cetaceans will be conducted to determine the impacts of changing foraging ecology and distribution on survival and reproduction.

PROJECT DELIVERABLES: The results will be published in the appropriate peer-reviewed scientific journals and presented at relevant scientific meetings. Also, the results can be integrated with the TOPP Program (www.toppcensus.org) to show how changing climate is influencing marine mammals' behavior and distribution. Since this research is highly relevant to ongoing studies on climate change, the findings will be integrated into larger-context climate and ecological models. A summary of the results and conservation implications will be distributed to relevant management and conservation agencies. It is also imperative to distribute the findings to the wider public, especially the implications of climate change on species conservation. To this end, the findings will be published in related general interest periodicals and trade magazines, as well as being presented via various media outlets, including related television programs and websites.

CONCLUSION: My goal is to investigate links between broad-scale climate change and marine mammal distribution and trophic interactions. I will combine recognized research methods and cutting-edge technologies, like satellite tracking, to provide essential information on the impacts of climate change on marine ecosystems. Considering that the climate is expected to continue changing at least throughout the next century due to carbon dioxide emissions, this research is not only timely, but crucial if we intend to protect populations of sensitive marine mammals.

1 IPCC (2007) *Climate Change 2007: Synthesis Report.* **2** Harley CD et al. (2006) *Ecology Letters* 9: 228-241. **3** Laidre KL et al (2008) *Ecological Applications* 18:S97-S125. **4** Soto KH et al (2006) *Marine Ecology Progress Series* 312:277-290 **5** Trites AW (2007) *Fisheries Oceanography* 16:46-47. **6** Block BA et al (2003) *Oceanologica Acta* 25:255-266. **7** Boehlert GW et al (2001) *Journal of Atmospheric and Oceanic Technology* 18:1882-1893. **8** Laidre KL et al (2007) *Oceanography* 20:30-35.