Identification of Foraging in Northern Elephant Seals Using
Archival GPS Tags and State-Space Models

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Project Summary

Foraging behavior is key to understanding the ecological role of marine predators. Many of the techniques available to terrestrial biologists are not feasible in the marine environment. To investigate the foraging behavior of the northern elephant seal (*Mirounga angustirostris*), I will use state-of-the-art geographic positioning system tags to acquire movement data at unprecedented spatial and temporal scales. Upon recovery of the tags, I will incorporate the spatial data into a state space model. This technique combines multiple random walks using markov chain monte carlo simulations in a Bayesian framework. Utilizing past tracking data, and validation using foraging data from a related species, this method will identify distinct behavioral states with respect to movement and foraging. I will collect additional tracking data on individuals over a two-year period to investigate variation in these states at a variety of temporal scales. These data will reveal foraging locations, spatial scale(s) of search effort, the degree of intra-specific behavioral plasticity, and the potential for resource partitioning.
Project Description

Determining how predators perceive and move through their environment in search of prey is essential to the understanding of their ecological role and their limitations as foragers. The distribution and identity of prey, the location and extent of foraging activity, and specific search strategies have revealed important insights into the trophic structuring of many terrestrial and near-shore systems (Riedman and Estes 1988, Lode 2000). In many terrestrial species (e.g. Jedrzewski et al. 2001) these processes have been studied through direct observation, radio-tracking, and stomach temperature loggers. Clearly, a large repertoire of techniques is available to researchers; however, the marine environment affords unique challenges to the study of feeding behavior, limiting the number of tools available. Extreme depths, long migration routes, and patchiness of prey resources all limit the feasibility of traditional methods to study most marine mammals.

Remote tracking data has proven to be invaluable for species that are not amenable to direct techniques. Movement models derived from this tracking data quantify a track by incorporating step length and turning angle into simple output parameters. These models have traditionally relied on the assumption that a single model and associated distributions could adequately classify the entire repertoire of movements or behaviors over the time scale of interest. These methods, such as correlated random walks, also make the assumption that the animal exists in a completely homogeneous environment. This may be an adequate description of movement for terrestrial grazers (although even these might be too complex, see Preisler et al. 2004), but behaviorally plastic (cognitive) animals that search for prey maintaining a patchy distribution require more than one model to facilitate a larger number of behavioral states (Morales et al. 2004). State-Space models (SSM) provide a framework to incorporate several random walk models and a method to predict switching between these states (Morales et al. 2004). SSM’s depend on prior knowledge, such as positional error estimates, and thus have the potential to be much more informative (Jonsen et al., in prep.). However, as the number of model variables increase, the computational power required to
complete the analysis becomes unfeasible. Jonsen and colleagues (2003) recently bypassed this problem by solving the model in a Bayesian framework using Markov-Chain Monte Carlo simulations. This method, although mathematically complex, has been compiled into a freely available software package (WinBugs) that allows non-experts access to bayesian techniques.

The over-arching goals of this project are to reveal how elephant seals perceive their environment, what behavioral decisions or rules govern their movement with respect to foraging, and how these factors vary between individuals and through time. Specifically, I will address four questions. (1) What spatial scale(s) are elephant seals utilizing? (2) Can state-space models identify foraging behavior? (3) How many unique behavioral states do elephant seals exhibit on a single trip to sea and which parameters are associated with foraging? (4) What is the variability of the detected behavioral states at several temporal scales (single season, between-seasons, between years, and between ocean regimes) and between individuals within a population.

To investigate the foraging behavior of elephant seals I will attach newly developed Geographic Positioning System (GPS) tags to three healthy females during the winter breeding season at Ano Nuevo State Reserve, California (37.1108 N, 122.3308 W). These tags, specifically designed to withstand the extreme depths an elephant seal reaches (up to 2000m), will record tracks of at-sea locations during a three-month foraging trip to the North Pacific Ocean. The tags will be recovered from the seals upon their return to the haul-out site for their annual molt.

Data analysis will consist of two components. To identify distinct behavioral states, I will incorporate the data into a state-space model. Because the GPS tags will allow analysis at finer spatial and temporal scales than previously possible, I expect the state-space model output to reveal a higher degree of complexity in the movement of northern elephant seals. Next, to identify the spatial scales of interest, I will run the data through a First Passage Time analysis program I created in the Matlab programming language (technique based on Fauchald and Tveraa 2003). Together, these techniques will provide insight into the location, extent, and behaviors implicated in the search
for prey. This analysis may reveal several distinct foraging states (at least within a single season) that female elephant seals employ to increase prey encounter rates, implying a variety of foraging strategies. The analysis may also reveal behavioral plasticity within the females of this species: revealing the potential behavioral effect of future perturbation. Further research may be able to extend the utility of the foraging models developed in this study to include potential affects on prey communities, such as density or demography, enabling a broader understanding of the dynamic north pacific ecology.

All work will be conducted with the permission of the reserve manager and head ranger at Año Nuevo State Reserve and the University’s Chancellors Animal Research Committee. My advising professor, Dr. Daniel Costa, has obtained all permits as required by the Marine Mammal protection Act. All work will be conducted with an experienced team of pinniped researchers, graduate students, and/or field assistants.

References


**Budget**

<table>
<thead>
<tr>
<th>Item</th>
<th>Requested funding from Myers Grant</th>
<th>Total project budget</th>
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<td>Graduate fees</td>
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**Budget Justification**

**Salary:**
I will be funded jointly through graduate student researcher (GSR) and teaching assistantship (TA) positions.

**Graduate fees:**
University fees will be paid from the GSR and TA positions.

**Supplies:**
Anesthetizing drugs, syringes, needles, saline solution, epoxy, etc. I am also requesting funding for blood tubes and storage tubes to facilitate a blood banking project underway for all study animals and possible future genetic analysis.

**GPS tags:**
Several manufacturers are developing commercially available GPS tags for marine use. These tags are expected to cost approximately $3,300 per unit and will be available for purchase within the next several months, enabling a testing regime prior to deployment. These tags will be purchased jointly by myself and my advisor. (If funding is supplied from my advisor, the data will likely be incorporated into the Tagging of Pacific Pelagics database).

**VHF tags:**
These tags are necessary to locate the animals upon their return to Ano Nuevo. MM160 elephant seal VHF transmitter tags will be purchased through Advanced Telemetry Systems, Inc.

**Re-battery charge:**
The batteries inside the VHF tags will be replaced by the manufacturer after each deployment to ensure successful recaptures.

**Field equipment:**
My lab is equipped with all remaining field equipment necessary for this project (e.g. tripod and scale for weighing, VHF receivers, portable ultrasound for blubber measurements, etc.)

**Travel:**
My lab is equipped with a dedicated vehicle for field research.