I plan to develop a new model that will provide the first assessment of bioenergetics for Weddell seals (*Leptonychotes weddellii*). I will perform a sensitivity analysis of model parameters and test model predictions using data collected from Weddell seals on their breeding grounds. I predict that changes in prey availability will greatly affect reproductive costs by decreasing foraging efficiency during a critical period for mass gain, and that the energy requirements for breeders will be much higher than those of the non-breeding seals.

Background: Pupping, molting and foraging are key components of the delicate balance between energy influx and efflux in mammals. Phenology of these components can impact population health by causing differential responses between predator and prey, thus decreasing foraging success and increasing both baseline and reproductive costs in predators. These effects are magnified in long-lived, k-selected species with specialized foraging ecologies and heavy reliance on unstable habitats. One particularly susceptible species, the Weddell seal, shows variation in survival rates and reproductive success, perhaps due to changes in sea-ice extent and prey availability associated with climate change and fishing pressures. Weddell seals spend >50% of their time foraging throughout the year in order to maintain lipid stores that are necessary for energetically-demanding breeding in Oct/Nov and subsequent molting in Jan/Feb[1].

In scenarios with challenging environmental conditions and/or altered prey availability, seals are required to increase their foraging effort (and therefore energy expenditure) in order to fulfill their gross energy requirements. For instance, during large scale climate oscillations, lower surface pressure gradients lead to higher sea surface temperatures, decreased sea-ice extent, delayed and lower magnitude phytoplankton productivity, and potentially reduced prey availability. Further, there exists a bio-energetic advantage of consuming higher trophic level pelagic fishes such as toothfish (*Dissostichus mawsoni*), which contain higher lipid and caloric densities, over lower trophic level benthic fishes, which contain lower lipid and caloric densities. Overfishing of high-energy prey items could lead to reduced prey availability and a dietary shift to low-energy prey items, which would force seals to compensate by increasing the duration of their foraging trips. Unfortunately, Weddell seal foraging overlaps spatially with the Antarctica toothfish fishery, which harvests ~3,500 metric tons of toothfish annually for human consumption[2]. Model scenarios must be simulated in order to understand potential consequences of shifts in phenology. Though energetic intake and output of pinnipeds have been studied at the individual and population levels, many of the existing models fail to consider energetic costs on a daily level, and as such, are insufficient to estimate energetic costs associated with fine scale changes in phenology and/or foraging success.

Methods: I will model the energy balance of free-ranging Weddell seals by simulating daily Gross Energy Requirements (GER) using the following framework[3]:

$$GER = \frac{Production + (Activity \times Maintenance)}{HeatIncrementFeeding \times Fecal \times Urine} + Reproduction + Molt$$

The model will be implemented in R and will rely on input parameters that are functions of other variables, as follows: *Production energy* will use seasonal mass change values and a published length-at-age curve to account for daily mass changes due to growth; *Activity energy* will be based on multipliers of basal metabolic rate for land/water[4], the proportion of time spent in the water, and the duration of each dive; *Maintenance energy* will consist of resting metabolic rate; *Reproduction energy* will add the energetic costs of gestation and lactation to the requirement of non-reproductive individuals; *Molt energy* will be comprised of the cost of hair biosynthesis and added thermoregulatory costs; and lastly, the model will account for energy losses due to indigestible (*Fecal*) or unmetabolizable (*Urine*) energy and the metabolic rate increase during digestion (*Heat Increment of Feeding*). Published values specific to Weddell seals are available for all model parameters aside from activity budget and seasonal mass changes.

I, and a team of researchers, will obtain values for the remaining parameters from adult, female Weddell seals (N=72) in McMurdo Sound (Antarctica, -77.62° to -77.87°S, 166.3° to 167.0°E) during three subsequent breeding (Nov/Dec) and molt (Jan/Feb) seasons. We will sedate known age, multiparous females in three categories: Early Breeders, who give birth in the first quartile of the pupping distribution; Late Breeders, who give birth in the last quartile of the pupping distribution; and Skip Breeders, who have previously pupped but are not parous in a given year. Target subjects will be selected based on an existing database of age and reproductive history. Each seal will be weighed using an electronic scale. To elucidate temporal foraging patterns during the period between reproduction and molt, I will instrument each seal with a flipper tag time-depth recorder, and small VHF tag to facilitate relocation. Monte Carlo simulations will be used to employ proper mathematical distributions and predict a range of energetic requirements for each model component by incorporating parameter variability. To determine how changes in parameters would affect the model predictions, I will perform a sensitivity analysis by systematically incorporating uncertainty into individual parameters while holding the other parameters constant at their median values.

During the Jan/Feb molt, I will conduct semiweekly demographic surveys to quantify the extent of hair loss in all flipper-tagged animals. These data will be combined with reproductive performance in $Year_{(t-1)}$,$Year_{(t)}$, and $Year_{(t+1)}$ based on sighting data. The demographic data provide sufficient power for the determination of realistic molt timing scenarios, while the smaller sample of handled seals is essential for obtaining physiology parameters. I will use the model to simulate scenarios of all combinations between early breeding, late breeding, early molting and late molting. These scenarios simulate shifts in foraging timing and/or changes in the duration of foraging that could result from severe climate patterns.

Predictions: Breeding, molting, and foraging patterns will likely result in large fluctuations in total energetic requirements[4]. As such, a decrease in food abundance or change in taxonomic composition resulting from climate change and/or fishing pressure would greatly affect reproductive rates by decreasing foraging efficiency during a critical period for mass gain[5]. Since breeding seals can reach a body mass about 1.5 times a non-breeder, and daily food requirements for lactating females[5] are likely >60% greater than those without pups[3], the energy requirements for breeders will be higher than those of the non-breeding seals.

Broader Impacts: The bioenergetics model can be applied to other species with similar life history characteristics. Values obtained through this project will be disseminated in peer-reviewed publications and presentations at scientific conferences. I will gain valuable experience as a mentor by supervising one undergraduate student through the NSF Research Experience for Undergraduates program. In addition, I will utilize my background in educational interpretation to develop an educational module for biology teachers that will allow for integration of mathematical modeling and bioenergetic concepts into high school classrooms. Lastly, my results will supplement a PolarTREC teacher in preparing interpretation exhibits and constructing participatory activities for students.

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