The role of diet, physiology, and behavior in thermoregulation and population growth of the invasive monk parakeet (*Myiopsitta monachus*)

Key Words: ***diet, fat, invasive, Myiopsitta monachus, thermoregulation, torpor, roosting***

Endotherms which have invaded cold climates pay a high price energetically, which many seek to minimize by strategically storing food as fat, entering torpor, or both. Fat selection has been widely studied in mammals that enter torpor. Surprisingly, this phenomenon is completely unstudied in birds, despite the importance of torpor to the survival in cold climates of the smallest birds (e.g., hummingbirds and tits). Mammals using torpor select diets richer in polyunsaturated fatty acids (PUFAs) than saturated fats, due in part to unsaturated fats' ability to stay liquid at cooler temperatures,[1] thus remaining functionally available as core body temperature decreases. Mammals that enter torpor with relatively high levels of PUFAs attain lower body temperatures, enter torpor for longer periods, and lose less mass during torpor.[2] A study examining the dietary fat selection and metabolism in migratory song birds, has found that the elevated PUFA make-up of their fat stores before migration is directly related to their diet.[3] However, there is a cost to metabolizing high levels of unsaturated fats: more free-radicals are released into the body due to increased lipid peroxidation.[4] Mammals that enter torpor also have an added free-radical load due to the oxidative stress that comes from arousal from torpor due to an over-production of reactive oxygen species.[5] It is presumed that birds react much the same way, but there is no published evidence to support this idea.[6] Preliminary results from an ongoing study suggest that migrating song birds prefer foods high in antioxidants, presumably to counteract the effects of oxidative stress from prolonged PUFA metabolism during migration.[7] Investigating the link between diet and torpor is fundamental to understanding cold adaptation in birds.

Monk parakeets (*Myiopsitta monachus*) present a particularly interesting case study. Introduced to North America by the pet trade, escaped monk parakeets have established multiple disjunct populations, some of which are larger, and growing faster, than others. In their native range, they are considered crop pests. Furthermore, their predilection for building nests on utility poles has caused many power outages and fires, creating a public safety hazard, and significant costs for utility companies. Lethal methods of control of the birds has caused public controversy, accompanied by lawsuits and attempts to establish legal protection for them in the United States. Since monk parakeets are largely sedentary,[8] they have isolated populations in the United States. Some are established in areas much colder than in their native range in South America (e.g., Chicago), while others have settled in areas that are warmer, on average, than their native range (e.g., Florida). The birds are capable of lowering their metabolic rate in the cold,[9] build large stick nests that may have considerable thermoregulatory benefits,[10] and roost gregariously, characteristics unique among parrots. During the winter in the U.S., their primary food source is bird seed from backyard bird feeders.[11] Since sunflower seeds make up the bulk of commercial bird seed mixes and are high in unsaturated fat, access to this food source may be critical to their survival in climates colder than their native range.

Using this species as a model system, I will evaluate the physiological limits of torpor, and assess the contribution of communal roosting, and the use of large nests to thermoregulation. I will also evaluate how the availability of specific fat types and antioxidants affect population growth and range expansion in different climates. I will conduct comparative behavioral studies of wild populations of monk parakeets in their native range, and in the U.S.. Finally, I will study captive birds in the lab under different diet, roosting, and temperature conditions. My hypotheses are:

H1: Monk parakeets will select a diet that is higher in PUFAs than saturated fats in a cold climate. Using captive birds from both warm and cold acclimated wild populations I will measure the percentage of PUFAs consumed and proportion present in body fat samples given free diet choice under experimental conditions manipulating ambient temperature (T_a), number of roosting birds, and access to a nest. I will also compare diet, body fat composition, and behavior in different wild populations. The captive experiments will also determine the physiologic limits of torpor in monk parakeets. I will use a Bayesian hierarchical regression to analyze the data compiled to test this hypothesis.

H2: The thermoregulatory benefits of both roosting and the nests will decrease the monk parakeets' dependence on unsaturated fat in colder climates. I will evaluate a nest's ability to reduce radiant heat loss, and compare the T_a at which the birds enter torpor with and without the nest in both controlled lab experiments and field study. I will also quantify, in lab birds in nests, core body T across a range of T_a. Using a similar approach, I will evaluate the thermoregulatory benefits of different numbers of roosting birds. I will evaluate the response to both nests and roosting partners given different diets (i.e. free choice v. high PUFA v. high saturated fat). I will use a Bayesian hierarchical regression or ANOVA (as appropriate) to analyze the data compiled to test this hypothesis.

H3: Monk parakeets will have higher population growth in areas where access to PUFAs and antioxidants are not limited, and/or climate is mild. I will compare the diet, behavior, population growth, and range expansion among different wild populations. I will analyze the data on past population growth (from Christmas Bird Counts and the Summer Breeding Bird Atlas) using a Bayesian hierarchical Poisson model and a Bayesian hierarchical logistic model to analyze range expansion.

Broader Impacts: My proposed investigation will be the first to assess the importance of unsaturated fats for achieving torpor in any bird. The introduction of monk parakeets provides a unique opportunity to study how behavior, physiology, and diet selection may interact in facilitating range expansions into cold climates. This information is not only important a basic understanding of the physiology of cold-adapted birds, but may also be useful in constructing predictive models of population growth and range expansion of monk parakeets in the future. Such predictive models would be useful in guiding management decisions and informing public policy regarding the control of this species. Given the spatial isolation among monk parakeet populations and their apparent ability to adapt to varying climates and environments, I will be in the rare position of studying a species in the act of adapting to different selective regimes, which may be forcing rapid evolutionary divergence among populations.

I already have a significant track record of working with the public and the utility companies most impacted by these birds. I will continue to educate and collaborate with utility companies, animal rights groups, and non-profit avian conservation organizations. I will also continue to use my website (www.eeb.uconn.edu/people/burgio) as a platform for engaging citizen scientists and teachers, and managing volunteer efforts, outreach, and education. As a Ph.D. student at the University of Connecticut, I am in an ideal position to conduct this research under the direction of M. Rubega and C. Elphick.

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