Project summary
The study of migration is a burgeoning area of scientific research due to the fascination of humans with this often spectacular biological phenomenon, technological advances in animal tracking systems and analytical methods, and the ecological importance of migration and its dramatic, global decline. Despite this biological and cultural significance, the evolution, mechanisms and maintenance of migration remain poorly understood and fundamental questions remain, such as under what combinations of individual traits and environmental conditions is migration an optimal movement strategy and why do partial migratory systems exist. Answering these questions is difficult because migration often involves large numbers of animals travelling over vast distances and is influenced by environmental, physiological, and life history factors that rarely act independently. The study proposed here will take advantage of a tractable "model" system recently documented by the research team, namely giant tortoise migration on the Galapagos Islands.

Galapagos offers an unprecedented opportunity to elucidate the drivers of movement due to the radiation of genetically and morphologically distinct taxa that have evolved under very different environmental conditions contained within a restricted geographical area. Building on recent work of project personnel that has demonstrated the feasibility and utility of Galapagos tortoises for migration research, the proposed study will address four key questions: (1) What are the environmental and ecological drivers of migration?, (2) What are the life history and physiological traits that determine when, where, how and why an individual will migrate?, (3) In partially migrating populations, does migration confer health and reproductive benefits over sedentarism?, (4) How is anthropogenic environmental change likely to impact migration and how can migration best be sustained?

To answer Question 1, the movements of adult tortoises from four different taxa on three islands will be tracked via GPS tags while tortoise range dynamics at the population level will be investigated through replicated transect surveys. Latent state models will be developed to characterize movements and assess the potential of environmental covariates as drivers of migration. Answers to Question 2 will derive from developing models that integrate the effects of environment, allometric scaling relationships, and life history priorities on movement and which are refined as empirical data become available from population distribution data, tortoise movements, and environmental, physiological and life history covariates. Responding to Question 3 will involve integrating data on health and reproductive status of migrating and non-migrating tortoises into movement analyses. Question 4 will be answered by incorporating current and projected human impact variables (transportation infrastructure, land use, invasive species and climate) into movement models to predict future migration scenarios.

The proposed program has outstanding intellectual merit resulting from the novel approach of integration into a single, analytical framework of movement of individuals and population-level data from multiple, closely related species living under very different environmental conditions. This approach will generate data-rich models to elucidate the drivers of migration and thereby answer long-standing questions of how and why animals move in response to environmental, physiological and life history constraints. This project will also generate important insights about the remarkably poorly known ecology of Galapagos tortoises, both the largest terrestrial ectotherms and, for several species, endangered with extinction.

Integral to the success of this project are its broader impacts that include (1) development of a Galapagos Education Partnership using tortoises as the vehicle to introduce 120 teachers and hundreds of school-aged young people to ecology and conservation both in the US (ethnically diverse, urban populations in Syracuse, St. Louis and Houston areas) and in Galapagos, (2) undergraduate and graduate training in ecological research, (3) international data sharing through the NSF-funded Movebank.org, (4) and translating science into management via direct interaction with key policy makers of iconic species and ecosystems.