Drivers of flammulated owl movement behaviors in Colorado

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This proposal pertains to an ongoing, multi-year project for which DFO has provided support in previous field seasons. As such, much of the background and methods are substantially similar to previous proposals, though are somewhat abbreviated in order to also include a brief description of associated (and concurrently performed) research aims that would also be supported by this proposal, if awarded.

The ideal free distribution predicts that animal abundances across sites will be proportional to the available resources in each site[1]. By extension, this implies that an animal's site selection accounts for the quantity of available resources in any given location leading naturally to optimal foraging theory and marginal value theorem. Taken together, these theories posit that optimally foraging animals move to maximize net energy intake[2,3]. Because animals do not always adhere to optimal foraging strategies[4], animal movements alone are insufficient to infer habitat quality. In other words, preferred habitats may be decoupled from prey availability.

In Colorado, flammulated owls (*Psiloscops flammeolus*) preferentially select Douglas-fir (*Psedotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) trees that are older and with larger live crown volumes when choosing home-ranges[5] and, at finer scales, foraging and roosting locations[5,6]. Furthermore, the proportion of preferred habitat found within a breeding territory may influence lifetime reproductive success[7] and breeding dispersal strategies[8]. However, the underlying reasons for this preference remain poorly understood. Prey abundance is a potential driver of the apparent preference for older forest stands. Lepidoptera comprised the majority of owl prey brought to nests during the breeding season in studies in Colorado[9] and Idaho[10].

In order to test the hypothesis that prey availability drives foraging habitat selection in flammulated owls, I am building a landscape model of prey availability (characterized as both relative abundance of putative prey and caloric value of putative prey) that can be used as a covariate in subsequent movement models fitted to archival-GPS data collected at the Hot Creek Research Natural Area (RNA) on the east slope of the San Juan Mountains in southern Colorado.

Methods. For the past three summers I have conducted habitat-stratified blacklight sampling targeting the owls' suspected primary prey: nocturnal lepidopterans[9]. Samples have been sorted to family and counted to estimate relative abundance by family. I will use bomb calorimetry to determine the per-moth caloric content by family.

Stable isotopes can be useful in determining the diet composition of organisms[11]. We recently completed C and N isotopic analyses which suggested that major lepidopteran families in our study area were isotopically indistinct. H and O analyses are ongoing to determine the geographic origin of captured moths (since some portion may be migratory). Because isotope-based mixing models of owl diet are unfeasible given the strong isotopic overlap in potential prey sources, I will filter blacklight samples to match published diet compositions for the species. I will then construct an interpolated landscape of owl prey availability which will become a covariate for subsequent movement models.

Using integrated step selection analysis, I will evaluate multiple candidate hypotheses about owl movement (e.g., random walk, Orenstein-Uhlenbeck models and/or movement driven by environmental covariates such as covertype or prey availability). This will provide an empirical test of whether owl habitat preferences are consistent with optimal foraging theory.

Seasonal Movements: There are geographic and seasonal biases in where and when ecological research is conducted[12]. One result of these biases is that much avian research is focused on the breeding season in the Northern Hemisphere[12–15]. However, non-breeding phases of an organism's life cycle may comprise the majority of an individual's lifetime and conditions experienced during one phase may interact with outcomes during other phases[13,16,17]. Therefore, it is critical to consider an organisms' full-annual cycle when examining, for example, population demography, evolution of life-history traits, or seasonal migrations[18–20].

In addition to the local-scale aims described above, the Hot Creek study area is also part of a continent-wide network of sites that I manage aimed at better understanding migration in the species range-wide (other sites in Teller County, CO; Manzano Mtns,. NM; Wasatch Front, UT; South Hills, ID; and Michoacan, Mexico). Specifically, this network seeks to understand migratory connectivity in the species and to understand the ecological drivers of long-distance movements as well as their timing. Work performed on the local-scale questions informs question about how prey availability influences full-annual phenology. We also use Hot Creek a site to deploy and recover archival GPS tags which document the species' migration with high spatial resolution. Specifically, up to 8 GPS tags are currently deployed on birds from Hot Creek with the potential to be recovered and more will be deployed during the 2020 field season.

We also collect feathers at Hot Creek for use in isotope-based geographic assignments. Stable isotopes provide a useful intrinsic marker of geographic origin in birds (whose feathers remain metabolically inert once grown, thus preserving the isotopic signature that was incorporated at the molt location[21,22]). We are developing an isoscape for flammulated owls using δ^2H measured from feathers collected from owls at known breeding locations. Flammulated owls putatively molt all remiges on their breeding grounds in late summer meaning that δ^2H measured from remiges collected from birds with known summer locations represents a local signal. The feathers for this analysis are coming from the same network of sites described above as well as museum specimens collected at known summer locations.

Once the assignment isoscape is completed, we will determine the breeding origin of previously collected specimens that were captured on the non-breeding grounds. For this analysis, we use feathers from museum specimens originally collected during the non-breeding period. The isotopic signature in those feathers represents the breeding location for that individual. The isotope-inferred location and the initial collection location have effectively reconstruct a single migratory track for that individual which contributes to migration analyses.

Project Location: Hot Creek RNA, Rio Grande National Forest, Conejos County, CO.
Timeframe: Overall project: 2016—2020. Field season: late May to early August.
Amount Requested: $2,000 to partially fund a field assistant.
Budget Justification: This project is supported by a Challenge Cost Share between the USFS and Colorado College (CC). Other direct support comes from Colorado College (CC) in the form of equipment and field support and the Smithsonian Institute's (SMI) Migratory Connectivity Project. I am requesting $2,000 to cover the stipend and living expenses for one of two research assistants. CU Denver supports a large proportion of non-traditional, historically under-represented, and low-income students many of whom work, making full-time volunteering at a remote study site >4 hours from campus unrealistic. This money will allow me to pay up to two undergraduate students as a seasonal field assistants. These assistants are not only vital to the project but also receive invaluable hands-on education during the summer.

Budget:

Year	Item	Description	Status	Cost
2020	**Field Assistant 1**	**Stipend and reimbursable expenses for field assistant**	**Requested from DFO**	$2,000
	Field Assistant 2	Stipend and reimbursable expenses for field assistant	Requested from other sources	$1,500
	Field Equipment	E.g. Banding equipment, moth traps, solar charger	Funded – USFS + Colorado College Cost Share Agreement	In-kind + $4,000 (over 5 years)
	GPS Trackers	Lotek Pinpoint GPS trackers	Funded – Migratory Bird Connectivity Project	In-kind

Conservation Outcomes: This research applies to a widespread forest type and will provide valuable information to land managers across western North America. I am collaborating with the USFS on this project and have conducted field tours with land managers, resource specialists, and fire personnel to increase awareness of the role of wildfire in this ecosystem. I anticipate a management-oriented manuscript based on this research and will continue to leverage my existing relationships with the USFS to disseminate publications, attend speaking engagements, and offer field visits. The migration project is a collaboration with the Smithsonian Institute, Migratory Bird Center that will contribute to globally-scaled strategies for bird conservation in light of climate change. Finally, animal movement data is used for a variety of purposes such as species conservation, mitigating human-wildlife conflict, resource management, and basic research questions. Our novel approach to explicitly link spatial patterns to generating behaviors has the potential to improve the available tools within this field.

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