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Using Behavior and Demographics to More Accurately Model Habitat Selection in Bighorn Sheep, with Implications for Conservation Corridors

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I. Summary of Proposed Project

Priority corridors for conservation are often identified using habitat selection models. However, corridors are generally used while animals are engaging in movement behaviors like dispersal and migration, and habitat selection may differ significantly during these behaviors. This study addresses how habitat selection differs during movement behaviors across demographic classes, using Rocky Mountain bighorn sheep (*Ovis canadensis*) as a focal species. Habitat selection data will be collected for one year using GPS collars and divided based on behavior and demographic class. Models will be developed in ArcGIS Pro using resistance surfaces and factorial least-cost path analysis. Models will be tested using a second year of telemetry data, camera traps, and transects for feces, tracks, and live sightings. Model suitability will be compared using ANOVA and intersection analysis. This work is significant because it uses behavioral data to improve an ecological modeling approach and has serious management implications.

II. Introduction

The way that animals move across a landscape includes several complex behaviors. Dispersal, the movement from one breeding or rearing site to another, varies dramatically between species and has major consequences for life history and population dynamics. The individuals that undergo dispersal are often of a specific demographic class[1] or of a particular personality type[2] instead of representing an even cross-section of the population. Migration, the seasonal movement between ranges, is another movement behavior critical to many species for access to seasonal forage. Individuals that are undergoing movement behaviors (including both dispersal and migration) may select habitat differently than individuals looking for suitable forage or breeding grounds, but still have requirements for shelter and are impacted by anthropogenic habitat changes.[3,4] The ability to disperse and migrate is important for utilizing resources and maintaining gene flow between populations, preventing inbreeding and the 'extinction vortex' that can occur in small, isolated populations.[3]

Population movement relies on the connectivity of habitat between different patches of suitable habitat. Unfortunately, habitat loss and fragmentation is one of the major anthropogenic causes of the current worldwide biodiversity crisis.[5] A number of global conservation projects, including a bill currently in congress in the US, look to increase the effective size of threatened populations by creating corridors or stepping stones that link small populations into metapopulations.[6] The ability to accurately identify functional corridors is a management priority. Since the early 2000s, modeling techniques like least-cost (LC) modeling have been used to predict what areas are important corridors for different species based on species-specific 'resistance values,' which represent how likely an individual is to move through a specific type of habitat.[7] However, these models often fail to take into account realistic variations in animal movement behavior, leading to poor predictions of actual corridors.[8] Many strategies for improving models have been proposed and attempted, including incorporating demography-specific habitat resistance data[1], using only habitat preferences of 'traveling' individuals[9], and looking at data from a range of more- and less- disturbance averse species[10]. These improvements require continued refinement and extensive behavioral data collection in order to develop functional models for the wide range of species that are current targets for corridor-based conservation.

Rocky Mountain bighorn sheep *(Ovis canadensis)* are North American herd-dwelling grazers that occupy only 30% of their historic distribution and are a target of connectivity-oriented conservation in several areas in the US due to their specific habitat needs and decreasing numbers[11,12]. They are relatively poor colonizers and dispersers [13], but many

populations do undergo seasonal migratory movements[14]. Sedentary behavior is associated with population decline in bighorn sheep populations[12], so maintained ability to undergo migratory movements seems to be important for their persistence. Male bighorn sheep are more likely to disperse than females[11] and females are often pregnant or with young during migration[15] so a model based on habitat preference of all individuals is unlikely to accurately identify their corridor use. Bighorn sheep are one of the species of concern for the Upper Rio Grande Wildlife Initiative, a group of organizations working to maintain connectivity in the Upper Rio Grande region of Colorado and New Mexico.[16] However, their relatively large numbers in the Upper Rio Grande area[17] make them a more viable species for study than other species of interest in this region, like the rare and elusive Canada Lynx (*Lynx canadensis*). While studies on all species of concern in this area should eventually be combined to identify all corridors of significance, that is outside of the scope of this project.

In this study, we will develop a set of models for habitat preference of bighorn sheep based on telemetry data and satellite images of groundcover. One set of models will be based on habitat preferences of individuals performing movement behaviors (dispersal and migration) and a second set will be based on demographic classes (adult males and adult females). These will be used to develop resistance surfaces and factorial least-cost models in order to identify corridors that should be prioritized for protection in the Upper Rio Grande Area. We will then assess the relative accuracy of these models through continued telemetry and camera trap monitoring. This will help determine what selective modeling strategies are most accurate. Our models can also be applied in other areas where bighorn sheep population connectivity is a concern.

III. Hypotheses to be tested

1. Dispersing and migrating bighorn sheep will select habitat differently than non-dispersing individuals.
2. Least-cost path modeling based on dispersing and migratory behavior habitat selection will better predict actual corridor use than models based on all habitat selection.
3. Alternately, adult males (the most likely demographic classes to disperse) will select habitat differently than adult females (who may be choosier due to nutritional needs).
4. Least-cost path modeling based on one specific demographic class, either adult males or adult females, will predict actual corridor use better than models based on combined demographic classes.

IV. Proposed research

During the first summer season, 25 adult males and 25 adult females from the Upper Rio Grande herd will be trapped using helicopter netting and fitted with GPS collars. GPS location data will be collected for 10 months and downloaded using GPS/GSM[18] through the migratory seasons, to get an accurate sense of habitat use in winter and summer ranges and during migration. These data will be separated based on type of movement: migratory movements (classified as movements resulting in a change of >500m elevation in <30 days[19]) and dispersal movements (classified as movements resulting in daily displacement of 1.4km or greater[20]) will be separated from other location data. Separately, the data will be sorted based on demographic class, with adult males and females separated.

Combined with land cover data from the National Land Cover Database[21], GPS data will be used to define habitat use resistance coefficients for the different behavioral and demographic classes. We will develop resistance surfaces for the different behavioral classes: One for dispersal, one for migration, and one combined model for all behaviors. We will also develop resistance surfaces for the different demographic classes (male and female) using a combination of all behaviors. For each of the 5 models, we will predict corridors using factorial least-cost modeling. Modeling will be performed using ArcGIS Pro 2.5[22].

For the following 10 months (July-April) we will continue to collect GPS data. 10 camera traps will also be placed: One in each of the two most likely corridors identified by each of the

five models. Camera trap detection levels will be compared using ANOVA between corridors identified by the different resistance surface models. Each of these ten corridors will also be monitored monthly for direct and indirect signs of bighorn sheep: a transect will be performed at a right angle to the proposed corridor, counting tracks, feces, and live sightings of sheep. The abundance of each of these will be compared using ANOVA between the corridors. Corridor use as identified by a combination of these detection methods and GPS data from the second year will be compared between corridors modeled using the different resistance surfaces. Similarity of corridors will be compared via intersection analysis[1] in order to determine which model best predicted actual habitat selection and corridor use. All statistical analysis will be performed in R.

Trapping and collaring sheep will be the most labor intensive and logistically challenging phase of the project. This will be supported by helicopter netting equipment and a small, experienced research team from the Rocky Mountain Research Station, along with additional funds from the Upper Rio Grande Wildlife Initiative. Almost all previously radio-collared individuals in this population have died[2,3], so these organizations are eager to start collecting location data again and happy to provide funding and personnel. Camera trap locations will be selected with advice from the Upper Rio Grande Wildlife Initiative. Camera trap placement and servicing, transects, and GIS analysis will be performed by me.

Timetable: GPS-collaring will be performed in July-August. Telemetry data will be collected for the next ten months, September through June. Camera traps will be placed in July. While the first round of data is used to develop models, GPS data collection and monthly transects will continue from July-April to test the accuracy of models. Model testing will be performed in May and June.

V. Predicted outcomes

Hypothesis one will be supported if habitat selection considerably differs between behavior classes. If models based on disperser or migratory behavior selection do a better job predicting actual corridor use, this supports hypothesis two. If habitat selection significantly differs between demographic classes, evidence will support hypothesis three. If a model based on only adult females or one based on only adult males more accurately predicts actual corridor use, this supports hypothesis four. If habitat selection doesn't differ between behaviors or demographic classes, a combined model may be appropriate. Because this data is difficult to collect, it's also possible continued data collection should be carried out to see if an improved habitat preference model can be made with multiple years of data.

VI. Importance of proposed research

Habitat selection, movement, and dispersal behaviors are heavily impacted by human-caused habitat change and challenging to study and understand. Quantifying habitat selection in different behavioral phases will contribute to our understanding of how bighorn sheep habitat selection is impacted by habitat fragmentation and loss. It also will suggest what kinds of patterns might be expected for similar sexually dimorphic, grazing, partially migratory species. On a smaller scale, our models will help determine conservation management priorities for the Upper Rio Grande herd and similar populations of bighorn sheep. If hypotheses one and two are supported, models based on behavior-specific habitat selection should be used to develop management priorities for bighorn sheep and similar species. If hypotheses three and four are supported, models based on whichever demographic class best predicted corridor use should be used to develop management priorities. No matter the results, this research will contribute to our understanding of the way habitat selection varies during movement behaviors and its potential implications for corridor conservation.

VII. References cited

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Animal Care Questionnaire

A. Does the proposed study involve endangered species or threatened populations? No

B. Does the proposed study involve trapping, netting, banding, or in any other way be potentially disturbing to wild populations? Yes. Logistical assistance and training in animal collaring will be provided by the Ecology, Ecosystems and Environment team at the Rocky Mountain Research Station, in partnership with the Upper Rio Grande Wildlife Initiative.

C. Does the proposed study involve the maintenance of animals in captivity? No

D. Describe the facilities and the animal care protocols. Be concise, but complete.

E. Will the animals be subjected to pain? (Yes/No) *If you selected Yes, have alternative procedures been considered? Please elaborate your answer, including the procedures to be used to minimize pain.

F. Will animals be killed? No