



Modeling connectivity and gene flow of American pikas in the Western United States

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Introduction

- American pikas (*Ochotona princeps*) are restricted to talus-like habitats and occupy a naturally fragmented landscape, characterized by patches of potential habitat surrounded by inhospitable terrain.
- Habitat fragmentation can lead to reduced gene flow and loss of genetic diversity. Modeling gene flow as a function of landscape resistance provides a robust framework for addressing how landscape features affect successful dispersal and population connectivity.
- We hypothesize that energy expenditure, as well as exposure to predators and extreme temperatures, limit pika dispersal.
- We test this hypothesis in 6 national parks in the western United States. Here, we present an analysis for Crater Lake National Park (Figure 1 A), in the Cascade Range of southern Oregon.

Methods

- We used a GIS with elevation and land cover data (Figure 1B, 1C) to create multiple resistance surfaces, each representing a hypothesis about landscape effects on successful dispersal and subsequent reproduction (Table 1, Figure 1 D-F).
- Land cover types were defined and ranked as 1) potential habitat (talus), 2) forested, 3) shrub/grassland, and 4) open, where lower rank implies lower resistance.
- We modeled gene flow as isolation-by-resistance (McRae 2006) using CIRCUITSCAPE (McRae and Beier 2007).
- We calculated pairwise genetic distance as Bray Curtis % dissimilarity, Rousset's A_{ij} , and PCA distances. Here we present results for Bray Curtis % dissimilarity.
- We used a 2-step optimization process using Mantel and partial Mantel correlations between genetic distance and resistance distance to determine 1) the best univariate resistance hypothesis for each landscape variable and 2) the best multivariate hypothesis combining multiple landscape variables (e.g., Shirk et al. 2010).

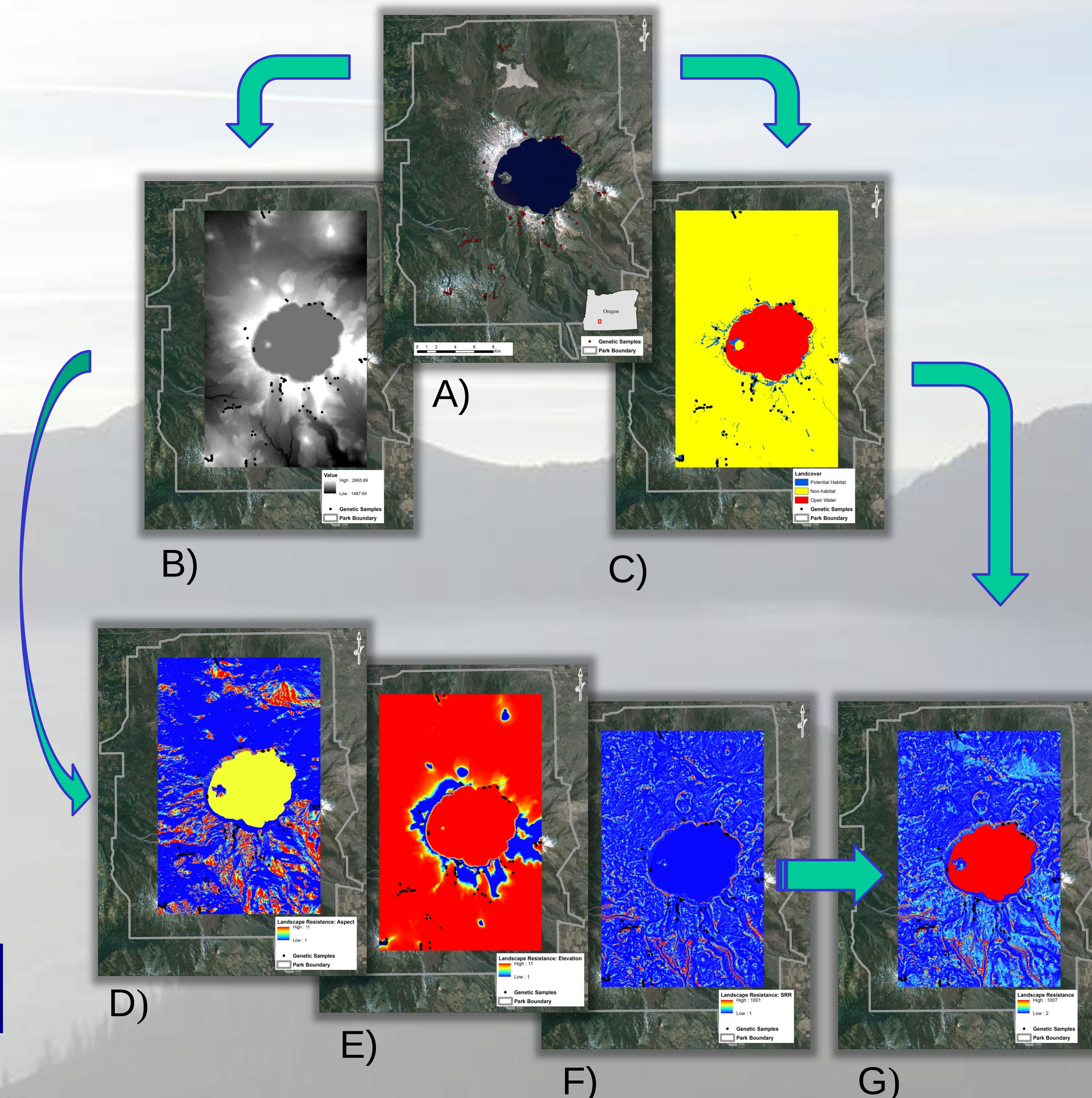


Figure 1. Study site (A) and flow diagram of resistance model optimization. Resistance surfaces were derived from a digital elevation model (DEM) (B) and land cover (C) data. Univariate resistance surfaces for aspect (D), elevation (E), and surface relief ratio (F). The multivariate resistance surface (G) is the sum of D, E, and F.

Results

- Elevation, aspect, land cover, and topographic complexity were correlated with genetic distance (Table 2)
- Mantel correlations varied slightly among genetic distances, but trends were consistent.
- The best supported univariate models were not always included in the final multivariate model (Table 2).



Table 1. Landscape variables and resistance functions tested. Each hypothesis includes a maximum resistance value, R_{max} .

Landscape Variable	Resistance Function	Components
Elevation (Elev)	Inverse Gaussian	Optimal elevation (E_{opt}) Standard deviation (sd)
Aspect (Asp)	Power function scaled to R_{max} Heat Load Index	Exponent (p) Optimal aspect (A_{opt}) Exponent (p)
Land Cover (LC)	Power function scaled to R_{max}	Ranked land cover categories Exponent (p)
Topographic Complexity (TC)	Surface Relief Ratio	Exponent (p)

Table 2. Mantel and partial Mantel correlations between genetic distance (GD) and each resistance hypothesis.

Model	Mantel r	p value	partial Mantel r GD ~ Model IBD	p value
GD ~ IBD	0.264	0.001	NA	NA
GD ~ Elev ¹ : E_{opt} 2250, sd 75, R_{max} 10	0.269	0.001	0.080	0.052
GD ~ Elev²: E_{opt} 2150, sd 75, R_{max} 10	0.263	< 0.001	0.108	0.008
GD ~ Asp¹: A_{opt} 0, p 0.5, R_{max} 10	0.275	0.001	0.128	0.005
GD ~ LC ¹ : PH 1, Other 10, lake barrier	0.286	0.001	0.120	0.002
GD ~ LC²: p1, R_{max} 10, lake barrier	0.277	0.001	0.123	0.004
GD ~ TC ¹ : p10, R_{max} 100	0.280	0.001	0.098	0.008
GD ~ TC²: p 10, R_{max} 1000	0.241	0.001	0.080	0.057
GD ~ Elev ¹ + Asp ¹ + LC ¹ + TC ¹	0.309	< 0.001	0.168	< 0.001
GD ~ Elev² + Asp¹ + LC² + TC²	0.324	< 0.001	0.197	< 0.001

¹Univariate model with the greatest Mantel r. ²Univariate component of the final optimized model.

Discussion

- Resistance increases as elevation increases or decreases away from the optimum elevation. This may be related to changes in temperature or vegetation type, energy expenditure, or the distribution of available habitat.
- North facing aspects pose less resistance. This supports the hypothesis that pikas are avoiding aspects with high sun exposure and may be heat intolerant.
- Potential habitat poses less resistance than non-habitat likely because it 1) supports breeding individuals and 2) provides more protection from predators as well as exposure to extreme temperatures.
- Extreme features, such as cliffs, pose greater resistance and may serve as potential barriers.

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