Title Combining Connectivity Science and Species Viability for Protected Area Network Design

Keywords habitat fragmentation, corridors, least cost path, metapopulation, extinction

Introduction

Preserving landscape connectivity is often proposed as a solution for preventing extinctions related to human-driven habitat fragmentation. It is assumed that corridors between habitat patches will increase movement, and that increased movement will reduce extinction probabilities. While methods from landscape ecology can quantify animal movement across a complex landscape (1), they do not address how movement affects population viability. Existing metapopulation models provide tools for evaluating extinction rates in a patchy landscape (2), but do not account for how heterogeneous inter-patch landscape features affect movement or colonization. Decision-making models that cannot measure population viability while incorporating the real complexities of fragmented landscapes are unlikely to lead to the best conservation planning for biodiversity preservation.

I propose to create a model that prioritizes the conservation of linkages between habitat patches based on their influence on extinction probabilities given variable resistance to species movement in the landscape. The model will combine (a) a connectivity analysis of focal species movement through a heterogeneous inter-patch landscape, and (b) a metapopulation viability simulation. After model verification, I will apply my combined approach to a current conservation problem by prioritizing the protection of linkages in a California landscape.

Hypotheses and Key Questions

1. Does using a least-cost-path connectivity metric that reflects inter-patch landscape features improve predictions of movement between habitat patches?
2. Does coupling connectivity analysis with metapopulation viability assessment reveal different priorities for linkage conservation than existing approaches?

Research Plan

Strategy and Methodology for Model Specification

I will first select a set of focal species based on the following criteria: species habitat preferences are known (for connectivity analysis), the species does not make significant use of inter-patch habitat (to meet assumptions of metapopulation models), and time-series patch occupancy data has been collected in other landscapes (for model verification).

I will estimate connectivity, or potential movement between patches, for each focal species using (a) GIS data on land cover, elevation, and distance from roads and urban areas, (b) species-specific preferences for each of these three factors, and (c) weighting values that reflect the relative importance of each factor. Combining these data in a rule based framework verified with empirical data (3-5) produces a map of the inter-patch landscape with each cell scored from zero to one according to its habitat suitability. The inverse of habitat suitability is taken as a measure of resistance to movement. The resistance map is used to calculate the least cost path, a measure of the shortest resistance-weighted distance, between each patch and its neighbors (6). Least cost path analysis is widely used to assess connectivity and plan linkage conservation (1,3).

I will next construct a metapopulation model simulation for estimating focal species extinction probabilities in the landscape. Stochastic patch occupancy models (2,7) that consider movement between patches, or patch colonization, to be a function of distance (e.g., Nearest Neighbor) or distance weighted by patch area and species dispersal (e.g., Incidence Function Models) are the most likely candidates. These models are widely used and relatively easy to parameterize from the literature. Occupancy models have limitations compared to more data-intensive spatially-explicit population models (8), but are appropriate for studies such as this one where relative extinction probabilities for different networks are more important than absolute extinction probability and focal species largely do not use inter-patch areas as habitat.

I will create a connectivity-weighted metapopulation model, which can estimate species-specific extinction probabilities in consideration of variable resistance to movement, by including least cost path data in the colonization function of my metapopulation model.

Question 1: Does the connectivity-weighted model better predict colonization?

I will test the ability of the connectivity-weighted model and the standard un-weighted model to predict patch occupancy and colonization using previously collected patch occupancy data from other fragmented landscapes (refs. in 9). I will compare the two models using metrics such as pseudo-R^2 and Akaike Information Criterion (AIC) values. I expect to find that connectivity weighting improves predictions of inter-patch colonization.

Question 2: Does the weighted model suggest different linkage conservation priorities?

Better predictions of colonization from the connectivity-weighted model indicate that the weighted model will also better assess overall landscape-scale extinction probabilities, which are a function of individual patch colonization and extinction rates. To test whether the connectivity-weighted and un-weighted models prioritize linkage conservation differently, I will apply both models to a fragmented landscape in the Mayacmas Mountain region of northern California, where preliminary GIS data and focal species habitat preference information have already been collected. For both models, for each focal species, I will calculate overall extinction probability over a set time period with all inter-patch linkages present. I will then simulate the removal of each individual linkage in turn, and use the marginal increase in extinction probability after each removal to rank the linkages in their relative importance to species viability. A sensitivity analysis will test the effects of uncertainty in parameterization.

I expect the standard un-weighted model to over-prioritize linkages to central patches that are surrounded by inhospitable terrain. I further expect to find that protecting the top ranked linkages from the connectivity-weighted model will lead to a lower risk of extinction than protecting those identified by the un-weighted model, suggesting that the use of connectivity weighting is important to designing protected area networks for biodiversity conservation.

Broader Impacts

My research will provide a quantitative basis for linkage conservation in a fragmented landscape based on species persistence, a critical need for conservation practitioners throughout the world. The results and methodology will be published in a peer-reviewed journal article and as an extension report for conservation planners designing protected area networks.

Literature Citations

(1) K. R. Crooks, M. A. Sanjayan, *Connectivity conservation*. (Cambridge Univ. Press, 2006). **(2)** I. Hanski, *Metapopulation Ecology*. (Oxford Univ Press, 1999) **(3)** P. Beier *et al.*, *Conservation Biology* 22, 836 (2008). **(4)** J. A. Hilty, *et al.*, *Biodiversity and Conservation* 15, 2853 (2006). **(5)** D. Majka, *et al.*, CorridorDesigner.org (2007). **(6)** F. Adriaensen *et al.*, *Landscape and Urban Planning* 64, 233 (2003). **(7)** A. Moilanen, *Ecological Modeling*, 179:533 (2002). **(8)** C. Carroll, pp. 369-389 in K. R. Crooks, M. A. Sanjayan, *Connectivity conservation*. (Cambridge Univ. Press, 2006) **(9)** A. Moilanen, M. Nieminen. *Ecology* 83, 1131 (2002).

Statement I attest that this proposal represents my original work.