FunConn Analysis of Habitat Connectivity Between the Green Mountains, VT and the Adirondack Mountains, NY.


Lake George. Photo by Kari Blood 2009

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Dan Zeh
In cooperation with
Paul Marangelo

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Abstract or Executive Summary

Wildlife corridor models were generated for fisher (*Martes pennanti*), black bear (*Ursus americanus*), and bobcat (*Lynx rufus*) using the Habitat Modeling toolset of the Functional Connectivity (FunConn) extension (Theobald et al. 2006b) for ArcGIS Desktop (Esri 2009). The toolset was used to generate habitat quality rasters and functional habitat patches leading to a corridor (landscape network) for each species within a study area connecting the Green Mountains near Rutland, VT, to the Adirondack Mountains, NY, an area of approximately 7,260 km^2.habitat quality rasters, functional habitat patches, and resulting corridors are shown in maps created in ArcGIS Desktop (Esri 2009).

Introduction

Landscape corridor models (landscape networks) were generated for fisher (*Martes pennanti*), black bear (*Ursus americanus*), and bobcat (*Lynx rufus*)) which are considered passage species, i.e., classified as individuals that can move between wildland blocks within a few weeks (Beier et al. 2008) using the Habitat Modeling toolset of the Functional Connectivity (FunConn) extension (Theobald et al. 2006b) for ArcGIS Desktop (Esri 2009). The Habitat Modeling toolset was used to create a network of functionally defined resource patches (Theobald et al. 2006a) highlighting potential corridors throughout a study area extending from the Green Mountains near Rutland, VT, to the Adirondack Mountains, NY, an area of 7,260 km^2 (2800 mi^2).

The Habitat Modeling toolset creates the network in three major steps: a habitat quality raster, a group of functional patches, and a landscape network for each species. Required parameters include relative sensitivity to disturbance caused by roads, relative quality of habitat defined by land cover, and relative landscape permeability. Roads are a leading cause of habitat fragmentation through the creation of edge effects that can permeate hundreds of meters into adjacent habitat, resulting in the loss of connectivity for wildlife (Beckmann et al. 2010; Glennon and Kretser 2005) and road avoidance due to traffic noise enhances the barrier effect (Forman and Alexander 1998). Consideration of road impacts is critical to corridor analysis and is a key component of the FunConn model of disturbance. Other types of land cover disturbances such as development and agricultural areas were considered through additional reclassification of habitat quality and species' permeability in the landscape.

Methods

The key base data required to run the FunConn Habitat Modeling analysis are GIS land cover data and GIS road data. Land cover and roads data from New York and Vermont were merged to create a single data file for each type of data. Roads were classified into three categories: High disturbance (major highways), medium disturbance (surface streets), and low disturbance (low volume and/or gravel roads with no winter maintenance). The road data was converted to raster, combined with the land cover data using the Raster Calculator in ArcGIS Spatial Analyst (Esri 2009), and labeled as the Land Use with Disturbance raster.

Four raster reclassification tables were required to run the Habitat Modeling Analysis tool set. A Disturbance Reclass table was created which defined the relative amount of disturbance from roads to the habitat at distances that we specified (providing definition to the edge effects). Second, a Resource Quality Reclass Table was created for each species (defining a score between 0 and 100 for each land cover type with 100 being the highest quality habitat for the species and 0 being no habitat). Third, a Patch Structure Reclass Table was created for each species to modify habitat quality based on the distance to the patch edge (a score ranging from 0 at patch edge to 100 at the patch interior), thereby defining the patch edge effect on the species. Fourth, a Landcover Permeability Reclass Table was created for each species (a value in the range 0 to 1 that defined the species' ability or willingness to pass through each land cover category).

Three tools of the FunConn Habitat Modeling toolset, Create Habitat Quality, Define Functional Patches, and Build Landscape Network, were run for each species with the required land cover rasters and reclassification tables using the parameters shown in the table Appendix A Page 1. The output of each tool was an input to the next tool.

When all tools were run for all species, the Functional Patches tool was run again for each species using a presence-only raster developed from research for a predictive occurrence model (Long 2006) in a subset of the present study area. The presence only raster was substituted for the habitat Quality raster input for the Functional Patches tool. The Functional Patch raster was successfully run for bobcat and used as the input raster for the Landscape Network tool.

Functional Patch rasters were converted to polygons in ArcView and areas calculated for each feature. The Functional Patches and Landscape Networks for bobcat, black bear, and fisher were combined using the ArcView Union Tool and analyzed for overlap and area. Maps were created that combined the Functional Patches and Landscape Networks for the three species, the union of the three species, and the predictive occurrence model for bobcat.

Results

Habitat Quality Output Rasters, Functional Patches Output Rasters, and Landscape Network Rasters were successfully created for all species. The resulting images may be viewed in Appendix B Pages 1 - 8. The Functional Patches output rasters included 66 individual functional patches for black bear totaling 3,995 km^2, 81 functional patches for bobcat totaling 3,800 km^2, and 407 functional patches for fisher totaling 3,082 km^2.

The Landscape Network rasters included 286 corridor pieces totaling 1037 km^2 for black bear, 429 corridor pieces totaling 1,021 km^2 for bobcat, and 1357 corridor pieces totaling 1,348 km^2 for fisher.

A functional patch-corridor analysis was completed by creating a union of overlapping functional patches and a union of overlapping corridors. Analysis showed the total area of the functional patches union to be 2259 km^2 for the three species. The total area for the overlapping corridors was 262 km^2 for all three species, 621 km^2 for two overlapping species combined, and 1,377 km^2 for single species combined.

Presence-only rasters for all species created during predictive habitat modeling (Long 2009) were used as inputs to the Functional Patches tool. A Landscape Network Raster was successfully created only for bobcat. 19 functional patches for bobcat were created for a total of 513 km^2. Bobcat corridor pieces totaled 78 with a total area of 513 km^2.

An analysis was completed to show the areas of overlap for functional patches and corridors resulting in 940 functional patches totaling 4,201 km^2 and 2503 corridor pieces totaling 2259 km^2. A single map was created that displayed one species combined, two species combined, and three species functional patches and corridors.

Discussion

Model Specifics

The outcomes described in this paper were dependent on the following model assumptions and data accuracy:

<u>GIS coordinate systems:</u> The GIS data from New York and Vermont came in five coordinate systems (projections): NAD 1983 State Plane Vermont FIPS 4400 (meters), USA Contiguous Albers Equal Area Conic USGS Version (meters), NAD 1983 UTM Zone 18N (meters), NAD 1927 UTM Zone 18N, and Clarke 1866 UTM Zone 18N. All GIS data was re-projected to NAD 1983 UTM Zone 18N (meters).

Base data included land cover, roads, streams, wetlands, water bodies, aerials (orthophotos) and elevation data. NY and VT have similar data and land use classifications. The accuracy of the land cover datasets ranged from 71.0% to 85.3% according to metadata (NOAA 1984).

Road data from the two states were categorized differently. Vermont GIS road data had 19 roads classes and New York GIS road data had 7 road classes. Each set was categorized into three groups based on description and then merged as one set for the analysis. Every effort was made to add the roads to the correct category based on metadata descriptions. Difference in category translated directly to difference in disturbance caused by roads and we found limited research on road disturbance in the literature with some variation. For example, we found one paper reporting that black bears avoided areas within 800m of gravel roads and avoided areas near gravel roads more than they avoided areas near paved roads (Reynolds-Hogland and Mitchell 2007) versus another paper that reported black bears preferring areas less than 200m from gravel roads based on food availability (Carr and Pelton 1984). Roads represented home range boundaries for seven out of nine bobcats in one study (Riley 2006).

Species land cover preferences: A Resource Quality Reclass Table was created for each species, defining a score between 0 and 100 for each land cover type with 100 being the highest quality habitat for the species. Relative land cover preferences were principally subjective because the literature described preferences in habitat terms but not in relative terms. For example, Sataloff(2008) stated that bobcats always selected forested and scrub/shrub and always avoided marshes whereas Koen et al.(2007) described habitat preferences in more hierarchical terms, stating that the fishers preferred coniferous forest over fields over deciduous forest when choosing home range.

Minimum Patch Size (estimated from home range): Minimum patch size was a required parameter for the first two analysis tools, Create Habitat Quality Tool and Define Functional Patches Tool. There was much variation in the literature as can be seen in the following summary table:

	Home Range (ha)	**Mean**	**SD**
Bobcat (n=8)	Min. 100 to 4600	1717.3	1587.7
	Max. 600 to 8300	3674.7	3157.2
Fisher (n=5)	Min. 700 to 4580	1832	1616.8
	Max. 1400 to 17334	6933.6	6275.5
Black Bear (n=12)	Min. 500 to 6890	2743.3	1751.3
	Max. 910 to 31800	12344.5	8957.7

The estimates vary widely between geographical areas. However, this appears to be a result of habitat and prey availability, not geography. Authors who addressed the differences suggested variations in prey availability and habitat quality were the principle reasons (Anderson and Lovallo 2003; Boyle and Fendley 1987; Knick 1990; Pelton 2003; Powell et al. 2003; Riley 2006). The FunConn software package included an example analysis for the lynx (*Lynx Canadensis*) and used a minimum patch size of 264ha (Theobald et al. 2006a). We selected a range of minimum patch size values after reviewing the corridor analysis of the Adirondack region (Brown et al. 2009) and our own analysis (see Appendix A-1). Experimenting with the software and resulting functional patches, we chose minimum patch sizes of 500ha for black bear, 500ha for bobcat, and 50ha for fisher. Our final values, which are close to the minimum home ranges in our literature review, were chosen to make certain that functional patches were created in the hilly/mountainous terrain that is crisscrossed with roads throughout most of our study area.

Patch/Foraging Radius: Defined as the distance an animal moves to forage (Theobald et al. 2006a), little data is available in the literature in terms of area/radius as most foraging data was given in distance, not area. For our model, we chose 1000m for black bear, 800m for bobcat, and 500m for fisher.

Species Land Cover Permeability: A challenge of modeling wildlife dispersion (corridors) is that no analytically tool comprehensively identifies where corridors are likely or which functional patches may be sources or sinks for the population (Hargrove et al. 2004).A key but somewhat ambiguous characteristic of dispersal is permeability. The relative values of Landcover Permeability Reclass Table were generally based on the species preference for land cover type.

Resource quality threshold: 75% minimum habitat quality acceptable to the subject species is the program default. Using 75, results were not clearly delineated between species but improved using 50. Each of our models uses 50 as the parameter.

Broader Discussion

Lake George: Lake George runs 32 miles north-south close to the center of the study area, invoking the question of whether Lake George is a barrier to wildlife movement. This study did not address that question directly but in the outputs from our analyses, the lake did not classify as a barrier. All results from the FunConn tool set were based on land cover characteristics and for each species, open water was given a relative score of zero in the Resource Quality Reclass Table. Yet, resulting landscape networks showed possible corridors moving across and around the end of the lake. For this study, any corridor crossing Lake George should be considered theoretical and proved out by additional research.

Roads: Improved roads data could alter analysis results (Jantz and Goetz 2008). Thanks to Paul's (Marangelo) knowledge of the study area, we identified several roads that were classified inaccurately in the model. After editing the roads, the model was run again with noticeable improvement of the local corridor (network). Local roads data, if available, would improve the resultant corridor map at the local level, strengthening conservation prioritization.

Resulting Maps:

Habitat Quality

There appears to be little visible difference between the habitat Quality maps for black bear, bobcat, and fisher. The study area is well-forested and the varieties of habitats found in the study area are very friendly toward these three species. Their quality habitats overlap to a high degree and it may be that, due to the large scale of the study area, the differences between parameters are relatively small for quality habitat of each species.

Functional Patches and Corridors

Functional patches and corridors were logically combined in a single map for each species. This allowed the visual opportunity to see how corridors made the connection between functional patches. In contrast to the habitat Quality data, there are visible differences between the Functional Patches for each species. Bobcat and black bear functional patches are similar mostly due to the similar home ranges and foraging radii. Fisher functional patches are much smaller and easily discerned from the other species' functional patches but overlap significantly with bear and bobcat. All functional patches are predominately found in the forested higher elevations. Lower elevations are a mix of functional patches and corridors.

Many corridors were created in the Landscape Network tool mainly due to the large areas of available habitat. Although there are some larger developed areas like Rutland and Lake George, much of the study area is available to wildlife at present.

The functional patches and corridors resulting from Long's presence-only rasters (Long 2009) are in sharp contrast to functional patches and corridors resulting from the other models. Visually, it is almost that the corridors and functional patches are reversed. This appears to be a result of presence-only data available in some areas and not available for others. Also, the entire set of functional patches and corridors data are a subset of the main study area.

Overlap Analysis

The species data for functional patches and corridors were analyzed for overlap. The overlapped data is clearly visible on the map. This may be one of the most useful maps for helping to prioritize conservation targets.

Concluding Remarks

The FunConn models are subject to much variability due to the range and approximation of parameters. In this study, the tools didn't always finish for some values of the parameters; as a result, we changed the values and re-ran the tools. Successful runs helped narrow the choices. As parameter values are defined in future area research, the tools could be run again to confirm more realistic models. Considering the large size of the study area, however, the results are useful immediately. Of particular usefulness is the overlap analysis. For purposes of picking conservation targets, an area containing all three species overlapped, whether functional patch or corridor, should be considered high priority.

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