Modeling Wildlife Habitat Corridors in the Greater Grand Staircase-Escalante Ecosystem

Dawn Hartley

Center for Landscape Analysis
The Wilderness Society
1424 Fourth Avenue, Suite 816
Seattle, WA 98101

and
Gregory H. Aplet

Center for Landscape Analysis
The Wilderness Society
7475 Dakin Street, Suite 410
Denver, CO 80221

Abstract. The Grand Staircase-Escalante National Monument was established, in part, to protect landscape connectors, a resource about which very little is known. In this paper we present a methodology that may be applied to identify potential wildlife movement corridors, in the absence of direct, scientific observation, but where something is known about habitat quality. Our analysis of the Monument landscape suggests that there are a number of places that deserve further scrutiny as potential movement corridors, including the heart of the Kaiparowits Plateau, the East Fork of the Virgin River east of Zion National Park, and the Dixie National Forest northeast of Bryce Canyon National Park. While we do not imply that these are movement corridors, we believe that our analysis provides new insights into potential habitat connectivity.

Key words: movement corridors, GIS modeling, least-cost path analysis, landscape ecology, roads, national monuments, Bureau of Land Management, Gap Analysis Program, Utah.

Email: Gregory Aplet, greg_aplet@tws.org

INTRODUCTION

For as long as principles of island biogeography have been applied to conservation, habitat connectivity has been understood to play an important role in the viability of species populations (Diamond 1975, Wilson and Willis 1975, Meffe and Carroll 1997). Habitat connectivity increases the likelihood of interaction among individuals within a population, which, in turn: (1) increases effective population size; (2) maintains gene flow; and (3) facilitates regular migration and dispersal. Each of these processes helps insure the viability and long-term persistence of a population (Primack 1993, Hunter 1996, Meffe and Carroll 1997).

The role of "corridors" in providing habitat connectivity is less well understood. Corridors, which are generally defined as strips of natural vegetation between protected blocks of habitat (Bentley and Catterall 1997, Beier and Noss 1998), have been proposed by some as crucial to the maintenance of healthy wildlife populations in otherwise degraded landscapes. Proponents of corridor protection note that wildlife seem to have preferred pathways through the land, as borne out by historical evidence, such as records of vehicle-wildlife collisions and the familiar "wildlife crossing" sign (Beier 1993). Protection of relatively good habitat strips cannot help but facilitate movement among patches (Noss 1987, Hobbs 1992, Noss and Cooperrider 1994).

Skeptics, on the other hand, argue that while wildlife certainly do not use all space uniformly, there is very little evidence that natural vegetation strips left on an otherwise developed landscape will be used as migration routes (Mann and Plummer 1995). They point to controlled experiments in which model species move more or less randomly about the landscape despite the provision of corridors (Ezzard 1992). Elsewhere, especially in sparsely vegetated desert settings, "corridors" may follow geological features not typically associated with habitat quality. Others have suggested that corridors might actually harm populations by facilitating the spread of disease or by concentrating prey species, making them easy targets for ambush predators (Simberloff and Cox 1987, Simberloff et al. 1992, Hess 1994). Some skeptics have argued that scarce conservation resources ought to be spent increasing the size of reserves rather than protecting movement corridors (Simberloff et al. 1992).

In the midst of this debate, in September 1996, President Clinton designated the Grand Staircase-Escalante National Monument in southern Utah. In addition to saluting the remoteness and natural beauty of the area, the President recognized the important role that the monument plays as a landscape connector, specifically mentioning riparian corridors as an object of conservation under the Antiquities Act (Clinton 1996). Belnap (1997) noted, "The Monument contains several perennial streams that connect the high plateaus to the low desert, thus preserving these migration corridors and increasing the Monument's ability to conserve genetic and population diversity of plants and animals." Belnap's report states further that "the connection the Monument provides between Glen Canyon, Canyonlands, Grand Canyon, Capitol Reef, and Bryce Canyon National Park units increases the value of all these areas for protection of viability of plant and animal populations."

This notion of a greater Grand Staircase-Escalante ecosystem, in which the

Monument helps sustain the health of a larger landscape, was explored by The Wilderness Society (1999) in "Crown of the Canyons: An atlas of the ecology, economy and future of the greater Grand Staircase-Escalante National Monument ecosystem." Despite the attention brought to the larger ecosystem by the President, scientists, and the conservation community, the management plan for the Monument (USDI Bureau of Land Management 2000) is virtually silent on the role of the Monument as a landscape connector. Locations and sizes of key connectors remain unresolved, leaving managers unable to address one of the purposes for which the Monument was established.

In this paper, we present a methodology for developing information about habitat connectivity in the absence of direct wildlife movement observations. To illustrate these methods, we modeled potential wildlife corridors between four established protected areas in the vicinity of the Grand Staircase-Escalante National Monument. While, there is much more work that needs to be done before we can rely on corridors to achieve conservation, we believe connectivity across landscapes should be maintained. We present herein one type of analysis that may help natural resource managers and researchers understand where to concentrate their future efforts.

METHODS

We employed methods derived from Walker and Craighead (1997, 1998) who modeled potential habitat corridors for grizzly bears, mountain lion, and elk in Montana. Walker and Craighead acknowledged the uncertainty surrounding the corridor issue, and rather than assert that they could identify transportation routes that animals would surely use, they suggest that it may be possible to identify habitat connectors that would likely increase the probability of animal survival. Thus, movement would be facilitated by these routes, whether animals actively followed them or not. Their approach was based on a set of four reasonable assumptions:

1) Good corridors are primarily composed of good habitat. That is, good habitat makes a better connector than bad habitat. The question of what constitutes "good habitat" continues to occupy wildlife biologists. This evaluation assumes that habitat quality can be determined.

2) Humans pose problems for successful wildlife transit. Specifically, roads and human developments create barriers to successful movement. Like habitat quality, the actual effect of roads on wildlife is a topic of intense scientific interest. This modeling approach assumes that habitat quality is diminished near roads.

3) Current human developments are permanent. Walker and Craighead's model does not evaluate the possibility of removing barriers to facilitate movement.

4) "Least-cost paths" constitute the best routes of transit. This key assumption allows that animals will follow an optimum route between two points that minimizes their exposure to low quality habitat. In reality, animals cannot know what lies beyond their sensory range and, so, cannot choose a truly optimum path. Instead, they select resources at a finer scale, which may not be "least-cost" across a broader landscape. Assuming a least cost path "balances habitat suitability, minimum Euclidean distance, and degree of 'connectivity' between the two endpoints" (Walker and Craighead 1997). Again, this is an assumption of the modeling process. The sensory range of wildlife varies with species, and some migrant wildlife species may respond to coarser-grained landscape cues (e.g., topographic gradients, riparian corridors) than are represented by our habitat grid. Actual behavior may vary with species, season, or time of day.

The process that we used is illustrated graphically in Figure 1. Geographic Information Systems (GIS) software from Environmental Systems Research Institute (ESRI) was used to model the spatial relationship between roads and species habitat to derive potential travel corridors for a number of species. The species, whose conservation was recognized in the President's proclamation as a reason for establishment of the Monument, included black bear, mountain lion, desert bighorn sheep, bald eagle, and peregrine falcon. We obtained species habitat suitability data in a 90-meter resolution grid from the Utah Gap Analysis Project (GAP) of the United States Geological Survey (USGS). The Utah GAP vegetation cover-type mod-

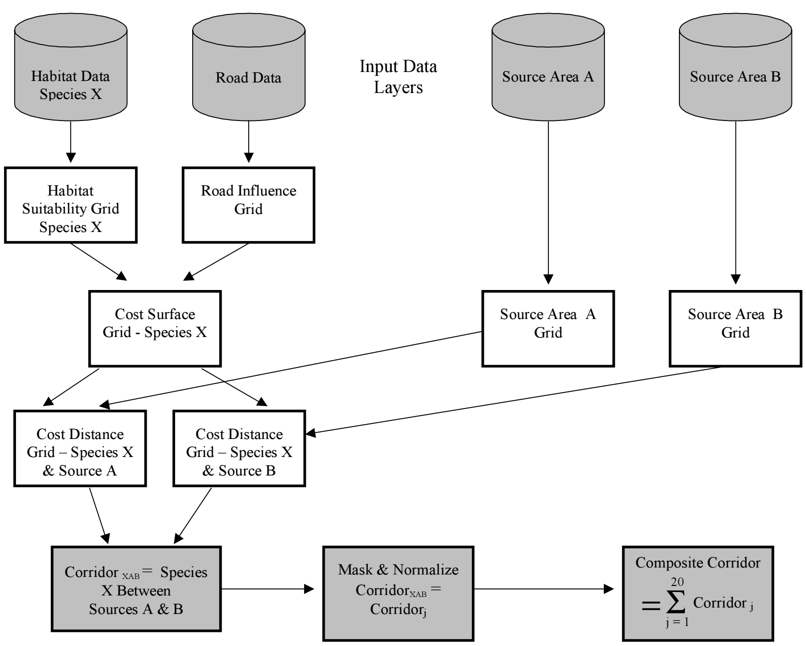

Figure 1. Flowchart describing the modeling process used in this study (see text for more specifics).

eling consisted of two phases: (1) correlation of cover-type associations with spectral values from 30-meter TM imagery; and, (2) ecological modeling based on ancillary information, which included 3 arc-second digital elevation data, slope, aspect, and region-specific vegetation cover-type polygons.

Classified pixel data were then aggregated to polygons (the GIS vector model) using a minimum mapping unit (MMU) of 100 ha. Riparian and wetlands polygons were derived with a 40 ha MMU. Species distribution was then predicted for each of the polygons based on the mapped cover-types, elevation, and existing species ranges. A distance-to-water buffer was also added to the species distribution models to correct distributions of species closely linked with water. These habitat suitability models are fixed in time and do not reflect seasonal variation in habitat quality, nor have they been empirically tested. Road data were obtained from the USGS as 1:100,000 digital line graphs (DLGs).

The GRID module of ESRI's ARC/INFO software provided the modeling tools that we used to develop our corridor identification methodology. The GRID module provides a built-in "corridor" function, which identifies the least cost path between two source areas. In this study, sources are defined as federally protected areas in the vicinity of the Monument, including Zion National Park to the west, Bryce Canyon and Capitol Reef National Parks to the north, and Glen Canyon National Recreation Area to the southeast (other potential source areas exist in Arizona, including the Vermilion Cliffs National Monument and Grand Canyon National Park, but these were not evaluated in this modeling effort). Movement between any two of these sources occurs across a "cost surface" that is a representation of species-specific habitat. Cost surfaces are based on the notion that low value habitat "costs more" (in terms of exposure to mortality risks, energy balance, etc.) to cross than does high-quality habitat.

A cost surface grid was derived for each species in the study based on GAP habitat suitability data. The GAP data identified habitat by five nominal classes (critical, high value, significant value, low value, and no habitat value), so we had to assign numerical values to these habitat classes in order to generate a cost surface. After conducting a sensitivity analysis in which we explored model behavior under a variety of scoring systems, we determined that a simple rating of 1 to 5 yielded the most acceptable model behavior. The sensitivity analysis involved varying the scores assigned to each nominal class (using constant, linear, and exponential increases) and the effect of roads as barriers. The model is extremely flexible and can be forced into a wide range of behaviors. Our sensitivity analysis led us to select parameter values that produced a reasonable wildlife movement behavior model.

Once developed, each cost surface was then modified to increase costs (i.e., degrade habitat value) according to the influence of roads. The USGS road data were divided into major (high volume) and minor (low volume) road classes. We subjectively determined that major roads have a zone of influence that extends 1600 meters, while minor roads have an influence to 400 meters. We recognize that our buffers are mostly arbitrary because different species respond differently to roads. As more is learned about the response of individual species to roads, the road effect may be tailored to fit particular species and road classes. For major roads, a road impact coefficient of 100 was applied at the surface of the road, with impact declining exponentially to a coefficient of one at 1600 meters. We assumed minor roads have 1/3 the maximum impact of major roads and, therefore, have a coefficient of 33 at the road, with influence decreasing exponentially to a coefficient of one at 400 meters. The final cost surface for each species was derived by multiplying the cell values from the respective habitat grids by the cell values from the road influence grid. The final cost grids represent the cost to move through a single grid cell.

To account for the accumulated cost of dispersing away from a source area, we next developed "cost distance" grids in pairs for reciprocal source areas. For example, to ultimately identify a corridor between Bryce Canyon NP and Capitol Reef NP, two cost surface grids are required — one that represents the accumulated costs of a species dispersing from Bryce Canyon NP and a reciprocal grid that represents the same species as it disperses from Capitol Reef NP. For each species, cost distance grids were derived for four pairs of source areas (Zion to Bryce, Bryce to Capitol Reef, Bryce to Glen Canyon, and Zion to Glen Canyon).

The pairs of cost distance grids were then combined using the GRID module's "corridor" function, resulting in a single grid that represented a continuum of values across the entire study area. Within this continuum, the corridor is represented by the lowest cell values, the "least-cost path." To isolate the corridor, a mask was applied to eliminate all but the lowest 1% of cell values. A total of 20 corridors were derived, one for each species between four pairs of sources (Fig. 2). To enable comparison, the cell values in each corridor were normalized to a scale of 1 to 50. A final, composite corridor (Fig. 3) was created by adding the normalized cell values from all 20 corridors and rescaling the resulting range of values from 1 to 255 to facilitate final map shading.

RESULTS AND DISCUSSION

The variability among species in corridors identified by our model shows clearly that model results are affected by the distribution of habitat quality for each species (Fig. 2). Though corridors do tend to avoid roads, roads do not drive the model. High quality black bear habitat on the Aquarius Plateau to the north of the Monument would allow bears to travel from Bryce to Capitol Reef through the forested uplands. Conversely, the absence of good habitat on the Aquarius Plateau for desert bighorn sheep forces sheep to travel from Bryce to Capitol Reef across the Kaiparowits Plateau. Our results seem to make biological sense, suggesting that this model may have utility in predicting where species are likely to move across the southern Utah landscape.

Despite these promising results, it is important to keep in mind that our model is speculative and represents only numerical manipulations. For example, while it may make sense for desert bighorn sheep traveling between Bryce and Capitol Reef to traverse the Kaiparowits Plateau, it may make no sense at all for bighorn sheep to even be found at Bryce Canyon. Desert bighorn sheep prefer open desert scrub, not

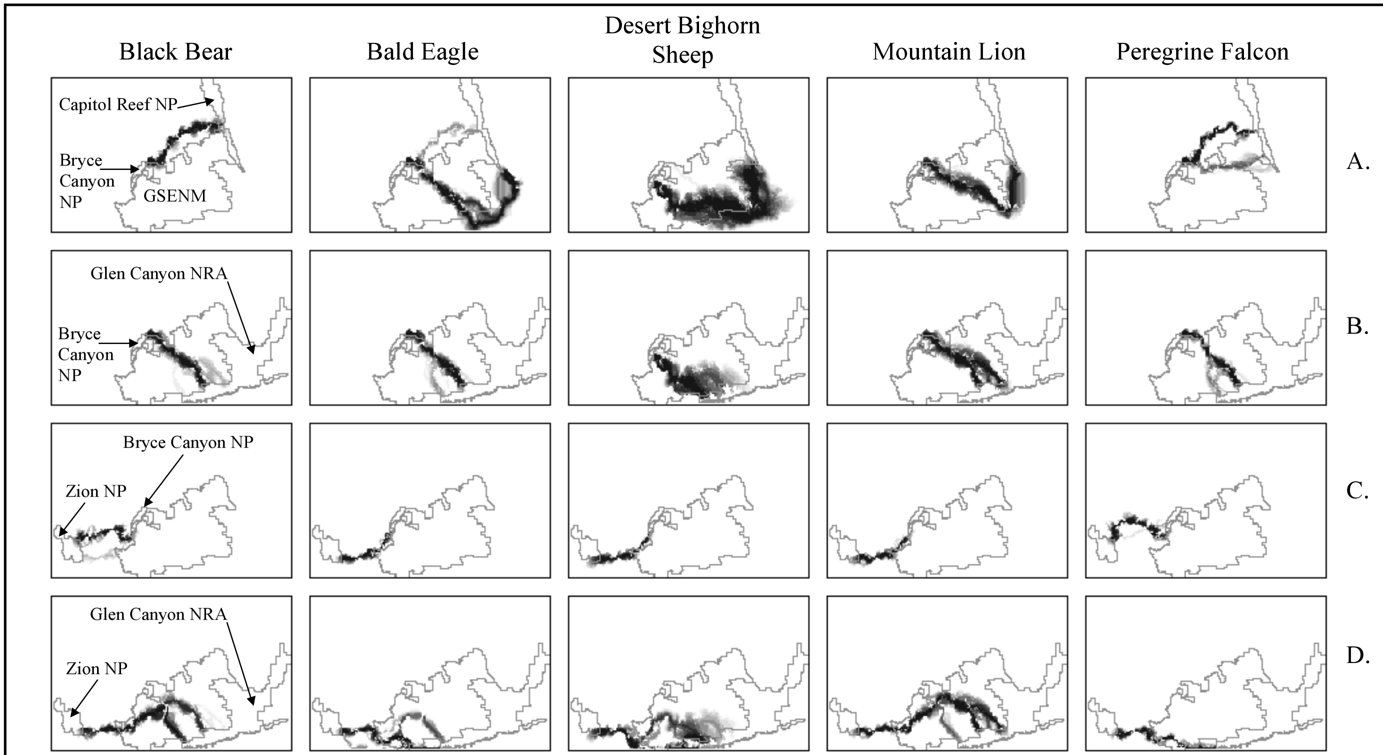

Figure 2. Potential wildlife habitat corridors for the five species between four pairs of protected areas in the greater Grand Staircase-Escalante ecosystem: A. Bryce Canyon National Park to Capitol Reef National Park; B. Bryce Canyon National Park to Glen Canyon National Recreation Area; C. Zion National Park to Bryce Canyon National Park; and D. Zion National Park to Glen Canyon National Recreation Area.

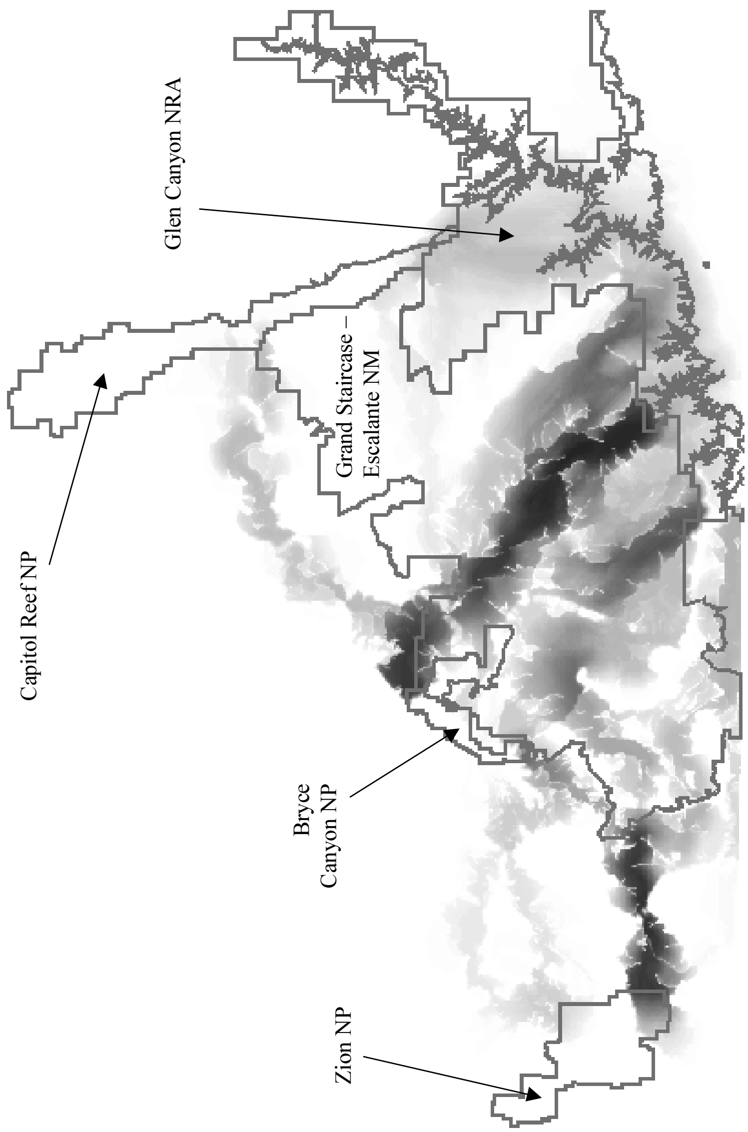

Figure 3. Composite wildlife habitat corridor map created by combining the 20 corridors in Figure 1. The darkest parts of the image indicate potential wildlife movement corridors.

the subalpine forests of the Paunsaugunt Plateau. We believe the best use of these results is to direct the attention of scientists and land managers to particular places on the landscape that are worthy of further investigation as wildlife habitat connectors. Nevertheless, in the absence of ground-based observations or scientific research, models such as this can provide new insights to land managers and scientists.

The compiled corridor map obscures information about individual species, but it does highlight some places that appear to be particularly important to landscape connectivity (Fig. 3). For example, the Kaiparowits Plateau in the center of the Monument is an obvious "hot spot." This is not surprising, given the area's legendary remoteness and unspoiled natural character.

Less predictable is the apparently very important connector east from Zion to the Monument along the East Fork of the Virgin River. This mostly BLM land was left out of the Grand Staircase-Escalante National Monument but has been recommended for inclusion in the National Wilderness Preservation System by the Utah Wilderness Coalition because of its outstanding natural character. In addition to the importance of the corridor, our image indicates a crucial constriction at Mt. Carmel Junction, where roads and development threaten to cut off connection. Similarly, the national forest land east of Bryce Canyon National Park in the vicinity of Powell Point appears to be an important connector between Bryce Canyon and the Aquarius and Kaiparowits Plateaus.

Managers of the Grand Staircase-Escalante National Monument will be making decisions implementing their management plan over the next several years. Among their decisions will be determinations of where to place developments and which roads to close and/or rehabilitate. Clearly, in the absence of scientific research to the contrary, our model suggests that they should maintain the corridor integrity between the Aquarius Plateau and Glen Canyon National Recreation Area. Similarly, managers of the Dixie National Forest should seek to protect habitat connectivity between Bryce Canyon and Powell Point, and the BLM, Forest Service, and local authorities should be concerned about development in the vicinity of Mt. Carmel Junction.

In presenting our model, we do not wish to assert that the corridors we have identified are the most important pathways for wildlife movement in the landscape. We are only suggesting that these may be productive places to focus further study. It is important to keep in mind that, ultimately, this work is only a mathematical model. However, in the absence of any other information on wildlife distribution and movement patterns, this represents the best available information, and management should take this information into account in conservation planning. Ultimately, we would prefer to see additional work done to examine the degree to which these *apparently* important corridors actually contribute to wildlife population viability. We hope that by presenting one feasible approach, we spur further work aimed at protecting wildlife habitat connectivity in this landscape and throughout the Colorado Plateau.

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(Insert sketch: Physical Resources)