Incorporating Wildlife Conservation within Local Land Use Planning and Zoning: Ability of Circuitscape to Model Conservation Corridors

Virginia L. Batha and Dr. Toru Otawa
University of Idaho, Department of Landscape Architecture

Introduction

Allocation of our world's natural resources will become increasingly important as the human population continues to grow. Apportionment is especially imperative when considering the health of wildlife populations' worldwide (Svoray, Bar, & Bannet, 2005; Theobald, Hobbs, Bearly, Zack, Shenk, & Riebsame, 2000). Efforts to provide basic infrastructure, housing, and food for a growing human population confounds the ability of wildlife to meet their own needs (Lagabrielle, Botta, Dare, David, Aubert, & Fabricius, 2010; Svoray et al., 2005). Previous research indicates that human conversion of native habitat is the leading threat to wildlife in the United States and throughout the world (Lagabrielle et al., 2010; Miller, Groom, Hess, Steelman, Stokes, Thompson, Bowman, Fricke, King, & Marquardt, 2009; Polasky, Nelson, Lonsdorf, Fackler, & Starfield, 2005; Stokes, Hanson, Oaks, Straub, & Ponio, 2009). Habitat conversion of the native landscape often results in the fragmentation of the landscape mosaic, severing the connection between habitat patches used by wildlife and populations of wildlife (Beir & Noss, 1998). Connectivity is crucial to wildlife for several reasons including dispersal, gene flow, and population persistence among other reasons (McRae, Dickson, Keitt, & Sirah, 2008).

Conservation planning seldom occurs at local levels (i.e. municipal, county) rather it is often a product of national, state, or regional decision-making (Press, Doak, & Steinberg, 1996). The government levels at which the majority of wildlife management transpires is rarely the level at which habitat conversion takes place, the local level (Azzerad & Nilon, 2006). Increasingly scientists, ecologists, planners, and community members have been converging to incorporate wildlife and other ecological information into local land-use planning and decision-making (Theobald et al., 2000). Their ability to achieve this goal has evolved with the advancement of technology, specifically habitat models and geographic information system (GIS) (Roloff, Donovan, Linden, & Strong, 2009).

This paper is a chapter within the context of a broader problem – loss of biodiversity worldwide, and its goal is to provide a summation of previous work centered on incorporating wildlife planning and subsequent ecological data within the framework of local land-use planning. In it, a review of current literature is summarized. In addition, 'Circuitscape,' a new and increasingly accepted corridor identification model is also examined. The primary objective of it is to provide techniques, tools, and processes by which planners and developers can attain wildlife conservation data in a format and scale deemed both meaningful and helpful.

Overview of Previous Work

Prior work concerning the integration of conservation and ecological data within land-use planning frameworks revealed a variety of processes, tools, and models by which this assimilation can be accomplished (Azerrad & Nilon, 2006; Darr, Dawson, & Robbins, 1998; Lagabrielle et al., 2010; Lopez, Hays, Wagner, Locke, McCleery, & Silvy, 2006; Miller et al., 2009; Newburn, Reed, Berck, & Merenlender, 2005; Pierce, Cowling, Knight, Lombard, Rouget, & Wolf, 2005; Press et al., 1996; Stokes et al., 2009; Svoray et al., 2005; Theobald et al., 2000;

Underwood, Francis, & Gerber, 2011). The majority of literature on this issue appeared in the 2000's. The reasons are unknown for the inundation of papers on this subject; however, two are conceivable: (a) previous work was inspired by a change in cultural ideology or (b) advancements in specific technology at this point.

Literature on the subject revealed three common premises by which researchers attempted to integrate ecological data within land-use planning frameworks: (1) process and model based approaches, (2) planning-based approaches, and (3) conservation tools and programs. While three primary themes were identified in the literature, it was not so easy to place all selected papers into a single category or for that matter within any of the three categories above. Two papers in particular (Miller et al., 2009; Stokes et al., 2009) were the results of two independent studies which conducted surveys on the topic of conservation and land-use planning. Yet another by Polasky et al. (2005) focused on the economics of conservation efforts.

Process and Model Based Approaches

Three primary processes were found in the literature by which planners and ecologists introduced ecological data into existing land-use planning structures. Fundamental to all three were collaborative planning and participatory processes (Lagabrielle et al., 2010; Pierce et al., 2005; Theobald et al., 2000). The System for Conservation Planning (SCoP) developed by Theobald et al. (2000) strongly emphasizes collaborative design and produced end products such as wildlife diversity, habitat, and connectivity maps which were made accessible to the community via the Internet. Lagabrielle et al. (2010) also used a participatory process in which participant input was used to build land-use scenarios which were then entered into a model named MARXAN which measured the conservation benefit of each land-use scenario. Interestingly, while the maps MARXAN produced were generally approved of, the model itself was primarily detested because of its complexity and further limited by its lack of an implementation plan. A third process led by Pierce et al. (2005) used the systematic conservation planning process originally created by Margules and Pressey (2000) as the basis for their approach and expanded upon it by finding ways to implement their resulting products into land-use planning frameworks. They included a Mapbook and Handbook which were designed to be used in synchrony by planners to inform future land-use decisions. Similar to Theobald et al. (2000), Pierce et al. (2005) also made their products available to planners over the Internet. Responses from planners using this system were favorable but this process still needs improvement, especially in identifying areas more suitable for development. In contrast to process-based approaches, Svoray et al. (2005) developed a model referred to as the Habitat Heterogeneity Model which uses habitat heterogeneity to inform biodiversity conservation efforts. Maps produced from this model were made available to planners who could then determine areas which needed protected and those locations suitable to future development.

Planning-based Approaches

On the topic of incorporating ecological data with land-use planning frameworks, a majority of papers were comprised of planning-based approaches. These approaches ranged from the use of Smart Growth Planning to amendments of existing land-use ordinances and direct acquisition of land by local governments for conservation purposes. Another approach even explored the potential for wildlife students to serve as conservation planning consultants to private landowners under the supervision of professional wildlife experts.

Smart Growth Planning is a form of development in which developers seek to provide necessary infrastructure while maintaining and preserving ecological features in the landscape (Underwood et al., 2011). Many developers using this design approach would often like to include more ecological data within their plans, but are often limited by those data which are available or lack thereof. Consequently, Underwood et al. (2011) created a flexible framework by which species threats and richness could be modeled, and by which planners could delineate areas for both conservation efforts and development.

Two process-based approaches identified in our review required greater involvement by local governments in conservation affairs. Research by Darr et al. (1998) involved amending an existing conservation tree ordinance in order to preserve large contiguous tracts of forest for the benefit of vulnerable species of birds. As part of their planning approach they created what they referred to as a "forest banking account" which was used to maintain connectivity between habitat patches above a minimum amount of land designated to preserve the forest's patch connectivity. Alternatively, Press et al. (1996) propose that direct acquisition of land by local governments for conservation is favorable, especially in the case of rare and endangered species because: (a) many of these species occur on small pieces of land which are more economically feasible for local governments to purchase and manage, (b) many endangered species are associated with specialized habitat that typically only represent a small percentage of the total landscape and (c) once such land has been acquired it is no longer threatened by development or the changing political views of the time.

Conservation planning consultation led students specializing in wildlife at institutions of higher learning was cited by both Lopez et al. (2006) and Stokes et al. (2009) as a way to help local landowners implement wildlife management plans. Lopez et al. (2006) provide a case study in which students and faculty from a state university along with state wildlife biologists partnered together to give students the opportunity to help local landowners create active management plans for their land to receive tax credit. The project proved to be of benefit to both local landowners and students who participated.

Conservation Tools and Programs

A variety of conservation tools and incentive-based programs exist to help advance conservation efforts. Incentive-based programs have increased in recent years as people began to realize the critical role private lands play in conservation endeavors. Yet in a review of protected area planning literature it was found that few programs had specific approaches for promoting such opportunities (Newburn et al. (2005). Likewise, results from a survey conducted by Miller et al. (2009) found that while many planning departments had access to conservation planning tools, few actually employed the use of such tools. Conservation tools and programs found in the literature include growth management programs (Azerrad et al., 2006; Miller et al., 2009), performance zoning (Miller et al., 2009), cluster zoning (Miller et al., 2009; Stokes et al., 2009), incentive zoning (Stokes et al., 2009), planned unit developments (Stokes et al., 2009), conservation easements (Newburn et al., 2005; Press et al. 1996), short-term management plans (Newburn et al., 2005), transferable development rights (Press et al., 1996; Stokes et al., 2009), and purchased development rights (Press et al., 1996). Other potential tools include state wildlife agency publications such as Washington State's Priority Habitat and Species (PHS) guidelines which provide information on the state's wildlife and critical habitats to aid planners in land-use planning decisions. In addition to such guidelines, the creation of newsletters and publications providing information on new articles and case studies related to conservation efforts could greatly aid planners in the decision-making ring (Azerrad et al., 2006).

Socio-economic Literature on Wildlife Conservation

Additional literature on the topic was discovered in the form of economic information and survey responses. Within the U.S. a majority of lands fall under private ownership and economics are a large determinant in conservation efforts. Contrary to customary thought, Polasky et al. (2005) reveal that in the majority of cases, careful selection of economic activities that align with species conservation can result in minimal effect on economic returns. This is good news in light of results from two independent studies which surveyed local planners and revealed that the greatest inhibitor to conservation at the local scale was funding (Miller et al., 2009; Stokes et al., 2009). With this knowledge it is conceivable that through thoughtful land-use planning and decision making, greater conservation objectives could be achieved while lessening the amount of funding needed to achieve conservation targets. Research by Polasky et al. (2005) reaffirms the importance of working with private landowners to achieve conservation objectives. Stokes et al. (2009) suggest that further support of conservation by local community members could be garnered through identifying benefits to people which are derived through conservation. Moreover, while state and federal mandates were acknowledged by local planners to have significant influence on a local jurisdiction's participation in conservation efforts, so were community values. A jurisdiction's participation in conservation activities was also found to be influenced by the composition of its staff as those jurisdictions with a conservation expert in the planning office were more likely to be involved in conservation efforts (Miller et al., 2009; Stokes et al., 2009).

Synopsis of Existing Literature

In summary, previous studies provided a range of methods and processes by which conservation data and subsequent ecological data can be included within land-use planning frameworks. Yet, few studies provide a holistic approach to accomplishing such a fusion. Furthermore, very little monitoring has occurred to evaluate the successes and limitations of each of these methods, processes, and tools. Further work needs to fill this gap to help determine the best methods by which planners and developers can plan for wildlife at the local level. In addition, new methods and processes need to be documented for the benefit of both the scientific and planning communities.

Data and Tools for Analysis

Connectivity between habitat patches and wildlife populations plays an integral role in the conservation efforts of wildlife species. Linkage allows for gene flow between populations and dispersal of individuals from one habitat patch or population to another for the purpose of finding mates, food, or establishing territories (Beier & Loe, 1992; McRae et al., 2008). While a few of the previously mentioned papers addressed connectivity in their research, none focused on it exclusively. Connectivity maps alone will not provide any standalone solution by which integration between conservation and land-use planning can occur, yet no solution would be complete without information regarding it. Any process used to integrate conservation data within land-use planning frameworks will require a variety of means to ensure a scientifically valid, user-friendly integration solution. With this in mind, we have elected to experiment with

Circuitscape, a corridor identification model which represents one possible solution to modeling connectivity for wildlife.

Circuitscape was released in 2008 and is based on principles used in electronic circuit theory. It has been used in previous research to model gene flow in both plants and animals in diverse landscapes (McRae, 2007). Similar to least-cost path models, it takes into account all feasible travel paths and their outcomes concurrently. Furthermore, Circuitscape is a flexible model that can be used at a variety of scales, but creators, Brad McRae and Viral Shah, encourage users to operate it at a scale in which "bottlenecks" inhibiting passage are visible. The term "bottlenecks" refers to elements such as roads and development (McRae et al., 2008).

This software was adopted to this research project due to its easiness, knowledge embedded in it and general acceptance by the community for wildlife preservation. Circuitscape presented a great potential to experiment with as it appeared fresh, user-friendly, required only minimal input data and was encouraged for use at the same scale as conservation land-use planning projects. It also provided the researchers with an ability to explore a holistic process by which we could incorporate conservation data within land-use planning frameworks. Because of the shortened time to identify potential connectivity, we were able to devote our effort to a literature review on the topic as appeared above and explore the issue of wildlife habitat linkage in depth. To reiterate, linkage is a critical component within wildlife conservation efforts.

Methods

Our project took place in Latah County, Idaho, located at the base of the Idaho panhandle. Latah County is primarily associated as being part of the Palouse Prairie (Latah County, 2007a), but it is also covered in large part by coniferous forest (Muir, 2006). The county itself has seen a small but steady increase in population over the last decade, and the largest economic drivers are agriculture and forestry (Latah County, 2007b; United States Census Bureau, 2013). The county has also been identified by Idaho Department of Fish & Game (IDFG) as being home to several species of greatest conservation need in the state comprehensive wildlife conservation strategy (CWCS).

The objective of the CWCS is to identify both species of greatest conservation need and habitats critical to their survival with the intent to minimize future listings under the federal Endangered Species Act. The CWCS Action Plan and Focal Areas Guide help give precedence to particular conservation actions at the local scale (Idaho Department of Fish & Game, 2013a). IDFG claim that this guide is beneficial for several reasons including helping parties interested in conservation make educated decisions, and promoting pro-active, cost-effective conservation measures.

The CWCS process revealed that a large portion of Latah County was identified as having three unique focal areas with an emphasis on resources, management, or both. Resource focal areas are those areas deemed essential for the continuation of a particular species and their habitats, while management focal areas are areas that can benefit a majority of species and habitats of greatest conservation need (Idaho Department of Fish & Game, 2013b).

Based on the CWCS, a prototypical township, T40N R4W, was selected to test the ability of Circuitscape for the identification of critical habitat and conservation corridors. The township includes typical land uses in the county, i.e., agriculture and forestry. It also presents land use features and patterns very common across the U.S. and around the world, namely urban and suburban expansion into rural landscapes. Figure 1 shows the location of our study area within the county.

Figure 2 Location of study - township T40N R4W, Latah County, Idaho, USA.

The prototypical township encompasses the majority of Moscow Mountain and lies approximately 6.4 kilometers to the northeast of the city of Moscow, Idaho at its southwest corner. The Palouse Prairie extends only faintly into the selected township as it serves as a transitory zone between the Palouse Prairie and the tips of the Clearwater Mountains. Elevations in the township range from 798.27 to 1521.6 meters. Agriculture and scattered development dominate the southern foothills of the township, while primarily coniferous forests compose the rest of it.

The township contains two of the three CWCS focal areas located in Latah County. First, Palouse R2, identified by the CWCS as a management focal area, has cultural significance for the Nez Perce tribe and lists several plants, animals and a landscape in need of conservation efforts. Among them is the Palouse Prairie, of which it is estimated that less than 1% of native prairie remains. The second focal area, Potlatch River, is deemed significant from a resource and management standpoint. It again has cultural significance for the Nez Perce tribe and lists several habitats and species in need of conservation efforts (Idaho Department of Fish & Game, 2013c).

To examine the applicability of Circuitscape, a common species, the moose (*Alces alces*) was selected. It is found in both focal areas mentioned above. Both focal area listings state that winter habitat is considered critical for moose within their boundaries (Idaho Department of Fish & Game, 2013c). In Idaho, moose are considered both an iconic and desirable game animal. A recent report on moose in Idaho found that hunters consider moose to be one of the most sought after trophy species in the state (Toweill, 2008).

Circuitscape requires two types of input data in the raster format; (a) a habitat map and (b) a focal area map. It also requires the same spatial extent and grid-cell size for the two. First, habitat maps display the ability of each cell in the landscape to carry current and are coded in either resistance or conductance. "Current" in this sense serves as a metaphor for the landscape's level of penetrability as seen by a particular animal. In habitat maps coded for resistance, higher cell values equate to those areas seen by animals as more hostile, less favored, or difficult to cross. For example, the cells with higher values may represent areas of development or habitat patches not utilized by a particular animal. Higher values associated with conductance maps indicate those areas of the landscape which are seen as more favorable or preferred by an animal. Therefore, resistance and conductance are simply the inverse of each other. Second, "Focal

Area" maps are comprised of focal nodes or regions and represent areas such as habitat patches or critical areas used or needed by an animal (McRae et al., 2008).

To create our habitat and focal area maps for use within Circuitscape, a specific literature review was conducted on habitat preferences for moose during the winter months as summarized in Table 1. In addition, the following data sets were obtained to construct our habitat and focal area maps: land cover, land use, roads, surface water sources, and a digital elevation model from which slopes, aspects, and elevation levels were calculated, as summarized in Table 2. Using Arc GIS Version 10.x (ESRI, 2011), these data sets were each re-classified into several categories and coded for their resistance. The resistance values ranged from 100-500, with 100 representing the lowest level of resistance to an animal and 500 representing the highest level or resistance to an animal. Table 3 lists the preference characteristics, their categories, and the resistance values used to construct the habitat map. As required by Circuitscape, spatial extent and grid-cell size were set consistently for all data layers. Consequently, the Raster Calculator tool was used to overlay all the layers together to create a cumulative or composite map, which shows a gradient of values representing areas of lesser or greater impedance to animals. It led us to select two areas of least impedance to serve as focal areas and was done by creating a new layer and manually creating polygons over those areas of least impedance.

Preference Variable/Factor	Supporting Literature
Dense Cover	Dussault, Courtois, & Ouellet, 2006 Phillips, Berg, & Siniff, 1973 Pierce & Peek, 1984 Poole & Stuart-Smith, 2006
Forage Availability	Dussault, Courtois, & Ouellet, 2006 Dussault, Courtois, Ouellet, & Girard, 2005 Pierce & Peek, 1984 Poole & Stuart-Smith, 2006
Interspersion of Food & Cover	Dussault, Courtois, & Ouellet, 2006 Dussault, Courtois, Ouellet, & Girard, 2005
Snow Constraint	Dussault, Courtois, & Ouellet, 2006 Dussault, Courtois, Ouellet, & Girard, 2005 Poole & Stuart-Smith, 2006
Distance to Geographic Features	Dussault, Courtois, & Ouellet, 2006 Poole & Stuart-Smith, 2006
Lower Elevations	Pierce & Peek, 1984 Poole & Stuart-Smith, 2006
Slope	Poole & Stuart-Smith, 2006
Solar Aspect (Southerly & Westerly Slopes)	Poole & Stuart-Smith, 2006

Table 1. Moose winter habitat preferences as identified by previous literature.

Title	Originator	Publisher	Publication Place	Publication Date
National Elevation Dataset for Idaho (1/3 arc second, 10-meter)	U.S. Geological Survey (USGS), EROS Data Center	U.S. Geological Survey	Sioux Falls, SD	1999
Land Use Map	Batha	Batha	Moscow, ID	2012
National Land Cover Database 2001 – Land Cover of Idaho (source NLCD 2001)	Idaho Department of Water Resources (IDWR) (source NLCD 2001)	Idaho Department of Water Resources	Boise, ID	2007
Idaho 1999 Average Annual Daily Traffic	ITD PLANNING DIVISION	Idaho Transportation Department (ITD)	ITD HQ Boise, ID	2008
Streams of Idaho (303(d) Impaired – 1998)	Idaho Department of Environmental Quality	Idaho Department of Environmental Quality	Boise, ID	2002

Table 2. Datasets used in the construction of project's habitat and focal area maps.

Habitat Preference Characteristic	Resistance Value (higher values = higher resistance)
Land Cover	
Evergreen Forest	100
Shrubland/Scrub	300
Deciduous Forest	300
Wetlands - Woody & Herbaceous	400
Grassland/Herbaceous	500
Crops	500
Developed	500
Slope	
≤10%	100
≥30%	250
≤90%	500
Aspect	
South	100
West	250
East	250
North	500
Elevation	
≤914.4 meters	100
≤1219.2 meters	250
≥1524.0 meters	500
Land Use	
Minimal (Forestland, Recreational, Meadow)	100
Intermediate (Grazing and Mining)	250
High Obstruction (Agricultural Land, Residential, Commercial, Industrial)	500
Distance to Road	
0.40 km	250
0.80 km	500
Distance to Stream	
0.80 km	100
1.60 km	200
3.21 km	300
6.43 km	400
9.65 km	500

Table 3. moose winter habitat preferences with re-classified categories and resistance values.

Preference Variable/Factor	Supporting Literature
Forage Availability in Open, Seral Habitats	Dussault, Courtois, Ouellet, & Girard, 2005 Muir, 2006 Peek, Urich, & Mackie, 1976 Phillips, Berge, Siniff, 1973 Pierce & Peek, 1984
Mature Cover for Shade & Concealment	Dussault, Courtois, & Ouellet, 2006 Muir, 2006 Pierce & Peek, 1984
Higher Elevations	Muir, 2006 Pierce & Peek, 1984
Cooler Aspects (Easterly Slopes)	Muir, 2006
Avoidance of Human Settlement	Muir, 2006
Closer Proximity to Water	Muir, 2006
Closer Proximity to Secondary Roads	Muir, 2006

Table 4. Moose summer habitat preferences as identified by previous literature.

Habitat Preference Characteristic	Resistance Value (higher values = higher resistance)
Land Cover	
Evergreen Forest	100
Shrubland/Scrub	100
Deciduous Forest	100
Wetlands - Woody & Herbaceous	200
Grassland/Herbaceous	200
Crops	400
Developed	500
Slope	
≤10%	100
≥30%	250
≤90%	500
Aspect	
East	100
West	250
East	250
North	500
Elevation	
≥1524.0 meters	100
≤1219.2 meters	250
<9.14.4 meters	500
Land Use	
Minimal (Forestland, Recreational, Meadow)	100
Intermediate (Grazing and Mining)	250
High Obstruction (Agricultural Land, Residential, Commercial, Industrial)	500
Distance to Road	
0.40 km	250
0.80 km	500
Distance to Stream	
0.80 km	100
1.60 km	200
3.21 km	300
6.43 km	400
9.65 km	500

Table 5. Moose summer habitat preferences with re-classified categories and resistance values.

Next, the GRIDASCII tool in Arc GIS was used to convert the two layers, the habitat and focal area maps, for input to Circuitscape. In the software menu, two options were chosen: (a) the pairwise iteration mode, which compares connectivity between focal node pairs, and (b) a cell connection of four neighbors. With the selection of all input requirements, the Circuitscape model was executed finally.

To help evaluate the model, we obtained the VHF location data of moose collected from a 2004-2005 wildlife study conducted in the same geographic area as our study. However, the data set was not collected during the winter months and only included locations of moose from the months of May to September (Muir, 2006). Consequently, another literature review revealed general moose habitat preferences in the summer months, as summarized in Table 4. This review enabled us to generate new habitat map and focal area maps for summer using the same procedure as the winter season as outlined previously. Table 5 lists the preference characteristics, their categories, and the resistance values used to construct the habitat map. Again, with all required layers converted to the ASCII format, Circuitscape was executed for the summer habitat maintaining all options as were used in the winter habitat evaluation.

Results

In both seasonal scenarios, the final cumulative habitat maps revealed distinct areas with minimal resistance. The winter habitat map depicts two distinct areas of least resistance, while the summer habitat map shows a total of three areas which were then used as the basis for our focal area maps. The winter map displayed a noticeable but not entirely distinctive path by which movement could occur between the focal areas. Figure 2 displays the connective strength of the winter data inputted to Circuitscape. The strength of the connection becomes most faint between the two locations, but the results indicate that a moderate amount of energy exists by which connectivity can be maintained. Alternatively, Circuitscape’s summer

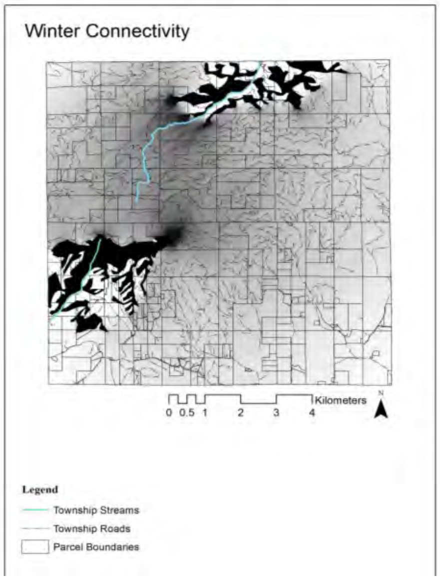

Figure 4. Predicted strength of connectivity between township's winter focal areas. Darker areas denote focal areas and a stronger connection. All layers projected as NAD 83 Zone 11N.

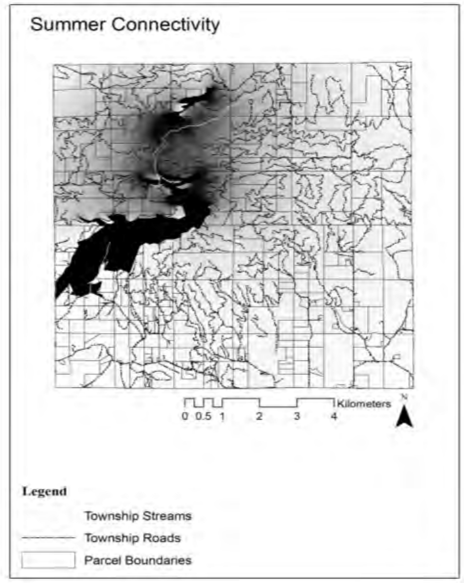

Figure 3. Predicted strength of summer connectivity between township's focal areas. Darker areas denote focal areas and a stronger connection. All layers projected as NAD 83 Zone 11N.

output map denoted a markedly strong connection between focal areas, as shown in Figure 3. It also exhibits an extremely strong, unbroken connection between focal areas, and seems to coincide in large part with the presence of the creek in this area.

As part of our validation of Circuitscape, we compared VHF location data on moose in this area against Circuitscape's summer current map, as shown in Figure 4. Comparison of the two revealed that while some of the moose locations occurred within the focal areas and strongest predicted connections, the majority of locations were distributed to the south and east of those locations they were predicted to occur. However, closer inspection of the data revealed that while the final output map by Circuitscape seemed to produce mediocre results, the habitat map used in its computation performed outstandingly. Close scrutiny of the habitat map and moose locations revealed that a majority of the sightings were located in those areas predicted by our habitat map to be of least resistance otherwise or those areas preferred by moose.

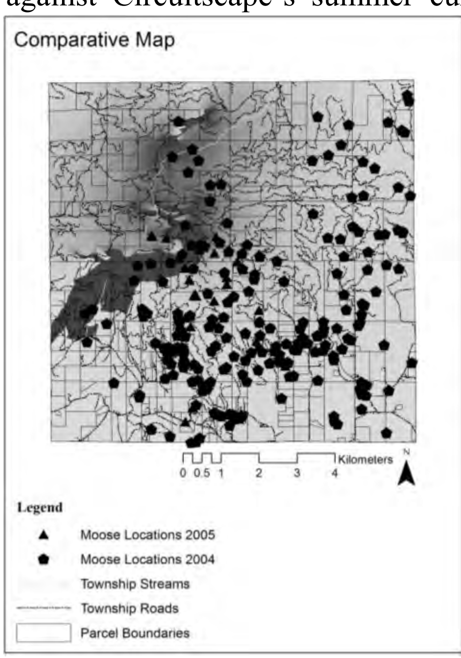

Figure 5. Comparative map of summer output map produced by Circuitscape and VHF location data of moose. All layers projected as NAD 83 Zone 11N.

Discussion

Our findings indicate that Circuitscape should not be the only tool used in the analysis and integration of conservation data into local land-use planning frameworks, although it is very useful. While the creation of habitat and focal area maps is relatively easy, it is highly recommended that those wishing to use this model consult with conservation experts regarding the criteria and variables of the model. Although previous literature by wildlife experts was referenced to construct maps for this study, an actual wildlife expert was not, thus limiting our predictive capabilities to some degree. As both our literature review and prototypical experiment reveal, a collaborative approach is necessary if true progress is to be made in the integration of conservation and local land-use planning.

Results from our modeling revealed three interesting points of discussion which are elaborated below: (a) the notable difference in the strength of connection between the seasonal connectivity maps, (b) the distribution of actual moose locations compared against those locations identified by Circuitscape, and (c) the support of our findings by Polasky et al. (2005).

First, we examined the difference in the strength of connection between Circuitscape's winter and summer linkage maps more closely. As previously noted, the winter season results displayed a faint but present connection between the two featured focal areas, whereas the summer season produced a markedly strong connection between the three featured focal areas. We hypothesize this difference in the strength of "current" exists because of assumptions previously made with the seasonal movement of this species. To elaborate, literature on this species habitat preferences and seasonal movements revealed that while moose are able to access a variety of habitats in the summer, they have limited accessibility in the winter due to the constraint of snow. Ultimately, this knowledge was applied to assigning resistance scores to the habitat variables and criteria used in the construction of our habitat maps which were then used in Circuitscape. We hypothesize that these greater restrictions on winter habitat criteria could have influenced the strength of the "current" in the winter linkage map to appear much weaker than that of the summer linkage map which had fewer resistances tied to its criteria.

Second, we analyzed more in depth Circuitscape's summer linkage map against the distribution of actual moose locations. Results from the summer linkage map by Circuitscape generate several thoughts. Though some of the reported sightings of moose occurred in locations identified as being part of focal areas and linkages, the majority of moose sightings were distributed outside of these areas. However, when the habitat map used in this scenario was inspected closely, it was revealed that a majority coincided with the locations of least resistance in the habitat map, which may otherwise be thought of as areas preferred by moose. These results invoke two thoughts, both related to scale. First, these results suggest that our focal areas in this situation were perhaps at a scale too coarse and that subsequent focal areas should encompass both smaller sizes and a larger number of locations. Second, these results placate the idea that while our broad landscape-level approach was successful in predicting critical linkages across a broader landscape, the locations observed by the VHF study (Muir, 2006) were actually just an example of habitat selection by moose at a finer scale. Previous work on this species and by experts in the wildlife profession supports the idea of multi-scale habitat selection by animals (Johnson, 1980; Muir, 2006). For example, moose must interpret their environment at several levels including the geographic range in which they chose to reside, the habitat patches they select to inhabit, and the plants upon which they choose to browse. Thus, the results from

Circuitscape in this scenario are not simply erroneous and are implying the importance of partnering with wildlife experts in to construct maps at an appropriate scale.

Finally, we conclude that our results further support work by Polasky et al. (2005) which provided that with careful selection of both economic activities and land-use decisions, conservation efforts can in most cases minimally affect economic returns. Our research supports this work as the majority of land in our prototypical township is owned by two timber companies which manage their land for the main purpose of timber harvest. In this particular situation, both their economic objective and conservation targets may be achieved as their land-use activities actually promote the type of habitats preferred by moose. While in this particular case such land-use activities help promote conservation efforts, it may not always be true for other species. Therefore, it is imperative that land-use planners and conservation experts work collaboratively to make the best decisions possible.

Conclusion

As previously noted, various literature indicates that our societies are trending towards a seamless cohesion between conservation planning and land-use planning. Yet gaps still exist in our efforts to create this seamless cohesion of conservation and land-use planning. Namely, encouraging the use of a variety of conservation tools and planning methods which are widely available but not utilized to their fullest extent (Miller et al., 2009; Stokes et al., 2009). Greater levels of refinement and monitoring of implementation methods also need to occur so that we can measure such methods level of effectiveness in integrating conservation data within existing land-use planning frameworks.

While our research was unable to conduct a holistic approach to integrating conservation data into existing land-use planning frameworks, we were able to focus our efforts on a comprehensive literature review of previous research conducted on the topic, and explore extensively the topic of linkage. In addition, our research provides a critical analysis of Circuitscape an increasingly popular corridor identification tool. While Circuitscape represents only one such tool by which linage can be analyzed, the concept of habitat linkage is imperative to any holistic conservation attempt. In conclusion, our research provides a valuable service to planners and conservation experts alike by providing them with techniques, tools, and processes by which they can attain wildlife conservation data in a format and scale both meaningful and helpful to their conservation endeavors.

References

Azerrad, J.M., & Nilon, C. (2006). An evaluation of agency conservation guidelines to better address planning efforts by local government. Landscape And Urban Planning, 77, 255-262. doi: 10.1016/j.landurbplan.2005.03.001

Beier, P., & Loe, S. (1992). In My Experience: A Checklist for Evaluating Impacts to Wildlife Movement Corridors. Wildlife Society Bulletin, 20(4), 434-440.

Beir, P., & Noss, R.F. (1998). Do Habitat Corridors Provide Connectivity? Conservation Biology, 12(6), 1241-1252.

Darr, L.J., Dawson, D., & Robbins, C. (1998). Land-use planning to conserve habitat for area sensitive forest birds. Urban Ecosystems, 2, 75-84.

Dussault, C., Courtois, R., & Ouellet, J. (2006). Canadian Journal of Zoology, 36: 1097-1107. doi:10.1139/X05-310

Dussault, C., Courtois, R., Ouellet, J., & Girard, I. (2005). Space use of moose in relation to food availability. Canadian Journal of Zoology, 83, 1431-1437. doi: 10.1139/Z05-140

Idaho Department of Fish & Game (a). (n.d.). Comprehensive Wildlife Conservation Strategy. Idaho Department of Fish & Game, Retrieved February 10, 2013 from - http://fishandgame.idaho.gov/public/wildlife/cwcs/

Idaho Department of Fish & Game (b). (n.d.). Idaho CWCS Action Plan. Idaho Department of Fish & Game, Retrieved February 10, 2013 from - http://fishandgame.idaho.gov/ifwis/ifwisweb/IDCWCS/FA/?id=22

Idaho Department of Fish & Game (c). (n.d.). Idaho Focal Areas Data. Idaho Department of Fish & Game, Retrieved February 10, 2013 from - http://fishandgame.idaho.gov/ifwis/ifwisweb/IDCWCS/FA/?id=23

Johnson, D.H. (1980). The Comparison of Usage and Availability Measurements for Evaluating Resource Preference. Ecology, 61(1), 65-71.

Lagabrielle, E., Botta, A., Dare, W., David, D., Aubert, S., & Fabricius, C. (2010). Modelling with stakeholders to integrate biodiversity into land-use planning – Lessons learned in Reunion Island (Western Indian Ocean). Environmental Modelling & Software, 25, 1413-1427. Doi: 10.1016/j.envsoft.2010.01.011

Latah County (a). (n.d.). Latah County, Idaho. Latah County, Retrieved February10, 2013 from - http://www.latah.id.us/

Latah County (b). (n.d.). History of Latah County. Latah County, Retrieved February 10, 2013 from - http://www.latah.id.us/history.php

Lopez, R.R., Hays, K., Wagner, M., Locke, S., McCleery, R., & Silvy, N. (2006). Integrating Land Conservation Planning in the Classroom. Wildlife Society Bulletin, 34(1), 223-228.

McRae, B.H. & Beier, P. (2007). Circuit theory predicts gene flow in plant and animal populations. PNAS, 104(50), 19885-19890. www.pnas.org/cgi/doi/10.1073/pnas.0706568104.

McRae, B.H., Dickson, B., Keitt, T., & Sirah, V. (2008). Using Circuit Theory To Model Connectivity In Ecology, Evolution, And Conservation. Ecology, 89(10), 2712-2724.

Miller, J.R., Groom, M., Hess, G., Steelman, T., Stokes, D., Thompson, J., Bowman, T., Fricke, L., King, B., & Marquardt, R. (2009). Biodiversity Conservation in Local Planning. Conservation Biology, 23(1), 53-63.

Muir, J.D. (2006). Habitat Selection and Reproduction by Shiras Moose (*Alces alces shirasi*) in Anthropogenic Landscapes in Idaho (Master's thesis). University of Idaho Libraries, QL737.U55M38 2006.

Newburn, D., Reed, S., Berck, P., & Merenlender, A. (2005). Economics and Land-Use Change in Prioritizing Private Land Conservation. Conservation Biology, 19(5), 1411-1420. doi: 10.1111/j.1523-1739.2005.00199.x

Peek, J.M., Urich, D., & Mackie, R. (1976). Moose Habitat Selection and Relationships to Forest Management in Northeastern Minnesota. Wildlife Monographs, 48, 3-65.

Phillips, R.L., Berg, W., & Siniff, D. (1973). Moose Movement Patterns and Range Use in Northwestern Minnesota. The Journal of Wildlife Management, 37(3), 266-278.

Pierce, S.M., Cowling, R., Knight, A., Lombard, A., Rouget, M., & Wolf, T. (2005). Systematic conservation planning products for land-use planning: Interpretation for implementation. Biological Conservation, 125, 441-458. doi: 10.1016/j.biocon.2005.04.019

Pierce, D.J. & Peek, J. (1984). Moose Habitat Use and Selection Patterns in North-Central Idaho. The Journal of Wildlife Management, 48(4), 1335-1343.

Polasky, S., Nelson, E., Lonsdorf, E., Fackler, P., & Starfield, A. (2005). Conserving Species in a Working Landscape: Land Use with Biological and Economic Objectives. Ecological Applications, 15(4), 1387-1401.

Poole, K.G. & Stuart-Smith, K. (2006). Winter habitat selection by female moose in western interior montane forests. Canadian Journal of Zoology, 84, 1823-1832. doi:10.1139/Z06-184

Press, D., Doak, D., & Steinberg, P. (1996). The Role of Local Government in the Conservation of Rare Species. Conservation Biology, 10(6), 1538-1548.

Roloff, G.J., Donovan, M., Linden, D., & Strong, M. (2009). Lessons Learned from Using GIS to Model Landscape-Level Wildlife Habitat. In J.J. Millspaugh & Thompson III, F.R. (2009), Models for planning wildlife conservation in large landscapes. (pp. 287-320). Amsterdam; Boston – Elsevier/Academic Press.

Stokes, D.L., Hanson, M., Oaks, D., Straub, J., & Ponio, A. (2009). Local Land-Use Planning to Conserve Biodiversity: Planners' Perspectives on What Works. Conservation Biology, 24(2), 450-460. Doi: 10.1111/j.1523-1739.2009.01356.x

Svoray, T., Bar (Kutiel), P., & Bannet, T. (2005). Urban land-use allocation in a Mediterranean ecotones: Habitat Heterogeneity Model incorporated in a GIS using a multi-criteria mechanism. Landscape and Urban Planning, 72, 337-351. doi: 10.1016/j.landurbplan.2004.05.001

Theobald, D.M., Hobbs, N., Bearly, T., Zack, J., Shenk, T., & Riebsame, W. (2000). Incorporating biological information in local land-use decision making: designing a system for conservation planning. Landscape Ecology, 15, 35-45.

Toweill, D. (2008). Progress Report – Moose (ProjectW-170-R-32). Boise, ID – Idaho Department of Fish and Game. Retrieved from - https://collaboration.idfg.idaho.gov/WildlifeTechnicalReports/Moose%20PR08.pdf

Underwood, J.G., Francis, J., & Gerber, L. (2011). Incorporating biodiversity conservation and recreational wildlife values into smart growth land use planning. Landscape and Urban Planning, 100, 136-143. doi: 10.1016/j.landurbplan.2010.11.014

United States Census Bureau. (n.d.). State and County QuickFacts Latah County, Idaho. United States Census Bureau, Retrieved February 10, 2013 from - http://quickfacts.census.gov/qfd/states/16/16057.html