Gateway Blueprint Model Workshop 2005

LEAMFrag applied to the St. Louis Region

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June 2005

Abstract:

Natural habitat is significantly decreasing with the increasing proportion of the landscape used by humans. Conversion of land for agricultural and urban development has turned large continuous unbroken patches of wild habitat into numerous small patches, isolated from each other among a matrix of inhospitable land-uses. Urbanization is considered a major cause of habitat fragmentation, recognized as a major threat to biological diversity and considered to be the primary cause of the current species extinction crisis, and therefore threatens the survival of many species worldwide. The purpose of the LEAMfrag model is to (1) determine the location of habitat patches likely to sustain populations, (2) estimate population size, and (3) assess the degree of connectivity and potential gene flow between the patches. This method, applied to a changing landscape, indicates changes in species-specific patch connectivity and determines the impact of land-use change on population isolation and therefore on population fragmentations, which could be used as an indicator of habitat fragmentation. We applied our model to the St. Louis landscape for both considered species and investigated the potential effect on their suitable habitat of development following the "Uber" scenario. The development under this scenario does not represent a direct threat on the survival of the considered species in the Saint Louis region. However, a large amount of the habitat lost occurs in the vicinity of the river, which often is used as a movement corridor for dispersing individuals.

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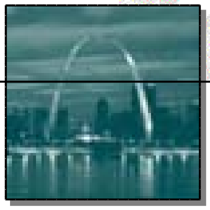


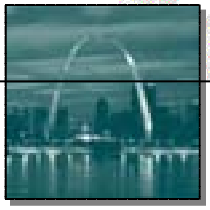
Introduction

The process of habitat fragmentation involves three factors, which have important repercussions on plant and animal species that originally occupied large continuous areas of wild habitat (Schmiegelow and Mönkkönen, 2002; Gehring and Swihart, 2003). First, fragmentation leads to large patches breaking into numerous smaller patches with a net habitat loss. This results in decreased amounts of resources and fewer shelter areas available to wild species, in turn leading to a general reduction in the number of individuals that can be hosted. Second, by opening core areas, fragmentation of continuous habitat patches leads to a dramatic increase in edges (Sih et al., 2000). Edges provide distinct micro-climatic conditions from the core; they may become less suitable for some species. Edges also contribute to higher predation rates by favoring generalist predator influx (Schmiegelow and Mönkkönen, 2002), which in turn greatly impacts the population of resident species. Third, habitat fragmentation results in the geographic isolation of “habitat islands” among a matrix of urban or agricultural land-uses. The mobility of some organisms might thus be restricted (Andreassen et al., 1996) thereby isolating some populations. Small isolated populations can be threatened by inbreeding, which represents a serious problem for their survival, and could lead, in the case of severe inbreeding, to population extinctions (Templeton et al., 1990; Schmitt and Seitz, 2002). Moreover, small populations are more sensitive to stochastic events, such as fires or epidemic outbreaks, which could drive a local population to extinction.

As the isolation of habitat patches increases, the probability of their recolonization decreases (Parker and Mac Nally, 2002). Therefore, long-term persistence of isolated populations cannot be assumed. Nonetheless, not all species have the same sensitivity to habitat fragmentation. Naturally rare, sedentary species, with specialized habitat requirements show a significant decline whereas abundant mobile generalist species are less affected (Mac Nally et al., 2000) or even favored, in the case of edge specialists (Tscharntke, 1992; Gehring and Swihart, 2003). Also the degree of isolation of habitat patches might depend on the migration capacity of each species living within them. As a consequence, habitat fragmentation cannot be generally described and should be specified for every individual species.

Methods

Our approach is composed of three successive steps that aim at: (1) identifying suitable habitat patches within a landscape based on specific species habitat preference and requirements; (2) modeling species dispersal through the landscape, based on its specific movement behavior across different land-uses; and (3) determining connectivity between



patches and providing an estimation of the population size capable of gene exchange between connected patches.

Step 1: identification of suitable habitat parches

In order to identify, from a landscape map, patches of habitat suitable to support a population of a considered species, a selection criterion should be defined. Considerations of patch area alone may be insufficient to estimate habitat suitability for a species, since patches of equal area but different shape may present a different proportion of edge and therefore may not be equally able to support a given animal population (Helzer and Jelinski, 1999). An estimation of the amount of core habitat per patch would represent a good estimator of habitat suitability for edge-sensitive species. However, Schumaker (1996) and Helzer and Jelinski (1999) reported that the distance through which edge disturbance infiltrates core habitat varied widely (between 8 to 240 meters) and also that the edge effect varied between geographical regions. Helzer and Jelinski (1999) emphasized the need for a relative measure of core, such as perimeter to area ratio, also shown by Schumaker (1996) to be correlated with habitat quality, to account for the amount of patch area exposed to edges without requiring a subjective estimation of edge depth.

The perimeter to area ratio, reflecting the area and shape of a patch, was later shown to be, for grassland birds, a good predictor of both individual species presence and overall species richness (Helzer and Jelinski, 1999). The area of a patch is usually much larger than its perimeter. To avoid working with very small numbers, we therefore decided to use the area to perimeter ratio (APr) (the inverse of the perimeter to area ratio) as a selection criterion to identify patches of suitable habitat.

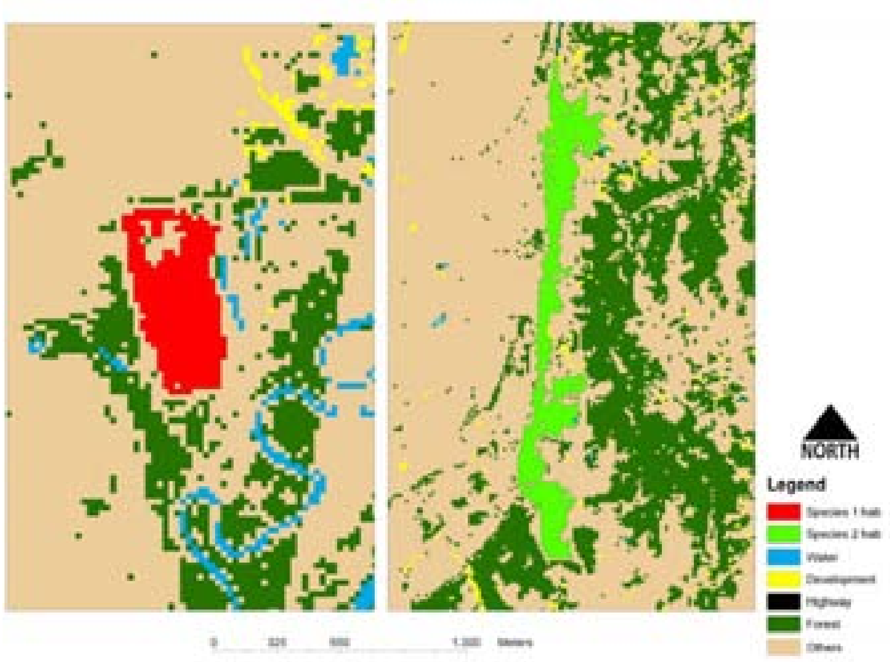
The threshold ratio value above which a habitat patch was considered suitable was defined as the APr of the smallest square shape (this is consistent with the use of a raster land-use map) able to sustain a population of at least one individual.

Study organism

Habitat fragmentation does not affect all species in the same way. Our model was designed to estimate habitat requirements for species sensitive to the fragmentation of their habitat. In the St. Louis area, we applied our model to two species. Both were defined as exclusive forest specialists with limited dispersal. Both species were given the same dispersal distance (22 cells =660 meters) and minimum suitable area requirements (5ha), but differed of their APr ratio (i.e. on their ability to tolerate edge disturbance).

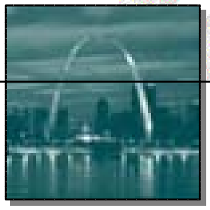
Species one, had an APr ratio of 56 (corresponding to the ratio of a 5ha square) and represents a species with low tolerance of habitat fragmentation, preferring exclusively clumped habitat patches (Fig. 1), while species two had an APr ratio of 20 and can tolerate much higher disturbance levels (Fig. 1). These species could be compared to a weasel, a squirrel or a small woodland bird.

Figure 1



Habitat selection

Forested land-uses served as focal habitat structure, while others served as the matrix within which forested patches were dispersed. For each forest patch, the APr was calculated and patches presenting a ratio ≥ than the defined threshold value were identified as suitable habitat (Fig. 2).



Step 2: model species dispersal in the landscape

Dispersal model

The dispersal of the species outside of suitable habitat patches was simulated in each land-use grid cell by a dispersal model created in STELLA 7.0.1. The first task performed by the dispersal model is a reclassification of the values of the "habitat" grid map into three categories: (1) suitable habitat, (2) barrier habitat and (3) crossable habitat, based on the classification displayed in Table 1. Suitable habitat cells represent origin cells out of which the species can disperse. Barrier habitat cells represent an insurmountable limit to the species movement and act as a barrier to dispersal. Crossable habitat cells represent habitats that can be readily crossed by the species and constitute a virtual road for the dispersing species.

We simulated the progressive dispersal of species away from their suitable habitat patches into the landscape matrix (Fig. 2). We fixed the dispersal distance as being equal to the average "straight line" dispersal distance of the considered species divided by grid cell resolution. This ensured the dispersal pattern covered any reachable cell located within the dispersal range of the species.

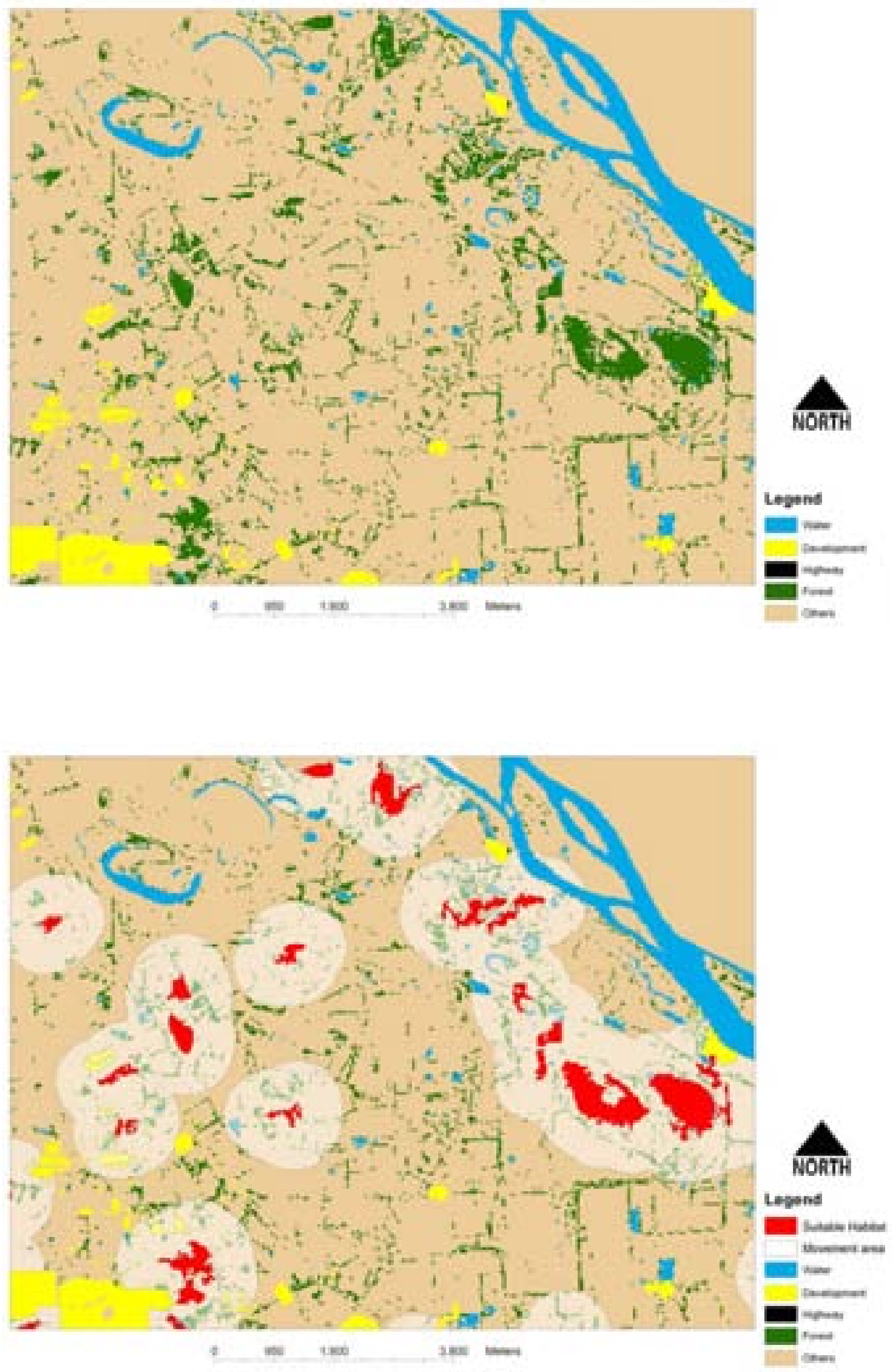
In a single simulation, the selective dispersal approach allowed us to investigate all potential paths able to be used by the species while dispersing outside of suitable habitat cells. At the end of the simulation, the impact on the dispersal pattern of species, of each specific land-use type surrounding suitable habitat, could be evaluated.

A population of the focal species was assumed to be able to send genes as far as the diffusion model allowed it to reach.

Step 3: estimation of connectivity between suitable habitat patches

Suitable patches of habitat were considered connected if they could exchange individuals (i.e. if individuals from one suitable habitat patch could disperse into another) (Fig. 2).

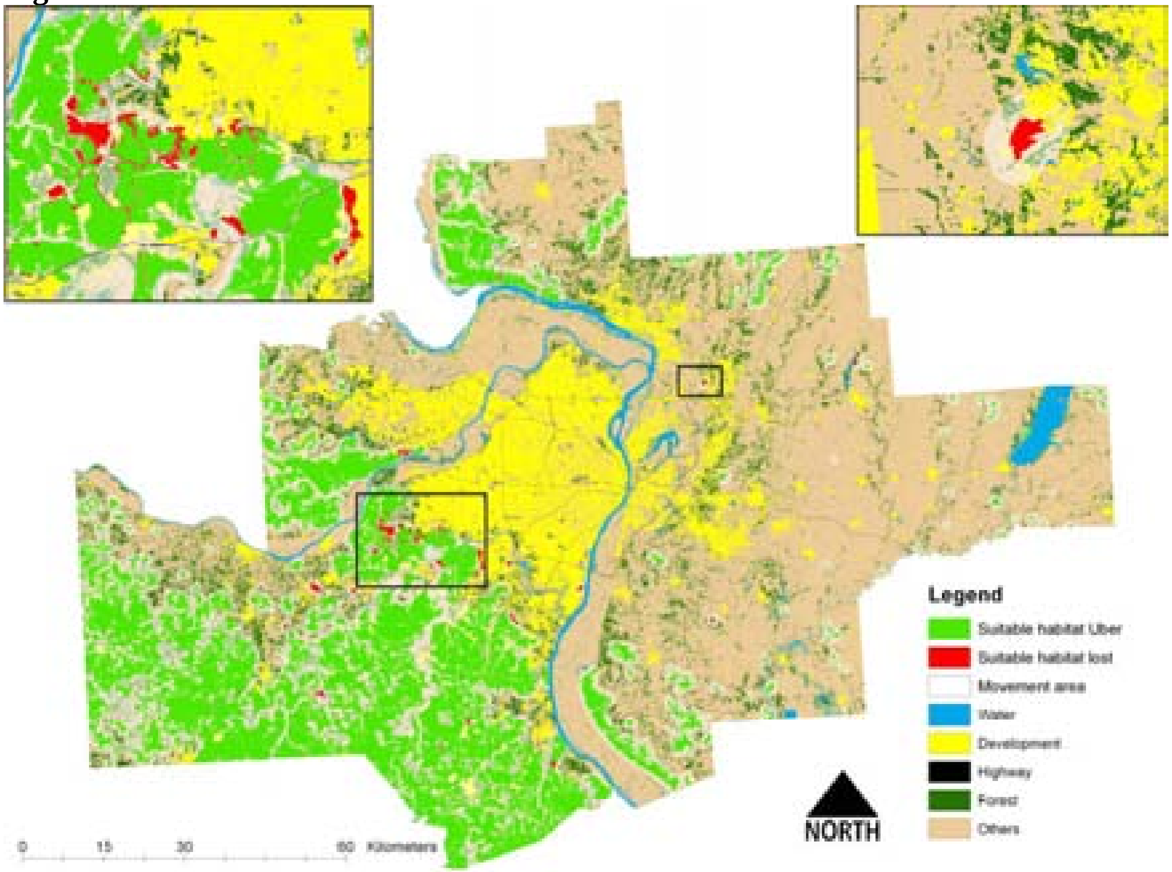
Figure 2


NORTH
Legend
Water
Development
Highway
Forest
Others
0
950
1,900
3,800
Meters
NORTH
Legend
Suitable Habitat
Movement area
Water
Development
Highway
Forest
Others
0
950
1,900
3,800
Meters

Results

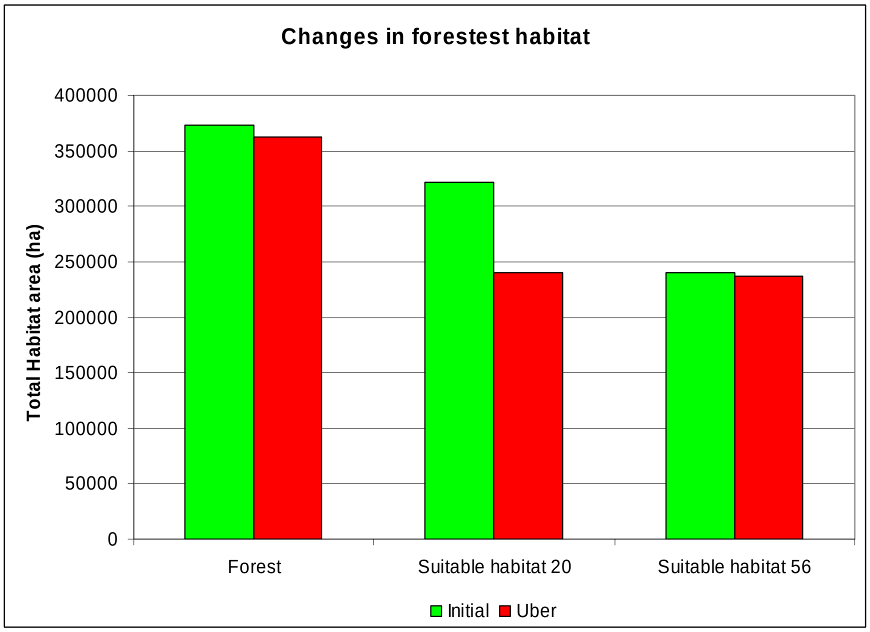
We applied our model to the St. Louis landscape for both considered species and investigated the potential effect on their suitable habitat of development following the Uber scenario. First of all, we observe (Fig. 4) that only a small proportion of the forested habitat is lost as a result of development. Figure 3 shows the potential changes in suitable habitat for Species one (APr=56). We observe in that a very small proportion of the habitat presently

Figure 3



suitable may be lost (Fig. 3). On the other hand, we observe from Fig. 4 and Fig. 5 that the effect on the amount of suitable habitat for species two is very different and the Uber development pattern leads to a much higher proportion of habitat loss.

Figure 4



This pattern of habitat loss is due to the fact (illustrated in Fig. 6) that development occurs mainly within lower quality habitat (usable for species two but not species one) but leaves large less fragmented habitat patches relatively untouched.

Figure 5

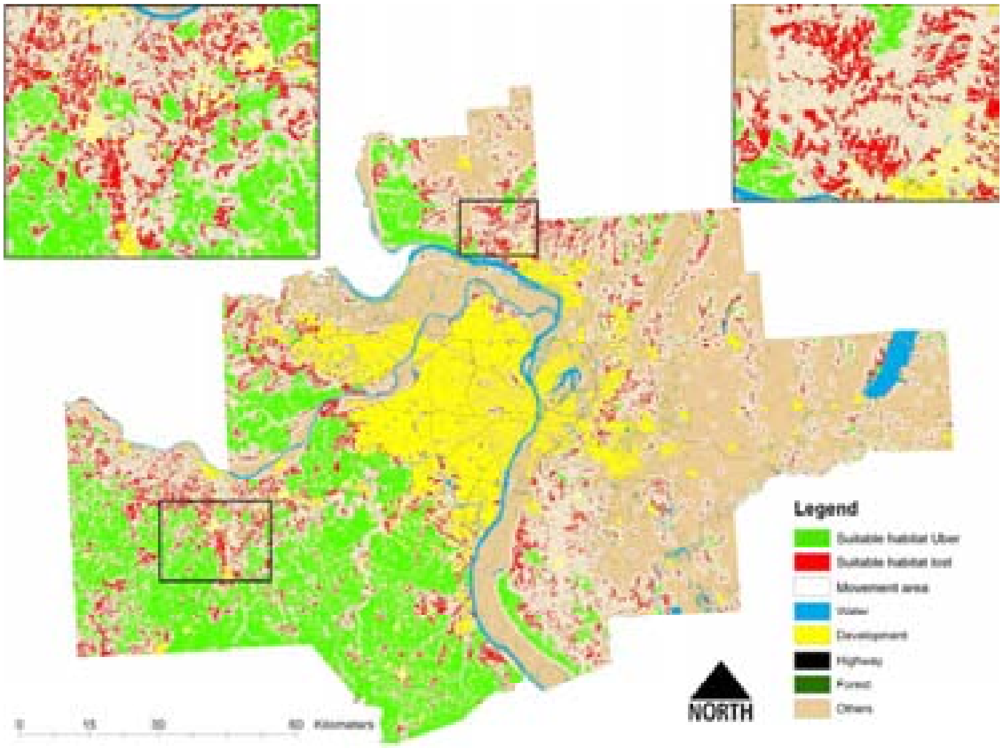
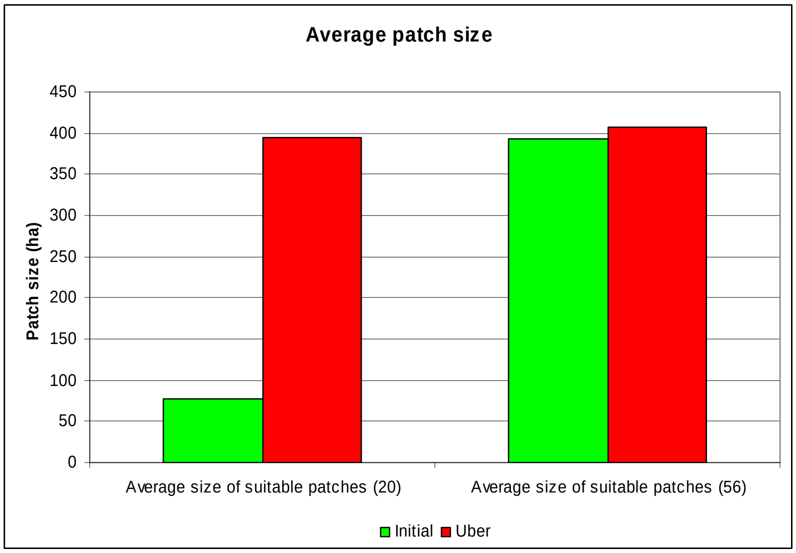
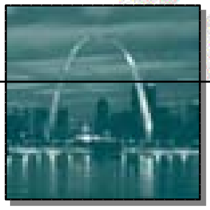


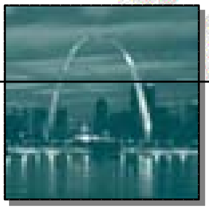
Figure 6





Conclusion:

The Uber development scenario leads to some habitat loss within low quality habitat but has minimal impact on the amount of high quality habitat. It will therefore not represent a direct threat on the survival of the considered species in the Saint Louis region. However, we also observe that a large amount of the habitat lost occurs in the vicinity of the river, which often is used as a movement corridor for dispersing individuals. While not endangering the long term survival of the local populations in the Missouri region (due to the presence of large non-fragmented continuous forest patches), this development pattern could, for species two, break the Illinois riverine corridor and lead to the genetic isolation of north and south regions.



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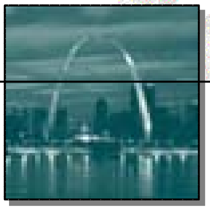

Tables:

Table 1: Landscape diffusion coefficients, obtained through reclassification of the NLCD land-use values, into crossable and barrier cells, based on the movement behavior of the focal species. (The numbers correspond to the NLCD numeric code for each land-use).

Crossable land-uses	**Barrier land-uses**
24: roads 31: bare rock/sand/clay 33: transitional 41: deciduous forest 42: evergreen forest 43: mixed forest 51: shrubland 71: grassland/herbaceous 81: pasture/hay 83: small grain 84: fallow 91: woody wetland 92: emergent herbaceous wetland	11: open water 12: perennial ice and snow 21: low intensity residential 22: high intensity residential 23: commercial 25: large roads such as state and national highways 32: quarries, strip mines 61: orchards 82: row crops 85: urban, recreational grasses