Animal Movements:

The utilization of white-tailed deer *(Odocoileus virginianus)* trails by vertebrates as a means of traversing gaps in landscape matrices

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Abstract

It is understood in ecology that most landscapes are not composed of homogeneous habitats, but a heterogeneous mix of several habitat types. Animals moving through this matrix must traverse the gaps between habitat type created in this matrix in order to move across the landscape for feeding, reproduction and immigration/emigration. While many studies have investigated how animals move through landscapes and utilize corridors, models predicting when an animal will attempt to cross a gap between habitats are not available. This study attempts to find a relationship between animal size and the length of gap crossing attempts by using trail cameras to monitor deer trails. Trails of three different lengths (< 25m, 25-50m, 50-75m) between mature deciduous forest were monitored for gap crossings. The results show that all animals, regardless of body size, utilize trails 25-50m significantly more than trails of other lengths to traverse gaps. The authors hypothesize that selection of this trail length could be due to the balance between detour efficiency with acceptable predator risk.

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In the natural world there are very few homogeneous landscapes. Instead, most form a patchwork, or matrix, of heterogeneously connected habitats (Foreman, 1995). This patchiness has important implications for the animals which inhabit these landscapes, as it causes gaps between patches of ideal habitat that the animals must cross when traversing the landscape. Understanding how animals traverse landscape matrices has important ecological implications (Johnson, Weins, & Crist, 1992), especially as habitat becomes increasingly fragmented by humans, forcing animals to choose new routes in order to move within the landscape. This changing landscape may confine certain specialist species to smaller habitat patches, or force the animal to try to weigh the predation risks of traversing a gap against the energetic cost of avoiding that gap (Russell, Swihart, & Feng, 2003 and McAlpine et al. 2006).

Baguette and Van Dyck (2007) found "grain" of a landscape (i.e. fragmentation level) to affect wildlife movements during both routine foraging and long-distance dispersal. It is known that animals change their behavior when crossing through gaps (Vasques, Ebensperger & Bozinovic, 2002), however the way that different species respond to fragmented habitat is complicated, and includes factors such as scale of heterogeneity, the movement capabilities of different species, and the actual form of the landscape matrix, making analysis of animal movements through heterogeneous landscapes difficult (Johnson et al, 1992). Despite the difficulties, the importance of understanding animal movements in heterogeneous landscapes is key to the conservation of species. Bolger, Alberts, and Sauvajot (1997) showed that fragmented habitats support fewer numbers of rodents than more connected ones. These findings highlight the need for further study looking into what conditions might be necessary for animals to move freely through a fragmented or patchy habitat. For example, Castellón and Sieving (2006) showed that South American bird dispersal was significantly constrained by open matrix, but that wooded corridors and shrubby matrix both facilitated bird dispersal equally well through the landscape.

However, the research done in this area has not created a conclusive, general model for the determining factors influencing gap crossing behavior. Interestingly, Bolger *et al.* (1997) did not find a relationship between isolation distance of a fragment and species diversity. Additionally, Bowman and Fahrig (2002) found that the probability of chipmunks crossing gaps to return to their home range after being transplanted was not related to the size of the gap that had to be crossed. A study investigating bird movement through patchy forest habitat found that forest specialists generally used wooded routes to navigate the landscape over open routes, even when they were three times longer. However, there was great variation among species, even though all were considered forest specialists. It was hypothesized that species more used to open areas such as tree tops may be more comfortable crossing larger gaps (Desrochers & Hannon, 1997). These studies point to the necessity of studying how gaps and corridors factor into animal movement throughout the landscape.

Studies focusing on movement within corridors, defined here as narrow strips of similar environment, found that rodents move farthest and fastest in corridors of medium width, suggesting the corridor size does play a factor in animal movement (Andreassen, Halle, & Anker, 1996), and that corridors are preferred by animals even when they do not seem to be necessary for their movement out of an isolated patch (Browne, Peles & Barrett, 1999). Butterflies have also been found to move much more frequently between patches of habitat that are connected by corridors, and more easily to closer patches than farther (Haddad, 1999). While corridors are traditionally thought of as narrow stretches of similar habitat, Lidicker (1999) defines corridors as “any narrowly delimited place in the environment that facilitates (relative to the matrix) movements of organisms between local populations (demes),” (p.339) greatly expanding the definition to possibly include deer trails through gaps as potential corridors for movement.

While it is clear that the presence of corridors affects how an animal will navigate a patchy landscape, few studies have been performed that explicitly test the effect of gap size on the crossing of gaps by mammals (Bowman and Fahrig, 2002). Mech and Zollner (2002) hypothesized that the ability of an animal to navigate the landscape and cross between similar pieces of the matrix may be dependent on perceptual range (that is, range at which an animal can detect similar habitat across a gap). While studying the European Lynx, Pe’er and Kramer-Schadt (2008) found that increased perceptual range results in strong changes in movement patterns and substantially enhances connectivity. However, while Mech and Zollner (2002) found perceptual range to be dependent upon body size, a study done in the Australian mountains found that body size was not correlated with response to fragmentation. While this might suggest body size and movement across fragmented landscapes may not be connected, this study focused on the potential for decline in a species due to fragmentation rather than an animals ability to move across gaps (Davies, Margules, & Lawrence, 2000). While testing Mech & Zollner’s model, Bakker and Van Vuren found that red squirrels were able to weigh the cost of crossing a gap against the efficiency of going around it and that animals were more likely to cross the gap opening when “detour efficiency” was low (Bakker & Van Vuren, 2004). Furthermore, a study by Lima, Valone, and Caraco (1985) reinforced the idea of perceptual range when discovering that grey squirrels can also weigh maximum energy gain verses predation risk when deciding whether to consume food in the middle of an exposed area or carry it to cover. Zollner and Lima (2005) also suggested a model based on balancing predation risk with perceptual range for nocturnal rodents and concluded that animals with low energy reserves favor high risk/high perceptual range conditions, while animals with high energy reserves favor situations with low predation risk, even though these provide less perceptual range and thus necessitate more search time. Finally, a study by Doak, Marino, and Karieva (1992) concluded that the scale of habitat clustering has a large effect on animal movement throughout that area. They suggest that more study be done in this area, as consideration of scale is necessary in planning successful conservation strategies. Therefore, it is possible to provide a broad, several species encompassing study of wildlife gap crossings which will start to fill in some of these missing links in gap crossing research.

Previous studies at the Pierce Cedar Creek Institute have shown that the landscape is naturally heterogeneous with a high degree of corridor connectivity between various matrix pieces (Walker & Keys, 2005). Many of these matrix pieces are connected by significant numbers of white-tailed deer (*Odocoileus virginianus*) trails across gaps in the landscape matrix. Heys and Keys (2006) found that on forested edges the use of these trails by other vertebrate species was high. Cameras positioned on these trails found use by coyote, fox, raccoons, opossum, various squirrel species, mice, and turkey. Further research specifically on raccoons by Paladino and Keys (2007) found that home ranges of raccoons covered a heterogeneous landscape matrix. This finding suggests that movement across gaps by forest species must be occurring, and given the proclivity of raccoons and other species to use deer trails throughout this landscape matrix leads us to hypothesize that gap crossings may be occurring by use of said trails. This study therefore hypotheses that:

1. vertebrate species (other than *Odocoileus virginianus*) make use of deer trails to cross gap openings between similar habitats.
2. animal size will correlate with gap crossing length, specifically that larger animals will cross longer gaps while smaller animals will attempt only shorter gaps.

Materials & Methods

Study Site

Research was conducted at the Pierce Cedar Creek Institute for Environmental Studies (PCCI) in Hastings, MI. PCCI covers 661 acres of varied habitat, including fen, wetland, field, forest, stream, lake, and several types of prairie. Previous study has found this landscape matrix to contain an extensive network of white-tailed deer (*Odocoileus virginianus*) trails to the extent that they are visible on aerial photographs of the site (Walker & Keys, 2005). Using the most recent aerial photographs available (2005), areas of high trail density and usage were identified and field proofed in early spring as potential study sites. Field proofing of study sites included searching for tracks, scat, and any other animal sign. Suitable trails were those that were currently being used and ran from forest habitat through a prairie, field or wetland habitat to another patch of forested habitat. Trails meeting these requirements were tagged with flagging tape and measured for distance. Gap sampling distances were designated as: 1) trails < 25m; 2) trails 25-50m; and 3) trails 50-75m. From the potential deer trails, ten sites were selected, five crossing a wetland habitat and five crossing the prairie or field habitats. In the wetlands, two trails < 25m; two 25-50m; and one 50-75m. In the uplands, one trail < 25m; two trails 25-50m; and two trails 50-75m. Line transects were used to determine vegetation type and the nature of the plant communities at each site. Line transects were run parallel to the deer trails, 0.5 – 1m off of the trail. A Thales Mobil Mapper® GPS unit was used to collect the positions of the trails.

Survey Methods

Animal usage of the deer trails across the gaps was monitored using a non-invasive method. Scout Guard 550 (HGO) trail cameras were used in conjunction with track plates at each site to collect information on animals using the trails to cross the gap (Campbell, Long, and Zielinski, 2008; Kays and Slauson, 2008; Ray and Zielinski, 2008). Two cameras were placed in the center of the gap trail facing opposite directions in an effort to capture the animal from both sides as it traversed the length of the trail (Figure 1).

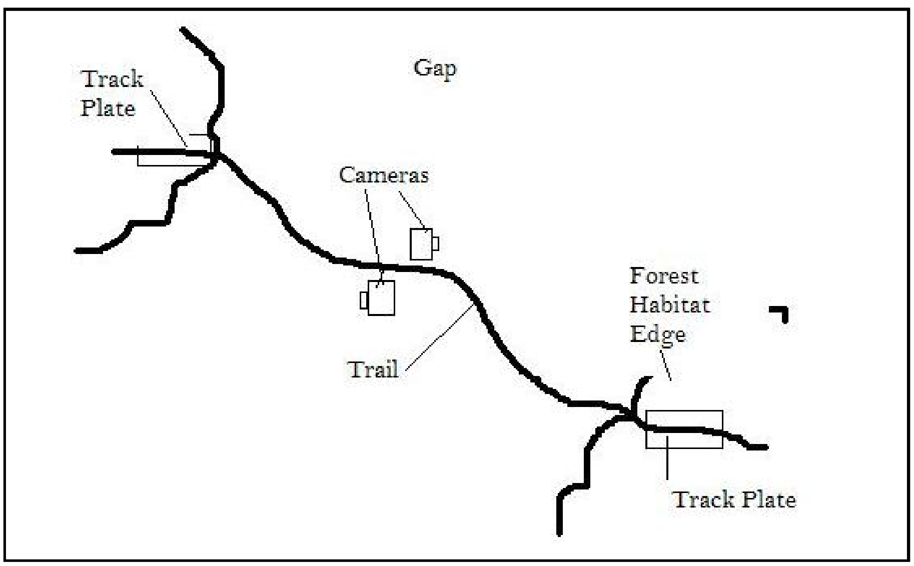

Figure 1. Camera and track plate placement on gap trails

Cameras were mounted on 4x4 posts buried 0.6m in the soil with wood slats attached to the bottom to prevent tampering with or removal of the camera posts. The cameras were mounted roughly 0.6m above ground and angled slightly downward for the most extensive view of the trail possible. The cameras were set to take a burst of three pictures when triggered by motion, and to continue taking pictures as often as triggered. No lag time was set for the cameras, however an internal lag time of about 3 seconds between each picture existed as a result of shutter speed and processing times. The cameras ran 24 hours a day, seven days a week, using an infrared flash in low-light/night-time situations.

In addition to the cameras, track plot areas were set up at either end of the trails, within the forest canopy to verify that animals were crossing through the entirety of the gap. These were approximately $0.6m^2$ patches where any groundcover was removed and the soils raked smooth. Most plots had soils unsuitable for track laying, and were supplemented with a sandy loam made by mixing topsoil and sand to create the correct consistency. Track plots were implemented only in the prairie sites, as the gap connectors in wetland areas were covered with a small amount of standing water for the majority of the study, and would not hold tracks.

The cameras and track plates were installed the third week in May, but did not begin recording until the fourth week in May due to difficulties with battery power and memory cards. Cameras were checked every other day and pictures transferred to laptop computer using an SD card reader while still in the field. Track plots were also checked for any animal sign present, which was recorded before smoothing out the surface once more.

Data Analysis

The photographs taken by the cameras were sorted on a daily basis, and any animals present recorded along with the time the photograph was taken, the weather at the time as recorded by Intellicast (www.intellicast.com), and the moon phase. In addition, any pictures of white-tailed deer were examined for identifying markings on the pelage to be used for individual identification. After failing to identify permanent body markings, facial markings were used extensively to identify individuals. Especially important identifying characteristics were the color, definition, and spread of the vertical snout patch, absence or presence of other facial marks such as dark “v’s” between the eyes or antlers, as well as the growth patterns of antlers on males. Each identified individual was given a number and characteristic photograph. Any future captures of the individual were labeled with the species identification number.

In order to conduct statistical analyses, the numbers of each species were tallied for each trail and split into classes based on approximate mass. Fox Squirrels and Eastern Cottontail Rabbits were classified as small animals; Raccoons, Skunks, and Woodchucks as medium-sized animals; and Wild Turkeys as large animals. To analyze for any statistically significant relationship between animals size and trail length, t-tests were run for animal size as a function of trail length as well as trail length as a function of animal size. Finally, an ANOVA test was run to test for variance between trail lengths for all animals, regardless of size class.

Results

At the conclusion of the study period, a total of 33 small-sized animals (20 eastern cottontail rabbits, *Sylvilagus floridanus*; 13 eastern fox squirrels, *Sciurus niger*), 112 medium-sized animals (98 raccoons, *Procyon lotor*; 13 woodchucks, *Marmota monax*; and one striped skunk, *Mephitis mephitis*) and 35 large-sized animals (turkey, *Meleagris gallopava*) had been photographed. Unfortunately, correlating animal tracks on the track plots with photographs did not work as planned, as any tracks were frequently obliterated by rain, and the capture of distinct tracks were often overlapped and not usable. The mean numbers of animals of a particular weight class were found for each trail length, and are recorded as follows in Table 1.

Table 1
Mean Number of Animals Per Trail Length

	Trail Length		
	< 25m trails	25-50m trails	50-75m trails
Small Animals	2.00	5.75	1.33
Medium Animals	1.33	23.50	4.67
Large Animals	0.33	7.50	1.33

A one-tailed T-test assuming equal variance on animal size as a function of trail length showed that medium-sized animals were significantly more prevalent on trails 25-50m than on trails < 25m (*n=112; t=2.02; p=0.038*). It also showed that medium animals were significantly more likely to use trails 50-75m than trails < 25m (*n=112; t=2.13; p=0.028*). No other sized animals showed significant preference of one trail length over another during the study (Table 2).

One-tail T-tests comparing trail length as a function of animal size to trail length reveal that on trails < 25m, medium animals are significantly more likely to use the gap crossing than large animals (*n=3; t=2.13; p=0.050*). On trails 25-50m, medium-sized animals are significantly more likely to use the trail than small animals (*n=4; t=1.94; p=0.043*). Finally, on trails 50-75m, medium-sized animals are significantly more likely to use the trail than small-sized animals (*n=3; t=2.13; p=0.045*) (Table 3).

Table 2
One-tailed T-test assuming equal variance *p* values for animal size as a function of trail length

	Trail Length		
Animal size class	< 25m vs. 25-50m	25-50m vs. 50-75m	< 25m vs. 50-75m
Small	0.1057	0.0714	0.3351
Medium	0.0380	0.0589	0.0278
Large	0.1882	0.2232	0.2536

In an analysis of trail preference for all animals cumulatively, a single-factor ANOVA was conducted. Results show that trails 25-50m are utilized significantly more than either trails < 25m (*p*=0.047) or trails 50-75m (*p*=0.0257), regardless of animal size.

Table 3
One-tailed T-test assuming equal variance *p* values for trail length as a function of animal size

	Animal Size		
Trail length	Small vs. Medium	Medium vs. Large	Small vs. Large
< 25m	0.3043	0.0506	0.1189
25-50m	0.0429	0.0884	0.3994
50-75m	0.0445	0.0684	0.5000

Identification of individuals based on pelage was determined to be only feasible for white-tailed deer, due to the fact that smaller animals tended to be less frequently photographed, had largely indistinguishable pelage differences, and were often blurred. However, 30 individual white-tailed deer (*Odocoileus virginianus*) were identified, sometimes on multiple trails over the span of the study period.

Discussion

While the original hypothesis that animal size would correlate with gap trail length could not be supported, this study did illuminate a general bias towards trails of 25-50m in length regardless of animal size. The question then remains, do these numbers show a preference for 25-50m length trails or avoidance of shorter and longer trails? Bakker and Van Vuren (2004), in studying red squirrel gap crossings, determined that animals may move through gaps according to “detour efficiency.” According to this model, the trails < 25m may have had a detour route with high enough efficiency that it was not worth the risk to travel through the gap. On the other hand, the trails 50-75m may have had too much predation risk associated with crossing so much open territory that the detour, while ineffective, was preferable to a risky crossing. Trails 25-50m may have provided the ideal conditions for gap crossing: an inefficient detour and a gap that was not too long to be considered unnecessarily risky. This may substantiate the work of Russel, Swihart and Feng (2003) showing that trails in the 25-50m length provide enough of an energetic advantage verses the predation risk associated with the length. This may provide an explanation for the numbers produced by this study, and provides plenty of material for future study.

It is also important to note that trails were used significantly more by medium-sized animals over animals of other sizes. Given the fact that most of the recorded animals were raccoons, which are also predatory, the energetic advantage for raccoons to use the trails in their foraging seems plausible, especially if they can increase their contact with prey animals by doing so.

Future Study

Gap crossing studies should be performed with typical North American wildlife species such as raccoons, woodchucks, and wild turkeys, even though these may be atypical study species. Bowman and Fahrig (2002) make a point of saying that more research needs to be done that explicitly tests the effects of gap size on the crossing of gaps by mammals. Future research on gap crossing theories should also be done over a longer period of time in an effort to extend the results over the changing seasons. Also, studies should be done to test the theory of detour efficiency for species other than red squirrels.

The secondary aim of identifying individuals non-invasively by their pelage is also an area necessitating further study. A study specifically researching the accuracy of identifying individuals by first tagging them in a way determinable on a photograph and then identifying by pelage, or testing the ability of non-partisan subjects to group those identified as the same individual would be interesting and fruitful.

If these theories hold up, the knowledge gained may be able to be extrapolated to provide practical guidelines for conservation efforts dealing with fragmented habitats such as landscape design and management techniques. Studies that provide an empirical basis for practical conservation and management techniques are more important than ever, as habitats become increasingly more fragmented due to human population growth and spread.

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