THE EFFECT OF ROADS ON SMALL MAMMAL MOVEMENT

By

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ABSTRACT

Barriers such as roads may decrease small mammal movement between patches in fragmented landscapes, which may decrease the likelihood that extinct patches will be recolonized by dispersing individuals. We hypothesized that there are three possible barrier effects of roads: aversion to roadside habitat due to increased noise or pollution levels associated with traffic volume, avoidance of the road itself, or increased probability of mortality due to collisions with vehicles. We evaluated the type of barrier effects that roads have on small mammal (white-footed mice and eastern chipmunks) movement using a combination of mark-recapture and translocation studies. We did not find that small mammals avoid roadside habitat or that they experience higher levels of mortality associated with traffic volume. Our results suggest that small mammal movement decreases because they avoided crossing the roads during short and long distance movements through the landscape.

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INTRODUCTION

The ability of animals to move through a landscape to recolonize habitat patches is important for overall population persistence (Fahrig and Merriam 1985; Kozakiewicz 1993). Roads can act as barriers to such movements, the degree to which will depend on the behavioural responses of the animals, as well as attributes of the road and traffic volume. Roads can act as barriers to animal movement in three ways (Figure 1). First, animals may avoid roadside habitat due to traffic emissions such as noise or pollution. This will tend to keep the animals away from the road, limiting movements across it. For example, Reijnen and Foppen (1994) showed that forest-dwelling birds were negatively associated with roadside edge habitat, due to increased noise and predation levels, even when the birds were categorized as edge nesters. Larger animals such as martens (Robitaille and Aubry 2000), wild reindeer (Nellemann et al. 2001) and wolves (Thiel 1985) also preferentially select habitat away from roads. For animals that avoid roadside habitat due to traffic emissions, the degree to which roads act as a barrier will depend on the traffic volume on the road.

The second situation in which roads can act as barriers to animal movement is when animals show an aversion to the road surface itself, and therefore may not attempt to cross the road (Figure 1). Such animals use habitat up to the road edge but do not attempt to cross roads during either foraging (Mader 1984; deMaynadier and Hunter 2000) or dispersal (Keller and Largiader 2003) movements. For example, roads act as linear barriers to movement for many species of ground beetles, significantly reducing gene flow and genetic variability (Mader et al. 1990; Keller and Largiader 2003). Develey and Stouffer (2001) showed that roads created linear boundaries to movements

by understory birds in mixed-species flocks. These birds moved within a few meters of open roads but avoided crossing even when provoked through antagonistic calls.

Although road verges are desired foraging habitat for species such as hedgehogs or badgers, these species do not cross roads at a rate that is expected if roads did not act as barriers to movement (Clarke et al. 1998; Rondinini and Doncaster 2002).

The third way in which roads can act as barriers is in situations where animals attempt to cross the road but the probability of successfully crossing the road without being killed by a vehicle is low (Munguira and Thomas 1992). In this case, the road acts as a barrier as well as a source of mortality (Figure 1). For example, Hels and Buchwald (2001) showed that 34 to 98 % of anurans that attempted to cross roads were killed, representing approximately 10 % of the overall population. Ashley and Robinson (1996) censused wildlife mortality over two years along a 3.6 km section of a two-laned paved highway and found 32,000 dead individuals including amphibians, reptiles, mammals and birds. Lode (2000) found that traffic exponentially increased mortality for many endangered species.

The purpose of my study was to determine whether and how roads affect small mammal movement. Small mammal populations are often subject to within-year extinctions and recolonizations (Merriam and Wegner 1992), and movement is necessary to ensure that regional populations persist (Middleton and Merriam 1981; Krohne 1997; Krohne and Hoch 1999). Existing studies suggest that roads decrease the ability of small mammals to move through the landscape (Mader 1984; Goosem 2001). Oxley et al. (1974) showed that although small mammals were capable of crossing roads, road clearance significantly negatively affected small mammal movement. Mader (1984)

showed that woodland mice adjust the edges of their territories to roads and that they rarely crossed. Goosem (2001) showed that crossing of 12 m to 20 m wide roads by small mammals was partially to severely inhibited, depending on the behaviour of the species. Taken together, these studies suggest that roads act as partial to complete barriers to small mammal movement.

Given that roads are barriers, what type of barrier effect do roads exert on small mammals? Overall, roads do not appear to decrease small mammal densities in forests that are delineated by roads (Garland and Bradley 1984; Rondinini and Doncaster 2002), and may in fact create additional habitat suitable for more generalist species (Adams and Geis 1983). This suggests that small mammals do not avoid roadside habitat due to traffic emissions. Since it is unlikely that small mammals are avoiding available roadside habitat, is the decreased movement across roads due aversion to the road surface itself or to traffic mortality? The existing literature does not provide a clear answer to this question. While some studies have shown little movement across roads (Oxley et al. 1974; Clark et al. 2001; Rondinini and Doncaster 2002), others show that some species readily attempt to cross roads (Goosem 2001) and experience high traffic mortality (Adams and Geis 1983; Lode 2000). If small mammals experience mortality on roads, we would expect higher mortality with higher traffic volume, which should result in lower movement success.

Are the road barrier effects different for different small mammal species? Interspecific differences in movement patterns due to roads can be attributed to behavioural phenomena (Ims 1995). For example, forest specialists may be reluctant to move across a road because they are unwilling to leave cover (Henein et al. 1998). On the

other hand, habitat generalists are capable of moving through and living in many types of habitats, and may not be as strongly influenced by unfamiliar cover types (Vestal and Hellack 1977). Finally, traffic volume, and the mortality associated with that volume, should affect diurnal species more strongly than nocturnal species since most traffic occurs during daylight hours (City of Ottawa, pers. comm.).

We chose to focus my study on eastern chipmunks (*Tamias striatus*) and white-footed mice (*Peromyscus leucopus*) because although both are woodland species, they are differentially distributed across habitat types (Seamon and Adler 1996b). Chipmunks are territorial, diurnal forest specialists (Henein et al. 1998; Dunford 1970; Getty 1981b; Bowers 1995). White-footed mice, on the other hand, are rarely territorial, are nocturnal, and are capable of living and moving through several types of habitats (Vestal and Hellack 1977; Nadeau et al. 1981; Halama and Dueser 1994). White-footed mice typically have higher densities in edge habitat (Anderson et al. 2003a), while eastern chipmunks show no preference for edge or interior habitat so long as there is ample canopy cover (Getty 1981b). With respect to road aversion, since white-footed mice are a generalist species, they may be more likely to move across roads during regular movements than the forest-specialist chipmunks who may avoid the road surface. We also expected eastern chipmunks would be more sensitive to traffic volume since they are a diurnal species. Therefore, they may experience higher mortality than white-footed mice.

Predictions

The questions, hypotheses and predictions are summarized in Table 1.

Question One: Are roads barriers to small mammal home range movement?

Based on existing literature, we hypothesized that roads are barriers to small mammal movement and predicted that small mammals would not move across roads at the same rate as they do within continuous forest. We also hypothesized that if roads are barriers to movement, small mammals should not be familiar with habitats across roads from where they normally occur. Small mammals that are moved to unfamiliar habitat tend to choose different paths than those moved within their home range (Clarke et al. 1993). For example, eastern chipmunks moved 100 m from their burrow entrance showed significantly longer paths to refugia than those moved 10 m from their burrow (Clarke et al. 1993). Additionally, small mammals moved to unfamiliar territories tend to move in straight lines but make u-turns if they do not encounter familiar visual cues (Bovet 1968; Thibault and Bovet 1999). Small mammals moved far outside their home ranges are not capable of orienting themselves back to their home range (Jamon and Benhamou 1989), even if they eventually return (Zollner and Lima 1997). If small mammals are unfamiliar with habitat across the road, they should produce different paths than when moved within the same patch. Specifically, we predicted that the paths of animals moved across roads should be more convoluted (i.e., more u-turns), less oriented towards the destination, and should be longer than animals moved within a contiguous forest.

Question two: What type of barrier response do small mammals show towards roads?

We hypothesized that roads can act as barriers to small mammal movement in three ways. The first hypothesis is that animals avoid roadside habitat because of increased pollution and noise associated with traffic volume. Existing literature has shown that small mammals do not appear to avoid road verges, and may actually seek out

roadside edge for habitat (Adams and Geis 1983). Thus, we expected that the number of small mammals trapped would be similar near the road and farther away from the road. However, if the first hypothesis were true, we would expect to trap more small mammals farther into the forest, and to find a negative effect of traffic volume on the number of animals trapped, since traffic emissions would be correlated with traffic volume on the roads.

Our second hypothesis was that the decreased movement of small mammals across roads is due to the avoidance of the road structure itself. If small mammals avoid the road surface but not the roadside habitat, we would expect the number of animals trapped in roadside habitat to be similar to the number trapped farther into the forest. We also expect that small mammals should cross roads less frequently than move within continuous forest.

Our third hypothesis is that small mammals do not avoid roads but experience high traffic mortality that decreases movement success. If small mammals experience high levels of mortality, then we would expect a significant effect of traffic volume on the movement of small mammals across roads. If high numbers of small mammals die on roads, we would expect to trap fewer animals in roadside habitat than farther away from roads.

Question three: Do white-footed mice and eastern chipmunks react differently to roads?

If we found support for the roadside habitat aversion hypothesis, we predicted that fewer chipmunks would be trapped at the roadside since white-footed mice are highly associated with edge habitat. We predicted that chipmunks would also be more sensitive to traffic volume since they are a diurnal species that may have a higher probability of

collisions with daily traffic volume. Finally, we predicted that we would recapture fewer chipmunks from translocations across roads than white-footed mice since chipmunks would avoid the surface of the roads due to their forest cover specificity.

METHODS

We employed three trapping protocols to test our predictions (Table 2). However, all protocols had the following features in common. We used Sherman™ non-folding aluminium traps baited with a peanut butter/sunflower seed mixture. The traps were capable of capturing animals that ranged from less than 15 g (e.g., *Sorex* spp., juvenile *Peromyscus* sp.) to over 500 g (e.g., *Sciurus* sp.). We trapped each site for 6 consecutive nights, and checked traps in early morning (8 - 10 A.M.) and late afternoon (4 - 5 P.M.). Each captured animal was given an individual number using sequentially numbered Monel™ fingerling tags, and species, sex, age and the trap location were recorded. The mass of the animals was read from a hanging Pezola™ scale with accuracy to 1 g. Adults were characterised by their golden brown (vs. light grey for juveniles) pelage, as well as secondary sexual characteristics.

Site Selection

All sites selected for trapping protocols one and two met the following criteria. Sites included a 100 m two lane paved section of road that did not have approaches, driveways, or culverts along its length (Figures 2 and 3). Streetlights and sidewalks were also not present. The road included shoulders and ditches. Road width (measured from forest edge to forest edge using a tape measure) ranged from 17 m to 28 m but averaged 20.9 ± 3.0 m (1 standard deviation). The edge of the roadside trapping grids was 10 m

from the road edge so traps were always in the forest, usually 2-3 m from the forest edge (Figures 2 and 3). The trapping sites were forested, dominated by maple (*Acer* spp.), pine (*Pinus* spp.) and spruce (*Picea* spp.). Although dominant vegetation varied among sites, habitat on both sides of the road was consistent within sites. We obtained traffic volume estimates (average annual daily traffic (AADT)) from the City of Ottawa (May – June counts), and selected road segments to cover a large range of values, from 50 to over 15000 AADT.

In 2003, we continued a study that was begun by Bender (2000) and followed his experimental protocol (trapping protocol three). He translocated white-footed mice and chipmunks from 20 forested sites to other forested sites across varying distances and number of roads (with varying traffic volumes). We selected an additional 4 sites to increase the number of roads that were in excess of 2000 AADT (3078, 8254, 10300, 13423 AADT) which resulted in 24 sites for the study (Figure 4).

Trapping Protocols

We employed three different trapping protocols: trapping protocols one and two were established at a combined 28 sites in the Ottawa-Carleton region of Ontario from May to mid-August during 2002 and 2003. Trapping protocol three was established in summer 1999 for 11 weeks during June through August, and continued for 4 weeks in 2003 during the summer months (Table 2).

Thirteen sites were established using trapping protocol one, which consisted of three trapping grids that contained 36 traps each (Table 2, Figure 2). The grids were set up perpendicular to the road and were centered within the 100 m road segment length. Within each grid, 6 transects separated by 10 m were parallel to the road. In each of these

transects, we laid 6 traps separated by 10 m, which resulted in a 6 by 6 grid. At each site, two grids (Roadside 1 and Roadside 2) were set up 10 m from the road edge, typically 2-3 m into the forest, on either side of the road. The third grid (Interior) had its first transect 80 m from the road (i.e., 30 m away from the interior edge of Roadside 1). The distance between Roadside 1 and 2 was not constant but varied less than 5 m among sites.

We established 15 sites that employed trapping protocol two, which consisted of one trapping grid that contained 36 traps (Table 2, Figure 3) laid out as in protocol one. Captured white-footed mice and eastern chipmunks were translocated in mesh bags 35 m from the edges of the grid, perpendicular to the road. Accordingly, those animals that were translocated across the road were released approximately 10 m inside the forest, while those translocated within the same patch ended up 85 m from the forest edge. At the two release points, the releaser always stood between the released animals and the trapping grid from which they were removed. After releasing the animals, the releaser returned directly to the grid.

Sites for trapping protocol one and two were often trapped in separate forest patches concurrently, but no more than 2 sites (trapping protocol one or two) were trapped per week.

Trapping protocol three was a continuation of Bender's (2000) trapping protocol. At each home patch, 4 transects of 18 traps, separated by 10 m were established running perpendicular to the road. Although the distance between transects ranged between 10 and 50 m in the original protocol, we kept the distance between transects at 10 m. Each transect began 10 m from the edge of the forest, and traps were separated by 5 m (Table 2).

Are roads barriers to small mammal movement?

Spontaneous Movement

To test whether roads are barriers to small mammal home range movements, we investigated the effect of roads on spontaneous (i.e., not forced) animal movement, and the number of captured individuals in roadside habitat versus farther into the forest (Table 2, Figure 2). We selected 13 sites using trapping protocol one to measure the movement patterns of small mammals across roads and within continuous forest. In each trapping grid, we trapped and marked all individual white-footed mice and eastern chipmunks, and then released them within 1 m of the trap from which they were removed.

To determine whether small mammals include roads in their home range, we conducted a contingency χ^2 test to compare whether fewer animals moved across roads between roadside grids than expected and whether more animals moved within continuous forest between the Roadside 1 and Interior grids than expected.

Familiarity

We also investigated whether small mammals were familiar with habitat across roads by comparing the paths of animals that were translocated across roads and within continuous forests using trapping protocol two (Table 2, Figure 3). We marked a subset of the translocated animals with fluorescent powder (Radiant Color Corp., Richmond, California), which sloughs off and leaves a trail depicting their movements following release. For this experiment, we used 13 (7 across the road, 6 within the patch) white-footed mice and 15 (7 across the road, 8 within the patch) eastern chipmunks. At the release point, we transferred animals from the mesh bag into a plastic bag containing a

small amount of fluorescent powder (Figure 5) and covered them as per Lemen and Freeman (1985). The powder sloughed off as the animal moved through the forest and fluoresced under ultraviolet (UV) radiation, which allowed us to follow the paths at night.

At night, we used a UV light and flagging tape to mark the trails left by the powdered small mammals. Flagging tape was placed on vegetation along each trail at approximately 1 m intervals and more frequently if the path was highly convoluted. We followed the paths until they entered the road or grid, or until the trail was so faint that 5 min of searching revealed no additional powder. On the following day, we used a compass and field measuring tape to measure the bearing and distance from the release point to the first flag, from the first flag to the next, and so on, until the last flag.

As mentioned, the releaser always stood between the released animal and the trapping grid from which the animals were moved. Since the first few meters of the path likely represented movement away from the releaser, we analyzed all paths starting 5 m away from the release point, and all paths < 10 m in length were removed from analysis.

The 25 remaining paths (4 mice, 8 chipmunks within patch, and 6 mice, 7 chipmunks across the road) were entered into a geographic information system (ArcView 3.2), to produce the paths created from the marked headings and distances between successive points for each individual. We used one-way t-tests to analyze the difference in linearity and length and orientation of paths created by small mammals in the two translocation directions (i.e., across the road vs. into the forest). See Appendix D for sample calculation of meaning bearings. Linearity compares the total distance travelled to the distance between the initial and final points in the path. The values range between 0 and 1, where $r = 1$ is a perfectly straight path. We expected animals to orient to their

home range after translocation, and so expected animals to orient relative to the trapping grid. We arbitrarily chose 180 degrees for animals translocated across roads and 360 degrees for animals translocated within continuous forest because of the opposite nature of the translocation directions (Figure 6).

What type of barrier effect do roads exert on small mammals?

Numbers Trapped

We compared the number of animals trapped near the road vs. farther into the forest using a pairwise t-test by taking the mean of the total number of animals trapped in Roadside 1 and Roadside 2 and comparing that to the number trapped within the forest Interior grid for each site (Figure 2). To test the prediction that traffic decreases the number of animals that are trapped, we performed a simple linear regression comparing the number of animals found at each site to the traffic volume, for both species combined and for each species separately.

Short Distance Translocations

To determine whether small mammals were more or less likely to cross roads during forced movement, we translocated animals after capturing them using trapping protocols two and three (Figures 3 and 4). We employed trapping protocol two in 15 sites to determine whether small mammals crossed roads when moved within their theoretical home range limits (475 - 700 m² for chipmunks (Getty 1981a), 100 m² range for white-footed mice (in (Nupp and Swihart 2000)). As noted above, after their initial capture, individually marked white-footed mice and eastern chipmunks were immediately translocated either across the road or within continuous forest. Any marked animals that were recaptured within the trapping session for each site (6 nights) were recorded as

successfully returned. We compared the return rates of small mammals translocated across the road to those translocated within the patch using χ^2 tests of independence.

Long Distance Translocations

Small mammals also travel longer distances for events such as dispersal. We continued a trapping protocol established by Bender (2000) to determine whether small mammals were less likely to move successfully through a landscape when road density and traffic volume increased. Animals were trapped in 24 sites using trapping protocol three (Figure 4). As per Bender (2000), each home patch was trapped for 6 consecutive nights; in 1999, two home patches were trapped per week, but only one home patch was trapped per week in 2003. On their initial capture, all white-footed mice and eastern chipmunks were marked with an ear tag and then translocated to one of three to five surrounding forest patches in the landscape over varying distances and number of intervening roads. Any tagged mice or chipmunks that returned within the 6 night trapping session were recorded as successfully returning from translocation. Although Bender (2000) used a GIS based application to measure edge-to-edge distance between destination and home patches, we used field marking tape since all animals in our 4 sites were translocated across one road into an adjacent forest. We used a stepwise multiple logistic regression with number of roads and interpatch distance as independent variables.

Traffic Volume

If small mammals readily attempt to cross roads but experience a high rate of mortality, traffic volume should be an important variable in the decreased small mammal movement success. We therefore added a traffic volume variable to our spontaneous movement and translocation studies. We performed a multiple logistic regression for

animals that either spontaneously crossed roads or returned from short distance translocations across roads to determine whether traffic volume affects movement success. We also added a traffic volume variable to the multiple logistic regression for long distance translocations. In this case, traffic volume was the sum of volumes for all of the roads between the home and destination patches.

Species

Life history and behavioural characteristics may also affect the degree to which roads are barriers to movement. We therefore added a species (white-footed mouse or eastern chipmunk) variable to our spontaneous movement and translocation (both short and long distance) multiple logistic regressions. Because we predicted chipmunks would be more strongly affected by traffic volume, we also added the interaction term between species and traffic to the multiple logistic regressions.

All statistical analyses were completed in SAS version 6 (1990) or by hand.

RESULTS

Are roads barriers to small mammal movement?

Spontaneous movement

We captured 136 white-footed mice and 104 eastern chipmunks in 8424 trap nights. Sixty-eight mice and 54 chipmunks were recaptured at least once after their initial capture (50 % and 52 % recapture rate, respectively). Forty-one small mammals spontaneously moved between grids, 36 (17 mice, 19 chipmunks) of 177 captured animals moved between Roadside 1 and Interior grids and 5 (4 chipmunks and 1 mouse) of 188 moved across roads between Roadside 1 and 2 (Figure 7). This difference was

statistically significant ($df = 1$, $\chi^2 = 24.4$, $p < 0.0001$). Due to the small number of animals spontaneously crossing roads, the multiple logistic regression of the effects of species, traffic volume and the interaction between species and traffic volume on the movement of small mammals across roads could not be performed.

Familiarity

Animals translocated across roads had significantly straighter paths than did those translocated within continuous forests (Figures 8 and 9, $t = 2.8$, $df = 23$, $p = 0.005$). This was also true for chipmunks, and tended to be true for mice, when analysed separately ($t = 2.31$, $df = 13$, $p = 0.02$; $t = 1.28$, $df = 8$, $p = 0.11$, respectively). There was no difference in the length of the paths of animals translocated across roads and continuous forests (Figure 10, $t = 1.04$, $df = 23$, $p = 0.15$), regardless of species (chipmunks: $t = 0.82$, $df = 13$, $p = 0.21$, mice: $t = 0.15$, $df = 8$, $p = 0.44$). There was also no significant difference in the orientation of the paths of animals translocated across the road or within continuous patches (Figure 11, $df = 23$, $t = 1.10$, $p = 0.28$).

What type of barrier effect do roads exert on small mammals?

Number Trapped

There was no significant effect of grid location on the number of animals captured (Figure 12; paired- $t = 1.79$, $df = 12$, $p = 0.099$), although roadside grids tended to have higher capture rates (mean 6.6 ± 0.14 individuals) than interior grids (mean 5.3 ± 0.13 individuals). This was due to significantly higher numbers of chipmunks caught in roadside grids than forest interior (paired- $t = 2.5$, $df = 12$, $p = 0.028$) since mice showed no difference (paired- $t = 0.16$, $df = 12$, $p = 0.88$). There was no effect of traffic on the

number of animals trapped in the sites (Figure 13, Table 3), even when white-footed mice (Table 4) and chipmunks (Table 5) were analysed separately.

Short Distance Translocations

Of the 92 small mammals translocated during trapping protocol two, 58 were recaptured. Of the 45 small mammals (21 white-footed mice, 24 eastern chipmunks) translocated across roads, 24 returned (14 mice, 10 chipmunks). Of the 47 small mammals (28 mice, 19 chipmunks) that were translocated with the same patch, 35 returned (19 mice, 16 chipmunks). The difference in the number of animals returning from translocation when translocated across roads vs. within forest was significant (Figure 14; $df = 1$, $\chi^2 = 7.28$, $p = 0.0070$). The results from the multiple logistic regression showed no significant effect of traffic volume, species, nor the interaction between species and traffic volume (Table 6) on small mammal return rates from short distance translocations across roads.

Long Distance Translocations

Altogether, we marked and translocated 310 (281 by Bender in 1999, 29 during 2003) individuals (197 white-footed mice and 115 eastern chipmunks) from 24 home patches over 10,368 trap nights using protocol three. After controlling for a strong effect of distance between home and destination patches, we found that the number of intervening roads also significantly negatively affected small mammal return rates (Figure 15, Table 7, $df = 1$, Wald $\chi^2 = 16.4$, $p < 0.0001$). Small mammal return rate decreased by about 50 % for every road that occurred between the home and destination patch. Traffic volume tended to decrease small mammal return rates (Figure 16, Table 7, $df = 1$, $\chi^2 = 2.98$, $p = 0.084$), but species ($df = 1$, Wald $\chi^2 = 0.34$, $p = 0.55$) and the

interaction between traffic and species ($df = 1$, Wald $\chi^2 = 0.0$, $p = 0.88$) did not significantly affect small mammal return rates from these translocations.

Over the course of the two field seasons, we spent approximately 600 hours on the roads at our sites. Although we did not systematically search for carcasses (as per Lode 2000), we did not observe any dead animals along the sites during the study.

DISCUSSION

Roads are barriers to small mammal home range movements. White-footed mice and eastern chipmunks were less likely to cross roads than expected if they were not affected by roads; this pattern of movement is like that reported for bank voles (Bakowski and Kozakiewicz 1988), desert rodent populations (Garland and Bradley 1984), tropical forest species (Goosem 2002), and grassland rodent species (Clark et al. 2001).

We hypothesised that if roads decrease small mammal movement, white-footed mice and eastern chipmunks should not be familiar with habitat across roads. We predicted that animals translocated across roads would have longer, less straight, less oriented paths than those translocated on the same side the road. However, only the test of linearity had a significant result, and it was opposite to our predictions. Both mice and chipmunks that were translocated across roads had straighter paths than those translocated within the forest. We expected to see increased u-turns because that is typically how small mammals orient themselves in unfamiliar areas (Thibault and Bovet 1999). We hypothesize that the mice and chipmunks were not familiar with the habitat across roads, but were using the roads as a cue. Since we translocated animals across roads in a mesh bag during daylight hours, it is possible that the mice and chipmunks

were aware of the translocation across the road and knew where to return. Although the animals that were translocated across roads were not significantly oriented towards the trapping grid, most were oriented towards the general area of the road, suggesting that the animals may have used the road as a cue to their movement. The lack of statistical significance for orientation or path length may have been affected by the small sample size in this portion of the study.

We did not find support for the hypothesis that animals avoid roadside habitats due to increased levels of pollution or noise associated with traffic emissions. We found that neither chipmunks nor mice avoided roadside habitat, and that chipmunks were trapped more often in habitat near roads. These results are similar to those found by Garland and Bradley (1984) who showed that there was no relationship between proximity to the road and home range size or life span of the desert rodents studied. Small mammals tended to be trapped more often in grids near roads than farther into the forest, likely because of the increased vegetative complexity that occurs there (Anderson et al. 2003b). Both white-footed mice and eastern chipmunks are associated with high vegetation complexity (Anderson et al. 2003b) and increased coarse woody debris (Zollner and Crane 2003b), which are in turn associated with forest edges. The number of animals trapped also did not depend on the traffic volume on the road. This result also suggests that small mammal movement is not affected by the pollution or noise associated with vehicular traffic.

We also did not find support for the hypothesis that decreased small mammal movement across roads is due to increased mortality associated with traffic volume. We predicted a negative relationship between traffic volume and small mammal movement if

mortality was responsible for the barrier effect. However, we found no effect of traffic volume on small mammals during short distance movements and only a marginal effect during long distance movements. These results support existing literature that traffic does not affect small mammal movement at the short distance level (Oxley et al. 1974; Goosem 2002). However, our results are the first to test for and find an effect of traffic on long distance small mammal movement. Although the existence of roads is a much stronger predictor of small mammal movement, over longer distances, small mammals may experience higher levels of mortality. These results suggest that for highly vagile animals that travel large distances for dispersal (i.e. white-footed mice have been shown to travel on the order of 1000's of m (Bowman et al. 2001; Maier 2002)), traffic volume may decrease movement success since it increases the probability of mortality.

Based on our results, we conclude that decreased movement across roads is due to road aversion. We found support for our three predictions: (1) small mammals were trapped at the same rate or more often in habitat near roads than farther away from roads, (2) there was a negligible effect of traffic and no evidence of increased mortality and (3) small mammals were less likely to move across roads than within continuous forest. These results support findings by Bakowski and Kozakiewicz (1988), who found that bank voles translocated into continuous forest return to the trapping grid faster and in greater numbers than those translocated to the other side of the road. Over longer distances, the probability of an animals returning from translocations decreased by approximately 50 % for every road that is inserted between the home and destination, suggesting that roads significantly negatively influence small mammal movement success through a landscape.

How strong the road effects are as barriers may depend on the incentive the animals have to move. Over 50 % of animals that were translocated across roads were recaptured, as compared to 3 % of animals spontaneously crossing the road. These results suggest that during regular home range movements, roads are avoided, but during times where movement across roads is necessary, small mammals are capable of crossing. Clark et al. (2001) showed the same trend in prairie rodent species that they trapped and translocated across roads: there is a slightly higher probability that displaced animals will cross roads than those animals that are not displaced. These results suggest that small mammals are capable of moving across roads but their behaviour towards roads prevents them from doing so. Patches that are separated by roads may not be isolated from each other since some individuals are capable of crossing roads, but dispersal behaviour has yet to be studied with regards to roads.

What is it about the road itself that reduces the likelihood of small mammals moving across it? Oxley et al. (1974) showed that road clearance or width, as compared to traffic load or substrate type, was the best predictor of small mammal movement, but this could be attributed to decreased canopy closure, ground cover and/or vegetation complexity. Eastern chipmunks have been shown to move through forest gaps upwards of 250 m successfully (Bowman and Fahrig 2002), which suggests decreased canopy cover may not significantly decrease their movement across roads. We showed that white-footed mice and eastern chipmunks were trapped in high numbers along roadside habitat where vegetation complexity is its highest in the forest (Anderson 2003a). Because small mammals do not often move through habitats with little or no ground cover or vegetative

complexity (McMillan and Kaufman 1995; Seamon and Adler 1996b; Zollner and Crane 2003a), we hypothesize this is the reason small mammal movement is decreased at roads.

We predicted that mice would be more mobile across roads than chipmunks for all of the hypothetical barrier effects, but we did not find a significant effect of species in any of the analyses. Several explanations for the lack of difference between chipmunks and mice are possible. Although white-footed mice are considered to be habitat generalists, they prefer to move and live in woodland habitat and rarely leave forest cover (Drickamer 1990; Seamon and Adler 1996a). Alternatively, although white-footed mice are capable of living in several different habitats, this may not increase the likelihood that they will successfully move across roads. Although chipmunks and mice have different activity times (diurnal vs. nocturnal, respectively), traffic has little to no effect on small mammal movement, which suggests activity times would have little effect on how small mammals react to roads.

Future Studies:

Recent studies show that mitigation structures such as culverts aid in movement of animals, including ungulates (Clevenger et al. 2001a), reptiles (Lode 2000), and small mammals (Yanes et al. 1995; Rodriguez et al. 1996; Lode 2000) from one side of the road to the other. However, most of these studies did not compare the movement of small mammals without culverts to movement when culverts are available (Clevenger et al. 2001b), but see Lode 2000). A continuation of our study would be to select sites that include culverts along their length and compare them to sites without culverts. Results from such a study would indicate whether the addition of such underpasses for small mammals could ameliorate the negative effects of roads on their movement.

Another study stemming from our research would be to investigate whether small mammal relative densities are related to road density. Our results show that movement decreases as road density increases. Because small mammal populations need movement to recolonize extinct patches, increased road density should negatively affect small mammal populations.

Conclusion:

Small mammal population dynamics are characterized by extinctions and recolonizations of habitat patches in fragmented landscapes and as such, movement is important for small mammal population persistence. Not only are small mammals reluctant to cross roads during daily movements, but at a larger scale, movement success decreases by about 50 % for every road that lies between the home and destination sites. Our results suggest that this is due to avoidance of the road surface itself, rather than aversion to traffic emissions or to traffic mortality. Small mammals experience lower movement success at roads not because they are incapable of crossing, but because their behaviour prevents them from attempting.

REFERENCES

- Adams,L.W. and Geis,A.D. 1983. Effects of roads on small mammals. *Journal of Applied Ecology* **20**: 403-415.
- Anderson,C.S., Cady,A.B., and Meikle,D.B. 2003a. Effects of vegetation structure and edge habitat on the density and distribution of white-footed mice (*Peromyscus leucopus*) in small and large forest patches. *Canadian Journal of Zoology-Revue Canadienne de Zoologie* **81**: 897-904.
- Anderson,C.S., Cady,A.B., and Meikle,D.B. 2003b. Effects of vegetation structure and edge habitat on the density and distribution of white-footed mice (*Peromyscus*

leucopus) in small and large forest patches. Canadian Journal of Zoology-Revue Canadienne de Zoologie **81**: 897-904.

Ashley, E.P. and Robinson, J.T. 1996. Road mortality of amphibians, reptiles and other wildlife on the long point causeway, Lake Erie, Ontario. Canadian Field-Naturalist **110**: 403-412.

Bakowski, C. and Kozakiewicz, M. 1988. The effect of forest road on bank vole and yellow-necked mouse populations. Acta Theriologica **33**: 345-353.

Bender, D.J. 2000. Wildlife movement in fragmented habitats: the influence of landscape complexity. Ph.d.

Bovet, J. 1968. Trails of deer mice (*Peromyscus maniculatus*) traveling on the snow while homing. Journal of Mammalogy **49**: 713-725.

Bowers, M.A. 1995. Use of space and habitats by the eastern chipmunk, *Tamias-striatus*. Journal of Mammalogy **76**: 12-21.

Bowman, J. and Fahrig, L. 2002. Gap crossing by chipmunks: an experimental test of landscape connectivity. Canadian Journal of Zoology-Revue Canadienne de Zoologie **80**: 1556-1561.

Bowman, J., Forbes, G.J., and Dilworth, T.G. 2001. Distances moved by small woodland rodents within large trapping grids. Canadian Field-Naturalist **115**: 64-67.

Clark, B.K., Clark, B.S., Johnson, L.A., and Haynie, M.T. 2001. Influence of roads on movements of small mammals. Southwestern Naturalist **46**: 338-344.

Clarke, G.P., White, P.C.L., and Harris, S. 1998. Effects of roads on badger *Meles meles* populations in south-west England. Biological Conservation **86**: 117-124.

Clarke, M.F., Dasilva, K.B., Lair, H., Pocklington, R., Kramer, D.L., and McLaughlin, R.L. 1993. Site familiarity affects escape behavior of the eastern chipmunk, *Tamias-striatus*. Oikos **66**: 533-537.

- Clevenger, A.P., Chruszcz, B., and Gunson, K. 2001a. Drainage culverts as habitat linkages and factors affecting passage by mammals. *Journal of Applied Ecology* **38**: 1340-1349.
- Clevenger, A.P., Chruszcz, B., and Gunson, K.E. 2001b. Highway mitigation fencing reduces wildlife-vehicle collisions. *Wildlife Society Bulletin* **29**: 646-653.
- deMaynadier, P.G. and Hunter, M.L. 2000. Road effects on amphibian movements in a forested landscape. *Natural Areas Journal* **20**: 56-65.
- Develey, P.F. and Stouffer, P.C. 2001. Effects of roads on movements by understory birds in mixed-species flocks in central Amazonian Brazil. *Conservation Biology* **15**: 1416-1422.
- Drickamer, L.C. 1990. Microhabitat preferences of 2 species of deermice *Peromyscus* in a northeastern United-States deciduous hardwood forest. *Acta Theriologica* **35**: 241-252.
- Dunford, C. 1970. Behavioral aspects of spatial organization in chipmunk, *Tamias striatus*. *Behaviour* **36**: 215-&.
- Fahrig, L. and Merriam, G. 1985. Habitat patch connectivity and population survival. *Ecology* **66**: 1762-1768.
- Garland, T. and Bradley, W.G. 1984. Effects of a highway on Mojave desert rodent populations. *American Midland Naturalist* **111**: 47-56.
- Getty, T. 1981a. Structure and dynamics of chipmunk home range. *Journal of Mammalogy* **62**: 726-737.
- Getty, T. 1981b. Territorial behavior of eastern chipmunks (*Tamias striatus*) - encounter avoidance and spatial time-sharing. *Ecology* **62**: 915-921.
- Goosem, M. 2001. Effects of tropical rainforest roads on small mammals: inhibition of crossing movements. *Wildlife Research* **28**: 351-364.

- Goosem, M. 2002. Effects of tropical rainforest roads on small mammals: fragmentation, edge effects and traffic disturbance. *Wildlife Research* **29**: 277-289.
- Halama, K.J. and Dueser, R.D. 1994. Of mice and habitats-tests for density-dependent habitat selection. *Oikos* **69**: 107-114.
- Hels, T. and Buchwald, E. 2001. The effect of road kills on amphibian populations. *Biological Conservation* **99**: 331-340.
- Henein, K., Wegner, J., and Merriam, G. 1998. Population effects of landscape model manipulation on two behaviourally different woodland small mammals. *Oikos* **81**: 168-186.
- Ims, R.A. 1995. Movement patterns related to spatial structures. *In* Mosaic landscapes and ecological processes. *Edited by* L.Hansson, L.Fahrig, and G.Merriam. Chapman and Hall, London. pp. 85-109.
- Jamon, M. and Benhamou, S. 1989. Orientation and movement patterns of wood mice (*Apodemus sylvanicus*) released inside and outside a familiar area. *Journal of Comparative Psychology* **103**: 54-61.
- Keller, I. and Largiader, C.R. 2003. Recent habitat fragmentation caused by major roads leads to reduction of gene flow and loss of genetic variability in ground beetles 69. *Proceedings of the Royal Society of London Series B-Biological Sciences* **270**: 417-423.
- Kozakiewicz, M. 1993. Habitat isolation and ecological barriers - the effect on small mammal populations and communities. *Acta Theriologica* **38**: 1-30.
- Krohne, D.T. 1997. Dynamics of metapopulations of small mammals. *Journal of Mammalogy* **78**: 1014-1026.
- Krohne, D.T. and Hoch, G.A. 1999. Demography of *Peromyscus leucopus* populations on habitat patches: the role of dispersal. *Canadian Journal of Zoology-Revue Canadienne de Zoologie* **77**: 1247-1253.
- Lemen, C.A. and Freeman, P.W. 1985. Tracking mammals with fluorescent pigments - a new technique. *Journal of Mammalogy* **66**: 134-136.

- Lode, T. 2000. Effect of a motorway on mortality and isolation of wildlife populations. *Ambio* **29**: 163-166.
- Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. *Biological Conservation* **29**: 81-96.
- Mader, H.J., Schelle, C., and Kornacker, P. 1990. Linear barriers to arthropod movements in the landscape. *Biological Conservation* **54**: 209-222.
- Maier, T.J. 2002. Long-distance movements by female White-footed Mice, *Peromyscus leucopus*, in extensive mixed-wood forest. *Canadian Field-Naturalist* **116**: 108-111.
- McMillan, B.R. and Kaufman, D.W. 1995. Travel path characteristics for free-living white-footed mice (*Peromyscus-leucopus*). *Canadian Journal of Zoology-Revue Canadienne de Zoologie* **73**: 1474-1478.
- Merriam, G. and Wegner, J. 1992. Local extinctions, habitat fragmentation, and ecotones. *In Landscape Boundaries: Consequences for biotic diversity and ecological flows. Edited by A.J.Hansen and di Castri F. Springer-Verlag, New York. pp. 150-159.*
- Middleton, J. and Merriam, G. 1981. Woodland mice in a farmland mosaic. *Journal of Applied Ecology* **18**: 703-710.
- Munguira, M.L. and Thomas, J.A. 1992. Use of road verges by butterfly and burnet populations, and the effect of roads on adult dispersal and mortality. *Journal of Applied Ecology* **29**: 316-329.
- Nadeau, J.H., Lombardi, R.T., and Tamarin, R.H. 1981. Population-structure and dispersal of *Peromyscus leucopus* on Muskeget Island. *Canadian Journal of Zoology-Revue Canadienne de Zoologie* **59**: 793-799.
- Nellemann, C., Vistnes, I., Jordhoy, P., and Strand, O. 2001. Winter distribution of wild reindeer in relation to power lines, roads and resorts. *Biological Conservation* **101**: 351-360.

- Nupp, T.E. and Swihart, R.K. 2000. Landscape-level correlates of small-mammal assemblages in forest fragments of farmland. *Journal of Mammalogy* **81**: 512-526.
- Oxley, D.J., Fenton, M.B., and Carmody, G.R. 1974. Effects of roads on populations of small mammals. *Journal of Applied Ecology* **11**: 51-59.
- Reijnen, R. and Foppen, R. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduce habitat quality for willow warblers (*Phylloscopus Trochilus*) breeding close to a highway. *Journal of Applied Ecology* **31**: 85-94.
- Robitaille, J.F. and Aubry, K. 2000. Occurrence and activity of American martens *Martes americana* in relation to roads and other routes. *Acta Theriologica* **45**: 137-143.
- Rodriguez, A., Crema, G., and Delibes, M. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. *Journal of Applied Ecology* **33**: 1527-1540.
- Rondinini, C. and Doncaster, C.P. 2002. Roads as barriers to movement for hedgehogs. *Functional Ecology* **16**: 504-509.
- Seamon, J.O. and Adler, G.H. 1996b. Population performance of generalist and specialist rodents along habitat gradients. *Canadian Journal of Zoology-Revue Canadienne de Zoologie* **74**: 1130-1139.
- Seamon, J.O. and Adler, G.H. 1996a. Population performance of generalist and specialist rodents along habitat gradients. *Canadian Journal of Zoology-Revue Canadienne de Zoologie* **74**: 1130-1139.
- Thibault, A. and Bovet, J. 1999. Homing strategy of the eastern chipmunk, *Tamias striatus* (Mammalia : Rodentia): Validation of the critical distance model. *Ethology* **105**: 73-82.
- Thiel, R.P. 1985. Relationship between road densities and wolf habitat suitability in Wisconsin. *American Midland Naturalist* **113**: 404-407.
- Vestal, B.M. and Hellack, J.J. 1977. Effects of available space on social interactions in male white-footed mice (*Peromyscus leucopus*). *Behavioral Biology* **19**: 289-299.

- Yanes,M., Velasco,J.M., and Suarez,F. 1995. Permeabililty of roads and railways to vertebrates - the importance of culverts. *Biological Conservation* **71**: 217-222.
- Zollner,P.A. and Crane,K.J. 2003a. Influence of canopy closure and shrub coverage on travel along coarse woody debris by eastern chipmunks (*Tamias striatus*). *American Midland Naturalist* **150**: 151-157.
- Zollner,P.A. and Crane,K.J. 2003b. Influence of canopy closure and shrub coverage on travel along coarse woody debris by eastern chipmunks (*Tamias striatus*). *American Midland Naturalist* **150**: 151-157.
- Zollner,P.A. and Lima,S.L. 1997. Landscape-level perceptual abilities in white-footed mice: perceptual range and the detection of forested habitat. *Oikos* **80**: 51-60.

Table 1. Questions, hypotheses, predictions and tests used to examine the effect of roads on small mammal movement.

Question	Hypothesis	Prediction	Statistical Test
1. Are roads barriers to small mammal movement?	Roads are barriers to small mammal movement	Fewer animals will move across roads than within continuous forest	Contingency test
	Small mammals are unfamiliar with habitat across roads	Paths of animals translocated across roads will be shorter, less straight and less oriented towards home	T tests
2. What type of barrier effect do roads have on small mammals?	Increased noise and pollution due to traffic emissions decrease movement through roadside habitat	Fewer animals will be trapped near a road vs. farther from the road	Paired T test
	Small mammals avoid the road itself	Traffic volume decreases the number of animals near a road	Simple linear regression
		No difference in animals captured near roads vs. farther from the road	Paired T test
		Small mammals move less often across roads than within continuous forest	Chi-square test and multiple logistic regressions
		No mortality/no effect of traffic on the movement or capture rate of animals	Add traffic variable to multiple logistic regressions
	No aversion, but increased probability of mortality associated with traffic volume	Negative traffic volume effect in the movement analyses	Multiple logistic regression
		Number of dead animals observed increases with increasing traffic volume	N/A*
3. Do white-footed mice and eastern chipmunks react differently to roads?	White-footed mice and eastern chipmunks will react differently depending on the type of barrier effect hypothesis being tested	Roadside aversion: fewer chipmunks trapped near roads than farther away from roads	Separate paired t test for each species
		Road avoidance: fewer chipmunks crossing roads spontaneously or after translocations	Add species and species*traffic variables to multiple logistic regressions
		Traffic mortality: higher chipmunk mortality	Add species and species*traffic variables to multiple logistic regressions

Table 2. Summary of trapping protocols. In both experiments, the grids were trapped for 6 consecutive nights (7 days). Twenty of the 24 sites that used trapping protocol three were trapped by Bender in summer 2000.

Protocol	Study	Grid Size (Traps)	Number of Grids Per Site	Number of Sites	Intertrap distance (m)	Inter-transect distance (m)
1	Spontaneous Movements Number Trapped	6 x 6	3	13	10	10
2	Short Distance Translocations Familiarity	6 x 6	1	15	10	10
3	Long Distance Translocations	4 x 18	1	24	5	10 to 50

Table 3. ANOVA table for the simple linear regression of the effect of traffic volume on number of animals trapped ($R^2 = 0.095$). Number trapped is the sum of the individuals trapped at all three trapping grids at each site using protocol 1 (Table 2, Figure 2).

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	113.5922	113.5922	1.159493	0.30462
Residual	11	1077.639	97.96714		
Total	12	1191.231			

Table 4. ANOVA table for the simple linear regression of effect of traffic volume on the number of mice trapped for each site ($R^2 = 0.0031$). Number trapped is the sum of the individuals trapped at all three trapping grids at each site using protocol 1 (Table 2, Figure 2).

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	1.404132	1.404132	0.034336	0.856365
Residual	11	449.8266	40.89333		
Total	12	451.2308			

Table 5. ANOVA table for the simple linear regression performed of effect of traffic on the number of chipmunks trapped for each site ($R^2 = 0.17$). Number trapped is the sum of the individuals trapped at all three trapping grids at each site using protocol 1 (Table 2, Figure 2).

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	89.73779	89.73779	2.315747	0.156284
Residual	11	426.2622	38.75111		
Total	12	516			

Table 6. ANOVA table for the multiple logistic regression of effect of traffic volume, species and the interaction between traffic and species on the movement success of small mammal translocated short distances using trapping protocol two (Table 2, Figure 3).

Type III Sums of Squares					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	0.74	0.65	1.32	0.25
Species PL	1	0.83	0.65	1.65	0.19
Traffic Volume	1	-0.00007	0.000059	1.35	0.24
Traffic*Species PL	1	-0.00005	0.000059	0.62	0.43

Table 7. ANOVA table for the stepwise multiple regression of effect traffic, interpatch distance and the number of roads between patches on small mammal return rates from long distance translocations using trapping protocol three (Table 2, Figure 3). Interpatch distance refers to the edge-edge distance between home and destination patches, traffic volume is the sum of the average annual daily traffic levels on each of the intervening roads between home and destination patches.

Type III Analysis of Effects					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	0.74	0.32	5.22	0.0224
Interpatch Distance	1	-0.0035	0.00069	25.7	<.0001
Traffic Volume	1	-0.00009	0.000053	2.98	0.084
Number of Roads	1	-1.00	0.25	16.4	<.0001

Figure 1. Three possible road barrier effects. a) Avoidance of roadside habitat due to increased pollution and noise levels associated with traffic volume. b) Avoidance of the road surface c) Animals attempt to cross roads but experience higher levels of mortality associated with traffic volume.

Figure 2. Depiction of trapping protocol one. The distance between Roadside grids 1 and 2 is approximately the same distance as between Roadside 1 and Interior grids. Each grid was composed of 6 transects with 6 traps in each, resulting in a 6 by 6 trapping grid. Intertrap and intertransect distance was 10 m. Every site (n=13) included a 100 m segment of a two lane paved road with no culverts, lights, driveways or access roads along its length. Sites were chosen to cover a wide range of traffic volumes, from 50 average annual daily traffic (AADT) to 15433 AADT.

Figure 3. Depiction of trapping protocol two, used for short distance translocations. White-footed mice and eastern chipmunks were translocated an average of 35 m from the edge of the grid either across the road or farther into the forest. The grids were composed of 6 transects each of which contained 6 traps separated by 10 m. Every site ($n=15$) included a 100 m segment of a 2 lane paved road that did not have culverts, lights, driveways or access roads along its length. Sites were chosen to cover a wide range of traffic volumes, from 50 average annual daily traffic (AADT) to 15433 AADT.

Figure 4. Depiction of hypothetical landscape with "home" patch for trapping protocol three. Four transects of 18 traps were set up in a home patch. White-footed mice and chipmunks were translocated from 20 home patches in 2000 and 4 home patches in 2003 to destination patches in the landscape across varying interpatch distances (0-1325 m), numbers of intervening roads (0-4) and traffic volumes (0-15433 AADT).

Figure 5. White-footed mouse covered with fluorescent powder.

Figure 6. Hypothetical paths of animals translocated within continuous forest and across roads. The mean bearing is calculated using the headings marked off in the path. We expected that animals would have a desire to return to their home range, and so should be oriented back towards the grid. Therefore, the expected relative heading for animals translocated across roads was 180 degrees while the expected relative heading for animals translocated on the same side of the road was 360 degrees.

Figure 7. Comparison of the number of animals that spontaneously moved across roads and within continuous forest. Of the 240 total small mammals trapped, 41 moved between grids. The proportion of animals that moved between roadside grids (5/177) was significantly less than the proportion that moved between grids on the same side of the road (36/188; $df = 1$, $\chi^2 = 24.4$, $p < 0.0001$). Each of the 13 sites used in this portion of the study was live-trapped for 6 nights.

Figure 8. The paths of 4 mice and 8 chipmunks that were translocated across roads, and 6 mice and 7 chipmunks that were translocated within the continuous forest patch from 15 sites. Chipmunks are notated by a light grey line, mice by a black line. Stars represent the release point. Paths do not start directly from the stars because the first 5 m of the paths were removed from analysis.

Figure 9. Comparison of the mean linearity for the paths of white-footed mice and eastern chipmunks that were trapped during protocol two ($\pm$ st. error). We analysed the paths of 4 mice and 8 chipmunks that were translocated across roads, and 6 mice and 7 chipmunks that were translocated within the continuous forest patch. Both species of small mammals moved across roads had significantly straighter paths than did those translocated within continuous forests when analysed separately (mice: $t = 1.28$, $df = 8$, $p = 0.11$; chipmunks: $t = 2.31$, $df = 13$, $p = 0.02$) and combined ($t = 2.8$, $df = 23$, $p = 0.005$).

Figure 10. Comparison of the mean length of paths for powdered mice and chipmunks translocated across roads and within continuous forest ($\pm$ st. error). We analysed the paths of 4 mice and 8 chipmunks that were translocated across roads, and 6 mice and 7 chipmunks that were translocated within the continuous forest patch. There was no difference in the length of the paths of animals translocated across roads and continuous forests ($t = 1.04$, $df = 23$, $p = 0.15$), regardless of species (i.e., chipmunks: $t = 0.82$, $df = 13$, $p = 0.21$, mice: $t = 0.15$, $df = 8$, $p = 0.44$).

Figure 11. Mean bearings of animals translocated across the roads and within continuous forest. We expected animals to orient to their home range after translocation, and so expected animals to orient themselves relative to the trapping grid. We arbitrarily chose 180 degrees for animals translocated across the roads and 360 degrees for animals translocated within continuous forest because of the opposite nature of the translocations (see Figure 6). White circles are mean bearings for mice, blue are the mean bearings for chipmunks. There was no significant difference in the orientations ($df = 23$, $t = 1.10$, $p = 0.28$).

Figure 12. Comparison of the number of individuals trapped in roadside and interior grids ($\pm$ st. error). We compared the number of animals that were captured in the roadside grids and grids farther away from the road for the 13 sites of protocol one using paired t -tests. There was no significant effect of grid location on the number of animals captured, regardless of site (Figure 12; $t = 1.79$, $df = 12$, $p = 0.099$), although roadside grids tended to have higher capture rates (6.61 ± 0.14 individuals) than forest interior grids (5.3 ± 0.13 individuals).

Figure 13. The effect of traffic volume (annual average daily traffic) on the number of mice and chipmunks trapped. There was no effect of traffic volume on the number of animals trapped in the sites ($F_{1,12} = 1.16$, $p = 0.30$), even when chipmunks ($F_{1,12} = 2.32$, $p = 0.16$) and white-footed mice ($F_{1,12} = 0.034$, $p = 0.86$) were analysed separately.

Figure 14. Comparison in the number of animals that were recaptured when translocated across roads and within continuous forest. Ninety one animals were translocated from 15 sites. Although over 53% of animals translocated across roads successfully returned from translocation, movement success was significantly higher when animals were translocated within continuous forest ($\chi^2 = 7.28$, $p = 0.0070$) than across roads.

Figure 15. The effect of the number of roads between home and destination patches on the number of animals recaptured from long distance translocations in protocol three. We translocated 312 small mammals from 24 home patches to destination forest patches over varying numbers of intervening roads. The proportion of returning individuals from translocations decreased by about 50 percent for every road than was placed between two forest patches. There was a significant, negative effect of intervening roads on small mammal movement success ($df = 1$, Wald $\chi^2 = 14.88$, $p < 0.0001$).

Figure 16. The effect of traffic volume (AADT) on the proportion of animals recaptured from long distance translocations. We translocated 312 small mammals from 24 home patches to destination patches over varying traffic volumes. The proportion of individuals returning from translocations tended to decrease with increasing traffic volume ($df = 1$, Wald $\chi^2 = 2.9$, $p = 0.084$).

Appendix A. Data for trapping protocol one. Locations are names of sites used in the summers of 2002 and 2003. Dates are for the first time that an individual was trapped. Traffic volumes are annual average daily traffic (AADT) volumes as estimated by the City of Ottawa (2002). ME: *Mustela erminea*, MP: *Microtus pennsylvanicus*, PL: *Peromyscus leucopus*, TH: *Tamiasciurus hudsonicus*, TS: *Tamias scurius*, CG: *Clethrionomys gapperi*, SF: *Sorex fumeus*, NI: *Napaeozapus insignis*, GS: *Glaucomys sabrinus*, SC, *Sciurus carolinensis*, SC: *Sorex cinereus*. Unmarked individuals trapped on the final day at each site were not marked and are labelled as nm in the table. Recaptured indicates the individual was recaptured at least one more time the 6 nights of a trapping session. Where indicates what direction an animal moved: *within* the continuous forest or *across* roads.

Location	Date	Traffic Volume	Grid	Tag	Species	Sex	Mass	Recaptured	Where
WHC 2002	08/05/02	13423	Roadside1	nm	PL	M	22	.	.
WHC 2002	08/05/02	13423	Roadside2	nm	PL	F	16	.	.
WHC 2002	08/05/02	13423	Roadside2	1033	TS	M	100	Y	.
WHC 2002	08/05/02	13423	Roadside2	1099	TS	M	92	Y	.
WHC 2002	09/05/02	13423	Interior	1030	CG	M	22	.	.
WHC 2002	09/05/02	13423	Interior	1090	CG	M	20	Y	.
WHC 2002	09/05/02	13423	Interior	1094	CG	F	22	.	.
WHC 2002	09/05/02	13423	Interior	1089	PL	M	19	.	.
WHC 2002	09/05/02	13423	Roadside2	1406	TH	F	190	Y	.
WHC 2002	09/05/02	13423	Roadside2	nm	TH	.	.	.	.
WHC 2002	10/05/02	13423	Interior	nm	CG	.	.	.	.
WHC 2002	10/05/02	13423	Roadside2	1175	PL	F	18	.	.
WHC 2002	10/05/02	13423	Roadside2	nm	PL	.	.	.	.
WHC 2002	10/05/02	13423	Interior	nm	PL	.	.	.	.
WHC 2002	10/05/02	13423	Roadside2	nm	TH	.	.	.	.
WHC 2002	10/05/02	13423	Roadside2	1116	TS	M	100	.	.
WHC 2002	10/05/02	13423	Roadside2	1117	TS	M	90	Y	.
WHC 2002	11/05/02	13423	Interior	nm	GS	.	.	.	.
WHC 2002	11/05/02	13423	Roadside1	1006	PL	.	.	.	.
WHC 2002	11/05/02	13423	Roadside1	1059	TS	M	95	.	.
WHC 2002	12/05/02	13423	Roadside1	1053	PL	M	25	.	.
WHC 2002	12/05/02	13423	Roadside2	nm	TS	M	100	.	.
WHC 2002	12/05/02	13423	Interior	nm	TS	.	.	.	.
Davidson	20/05/02	1670	Roadside2	1142	TH	M	196	.	.
Davidson	20/05/02	1670	Roadside2	1165	TH	F	206	Y	.
Davidson	20/05/02	1670	Roadside1	nm	TS	M	110	.	.
Davidson	21/05/02	1670	Interior	1029	CG	M	30	.	.
Davidson	22/05/02	1670	Interior	1007	CG	M	25	.	.
Davidson	22/05/02	1670	Interior	nm	CG	F	20	.	.
Davidson	22/05/02	1670	Roadside2	nm	SF	M	.	.	.
Davidson	22/05/02	1670	Roadside1	1088	TH	F	170	Y	within
Davidson	24/05/02	1670	Roadside2	1185	TH	M	178	Y	.
Davidson	24/05/02	1670	Roadside1	1021	PL	M	25	.	.
Davidson	24/05/02	1670	Roadside2	nm	SC	.	.	.	.
Davidson	24/05/02	1670	Roadside2	1158	TH	M	176	Y	.

Appendix A cont...

Location	Date	Traffic Volume	Grid	Tag	Species	Sex	Mass	Recaptured	Where
Davidson	24/05/02	1670	Interior	1009	TS	M	90	.	.
Davidson	25/05/02	1670	Roadside1	1081	PL	M	23	.	.
Davidson	25/05/02	1670	Interior	nm	TH	.	.	.	.
Davidson	25/05/02	1670	Interior	1041	TS	.	.	Y	.
Mer Bleu	31/05/02	47	Roadside2	1124	MP	M	24	.	.
Mer Bleu	31/05/02	47	Roadside2	1114	PL	M	24	Y	.
Mer Bleu	31/05/02	47	Roadside2	1133	TS	F	105	Y	across
Mer Bleu	01/06/02	47	Roadside1	nm	ME	.	112	.	.
Mer Bleu	01/06/02	47	Roadside2	nm	PL	F	24	.	.
Mer Bleu	01/06/02	47	Roadside1	1056	TS	F	105	Y	within
Mer Bleu	01/06/02	47	Roadside2	nm	TS	F	108	.	.
Mer Bleu	02/06/02	47	Roadside2	1093	PL	M	30	.	.
Mer Bleu	02/06/02	47	Roadside2	1153	TS	M	120	.	.
Mer Bleu	02/06/02	47	Roadside2	nm	TS	M	100	.	.
Mer Bleu	03/06/02	47	Roadside1	nm	TS	M	115	.	.
Mer Bleu	04/06/02	47	Roadside2	nm	ME	.	194	.	.
Mer Bleu	04/06/02	47	Roadside2	nm	MP	F	20	.	.
Mer Bleu	04/06/02	47	Roadside2	nm	TH	.	.	.	.
Mer Bleu	04/06/02	47	Interior	1009	TS	.	.	Y	within
Mer Bleu	04/06/02	47	Roadside2	1155	TS	M	112	Y	.
Mer Bleu	04/06/02	47	Roadside2	1164	TS	M	110	Y	.
Mer Bleu	05/06/02	47	Roadside1	1039	TS	M	120	Y	within
Mer Bleu	05/06/02	47	Roadside2	1069	TS	F	125	.	.
Mer Bleu	06/06/02	47	Interior	1064	TS	M	100	Y	within
Davidson	08/06/02	1670	Roadside2	nm	PL	F	102	.	.
Slack	22/06/02	2677	Roadside1	1027	PL	F	30	.	.
Slack	22/06/02	2677	Interior	1032	PL	M	.	Y	.
Slack	22/06/02	2677	Interior	1068	PL	F	25	Y	within
Slack	22/06/02	2677	Interior	1011	TH	M	.	.	.
Slack	22/06/02	2677	Roadside2	1102	TH	M	204	Y	.
Slack	22/06/02	2677	Roadside2	nm	TH	F	194	.	.
Slack	22/06/02	2677	Roadside2	nm	TH	.	.	.	.
Slack	22/06/02	2677	Roadside2	nm	TS	F	70	.	.
Slack	23/06/02	2677	Interior	1104	TH	M	205	.	.
Slack	25/06/02	2677	Roadside1	1024	PL	F	24	.	.
Slack	25/06/02	2677	Roadside2	1166	PL	F	20	Y	.
Slack	25/06/02	2677	Roadside2	nm	PL	F	42	.	.
Slack	26/06/02	2677	Interior	1080	PL	M	20	.	.
Slack	26/06/02	2677	Roadside2	1131	TS	F	92	Y	within
Slack	27/06/02	2677	Roadside2	nm	GS	.	.	.	.
Slack	27/06/02	2677	Interior	2624	PL	F	.	.	.
Slack	27/06/02	2677	Interior	nm	SF	.	.	.	.
Slack	28/06/02	2677	Roadside2	nm	PL	M	20	.	.
Slack	28/06/02	2677	Interior	nm	PL	F	24	.	.
Lester	14/07/02	7760	Roadside1	617	CG	F	25	Y	.
Lester	14/07/02	7760	Roadside2	224	PL	F	16	Y	.

Appendix A cont...

Location	Date	Traffic Volume	Grid	Tag	Species	Sex	Mass	Recaptured	Where
Lester	14/07/02	7760	Roadside2	225	PL	F	16	Y	within
Lester	14/07/02	7760	Interior	604	PL	M	25	Y	.
Lester	14/07/02	7760	Roadside1	608	PL	F	25	.	.
Lester	14/07/02	7760	Roadside1	219	TS	F	88	Y	across
Lester	15/07/02	7760	Roadside1	nm	CG	.	12	.	.
Lester	15/07/02	7760	Interior	606	PL	F	20	.	.
Lester	15/07/02	7760	Roadside1	607	PL	M	20	Y	.
Lester	15/07/02	7760	Roadside1	613	PL	M	15	Y	.
Lester	15/07/02	7760	Roadside1	603	TS	F	85	Y	across
Lester	15/07/02	7760	Roadside1	nm	TS	.	.	.	.
Lester	16/07/02	7760	Roadside1	296	CG	M	22	.	.
Lester	16/07/02	7760	Interior	nm	ME	.	.	.	.
Lester	16/07/02	7760	Interior	221	TS	M	90	Y	within
Lester	16/07/02	7760	Roadside1	611	TS	M	80	Y	.
Lester	16/07/02	7760	Roadside1	nm	TS	F	112	.	.
Lester	17/07/02	7760	Roadside2	258	CG	M	18	Y	.
Lester	17/07/02	7760	Roadside2	268	PL	F	24	.	.
Lester	17/07/02	7760	Roadside2	277	PL	F	28	Y	.
Lester	17/07/02	7760	Roadside1	284	TS	F	120	.	.
Lester	18/07/02	7760	Roadside1	289	CG	.	26	.	.
Lester	18/07/02	7760	Interior	96	PL	M	25	.	.
Lester	18/07/02	7760	Roadside2	213	PL	M	14	Y	.
Lester	18/07/02	7760	Roadside2	285	PL	M	20	Y	.
Lester	18/07/02	7760	Roadside2	nm	SC	.	.	.	.
Lester	18/07/02	7760	Roadside2	nm	TH	.	.	.	.
Lester	18/07/02	7760	Roadside2	nm	TH	.	.	.	.
Lester	19/07/02	7760	Roadside1	208	TS	.	104	Y	.
Lester	19/07/02	7760	Roadside1	316	TS	M	100	.	.
Lester	20/07/02	7760	Roadside1	nm	CG	F	30	.	.
Lester	20/07/02	7760	Roadside1	320	PL	F	25	.	.
Lester	20/07/02	7760	Roadside1	nm	PL	F	18	.	.
Lester	20/07/02	7760	Roadside2	nm	PL	.	.	.	.
Lester	20/07/02	7760	Roadside2	nm	PL	.	10	.	.
Lester	20/07/02	7760	Roadside2	nm	PL	.	10	.	.
Lester	20/07/02	7760	Roadside2	nm	PL	.	10	.	.
Slack B	25/07/02	2923	Roadside1	nm	CG	M	16	.	.
Slack B	25/07/02	2923	Roadside2	201	PL	F	32	Y	.
Slack B	25/07/02	2923	Roadside2	207	PL	M	16	.	.
Slack B	25/07/02	2923	Roadside1	283	PL	M	18	Y	.
Slack B	25/07/02	2923	Roadside1	308	PL	F	25	Y	.
Slack B	25/07/02	2923	Interior	313	PL	M	20	Y	.
Slack B	25/07/02	2923	Interior	315	PL	M	17	.	.
Slack B	25/07/02	2923	Roadside1	322	PL	M	15	Y	within
Slack B	25/07/02	2923	Interior	330	PL	.	26	.	.
Slack B	25/07/02	2923	Roadside2	nm	PL	.	210	.	.
Slack B	25/07/02	2923	Roadside1	nm	SC	.	.	.	.
Slack B	25/07/02	2923	Interior	nm	TH	M	98	.	.

Appendix A cont...

Location	Date	Traffic Volume	Grid	Tag	Species	Sex	Mass	Recaptured	Where
Slack B	25/07/02	2923	Roadside2	252	TS	M	102	Y	.
Slack B	25/07/02	2923	Roadside2	263	TS	F	92	.	.
Slack B	25/07/02	2923	Roadside2	288	TS	F	114	Y	.
Slack B	25/07/02	2923	Interior	323	TS	F	90	.	.
Slack B	26/07/02	2923	Roadside2	290	PL	F	26	.	.
Slack B	26/07/02	2923	Interior	309	PL	F	25	Y	within
Slack B	26/07/02	2923	Interior	312	PL	M	25	Y	.
Slack B	26/07/02	2923	Roadside1	314	PL	M	.	Y	.
Slack B	26/07/02	2923	Roadside2	254	TS	F	100	Y	.
Slack B	27/07/02	2923	Roadside2	279	CG	.	17	.	.
Slack B	27/07/02	2923	Roadside2	259	PL	F	27	.	.
Slack B	27/07/02	2923	Roadside1	309	PL	F	.	Y	within
Slack B	27/07/02	2923	Roadside2	nm	PL	F	10	.	.
Slack B	27/07/02	2923	Roadside2	nm	TH	.	95	.	.
Slack B	27/07/02	2923	Roadside1	302	TS	M	80	.	.
Slack B	27/07/02	2923	Roadside1	318	TS	F	90	Y	within
Slack B	28/07/02	2923	Roadside2	230	CG	F	25	.	.
Slack B	28/07/02	2923	Roadside1	499	CG	M	21	.	.
Slack B	28/07/02	2923	Roadside2	nm	CG	F	20	.	.
Slack B	28/07/02	2923	Roadside2	217	PL	F	21	Y	.
Slack B	28/07/02	2923	Roadside2	291	PL	M	18	.	.
Slack B	28/07/02	2923	Roadside2	220	TS	F	93	.	.
Slack B	28/07/02	2923	Roadside1	518	TS	.	.	Y	.
Slack B	28/07/02	2923	Roadside1	602	TS	M	93	Y	.
Slack B	29/07/02	2923	Interior	304	PL	F	15	.	.
Slack B	29/07/02	2923	Roadside1	325	PL	M	25	Y	.
Slack B	29/07/02	2923	Interior	292	TS	M	95	Y	within
Slack B	30/07/02	2923	Roadside1	310	CG	M	20	.	.
Slack B	30/07/02	2923	Roadside1	450	CG	F	21	.	.
Slack B	30/07/02	2923	Roadside1	455	CG	F	23	.	.
Slack B	30/07/02	2923	Interior	325	PL	F	25	Y	.
Slack B	30/07/02	2923	Interior	300	TH	.	.	.	.
Slack B	30/07/02	2923	Roadside1	453	TS	F	107	Y	.
Slack B	30/07/02	2923	Interior	469	TS	F	100	Y	within
Slack B	30/07/02	2923	Roadside1	471	TS	F	95	.	.
Slack B	31/07/02	2923	Interior	497	PL	.	15	.	.
Slack B	31/07/02	2923	Roadside1	251	TS	F	92	.	.
Slack B	31/07/02	2923	Roadside2	nm	TS	F	91	.	.
Slack B	31/07/02	2923	Roadside2	nm	TS	.	.	.	.
Timm	05/08/02	2346	Roadside1	342	PL	F	25	Y	within
Timm	05/08/02	2346	Interior	342	PL	F	30	Y	within
Timm	05/08/02	2346	Interior	346	PL	F	25	Y	.
Timm	05/08/02	2346	Interior	348	PL	M	20	Y	within
Timm	05/08/02	2346	Roadside2	460	PL	M	22	Y	.
Timm	05/08/02	2346	Roadside2	496	PL	M	17	.	.
Timm	05/08/02	2346	Roadside2	403	TS	F	83	.	.

Appendix A cont...

Location	Date	Traffic Volume	Grid	Tag	Species	Sex	Mass	Recaptured	Where
Timm	06/08/02	2346	Interior	324	PL	F	22	Y	.
Timm	06/08/02	2346	Roadside1	328	PL	M	20	Y	.
Timm	06/08/02	2346	Roadside1	418	PL	M	17	Y	.
Timm	06/08/02	2346	Roadside1	450	PL	M	17	.	.
Timm	06/08/02	2346	Roadside1	456	PL	M	18	Y	.
Timm	06/08/02	2346	Roadside2	404	TS	F	83	Y	.
Timm	07/08/02	2346	Interior	347	PL	M	13	Y	.
Timm	07/08/02	2346	Interior	350	PL	M	22	.	.
Timm	07/08/02	2346	Roadside2	422	PL	M	13	Y	.
Timm	07/08/02	2346	Interior	nm	SF	.	25	.	.
Timm	07/08/02	2346	Roadside2	338	TS	M	105	.	.
Timm	07/08/02	2346	Roadside2	416	TS	M	101	.	.
Timm	08/08/02	2346	Interior	405	PL	M	19	Y	across
Timm	08/08/02	2346	Roadside2	457	PL	M	17	Y	.
Timm	08/08/02	2346	Roadside2	451	TS	M	97	Y	within
Timm	08/08/02	2346	Interior	452	TS	F	103	.	.
Timm	08/08/02	2346	Interior	487	TS	M	104	Y	.
Timm	09/08/02	2346	Roadside2	449	PL	F	17	.	.
Timm	09/08/02	2346	Interior	nm	SF	.	.	.	.
Timm	09/08/02	2346	Roadside1	445	TS	F	91	Y	.
Timm	10/08/02	2346	Roadside1	nm	TS	M	85	.	.
Timm	10/08/02	2346	Roadside2	nm	TS	M	103	Y	.
Timm	10/08/02	2346	Roadside2	nm	TS	M	103	Y	.
Richmond02	14/08/02	5827	Roadside1	365	CG	F	25	Y	.
Richmond02	14/08/02	5827	Roadside1	355	PL	M	25	.	.
Richmond02	14/08/02	5827	Roadside1	489	PL	F	23	.	.
Richmond02	14/08/02	5827	Roadside1	nm	TH	.	.	.	.
Richmond02	14/08/02	5827	Roadside1	367	TS	M	85	.	.
Richmond02	14/08/02	5827	Roadside1	371	TS	F	105	.	.
Richmond02	14/08/02	5827	Roadside2	448	TS	F	89	Y	.
Richmond02	15/08/02	5827	Roadside1	359	PL	M	21	Y	within
Richmond02	15/08/02	5827	Roadside1	443	PL	M	13	Y	within
Richmond02	15/08/02	5827	Roadside2	468	PL	F	19	Y	.
Richmond02	15/08/02	5827	Interior	477	PL	F	12	Y	within
Richmond02	15/08/02	5827	Interior	493	PL	M	18	Y	.
Richmond02	15/08/02	5827	Roadside2	498	PL	M	22	Y	.
Richmond02	15/08/02	5827	Roadside2	nm	TH	.	.	.	.
Richmond02	15/08/02	5827	Roadside2	357	TS	.	95	Y	.
Richmond02	15/08/02	5827	Roadside1	447	TS	M	111	Y	.
Richmond02	16/08/02	5827	Interior	435	PL	M	23	.	.
Richmond02	16/08/02	5827	Roadside1	478	PL	M	15	Y	within
Richmond02	16/08/02	5827	Roadside1	440	TS	M	91	Y	.
Richmond02	17/08/02	5827	Roadside2	446	PL	M	25	Y	within
Richmond02	18/08/02	5827	Roadside2	369	PL	F	20	.	.
Richmond02	19/08/02	5827	Interior	nm	CG	.	15	.	.
Richmond02	19/08/02	5827	Interior	419	PL	M	25	Y	within

Appendix A cont...

Location	Date	Traffic Volume	Grid	Tag	Species	Sex	Mass	Recaptured	Where
Richmond02	19/08/02	5827	Interior	nm	PL	M	22	.	.
Richmond02	19/08/02	5827	Roadside1	nm	TS	M	103	.	.
WHC	26/05/03	15433	Roadside1	876	PL	F	22	Y	within
WHC	26/05/03	15433	Interior	383	TH	M	255	Y	.
WHC	26/05/03	15433	Roadside1	900	TH	F	280	y	.
WHC	26/05/03	15433	Interior	878	TS	M	103	Y	.
WHC	27/05/03	15433	Interior	838	PL	F	22	Y	.
WHC	27/05/03	15433	Interior	377	TH	F	230	.	.
WHC	27/05/03	15433	Roadside2	821	TH	F	180	Y	.
WHC	27/05/03	15433	Roadside2	872	TH	F	200	Y	.
WHC	27/05/03	15433	Roadside2	820	TS	F	105	Y	.
WHC	28/05/03	15433	Interior	819	TH	.	185	.	.
WHC	28/05/03	15433	Roadside2	828	TH	F	230	Y	.
WHC	28/05/03	15433	Interior	829	TH	M	220	Y	.
WHC	28/05/03	15433	Roadside2	802	TS	M	105	Y	.
WHC	28/05/03	15433	Roadside1	803	TS	F	105	Y	across
WHC	29/05/03	15433	Interior	871	PL	M	21	.	.
WHC	29/05/03	15433	Roadside2	870	TH	M	200	Y	.
WHC	29/05/03	15433	Interior	830	TS	F	110	.	.
WHC	29/05/03	15433	Roadside1	831	TS	M	110	.	.
WHC	30/05/03	15433	Roadside2	832	PL	M	18	.	.
WHC	31/05/03	15433	Roadside1	851	TH	F	235	.	.
WHC	31/05/03	15433	Roadside2	nm	TH	M	215	.	.
Richmond	03/06/03	7956	Roadside2	841	PL	M	22	Y	.
Richmond	03/06/03	7956	Interior	854	PL	F	22	Y	.
Richmond	03/06/03	7956	Roadside2	889	TH	M	230	.	.
Richmond	03/06/03	7956	Roadside1	853	TS	F	79	Y	.
Richmond	04/06/03	7956	Interior	867	FS	M	125	.	.
Richmond	04/06/03	7956	Interior	nm	FS	.	.	.	.
Richmond	04/06/03	7956	Interior	855	PL	F	17	Y	.
Richmond	04/06/03	7956	Roadside1	856	TH	F	215	.	.
Richmond	04/06/03	7956	Roadside1	897	TH	M	190	Y	.
Richmond	05/06/03	7956	Roadside2	nm	PL	.	.	.	.
Richmond	05/06/03	7956	Roadside1	877	TH	M	195	Y	.
Richmond	05/06/03	7956	Roadside1	880	TH	F	137	.	.
Richmond	05/06/03	7956	Roadside1	nm	TH	M	.	.	.
Richmond	05/06/03	7956	Roadside1	887	TS	M	106	Y	.
Richmond	06/06/03	7956	Interior	883	FS	F	106	Y	within
Richmond	06/06/03	7956	Interior	894	PL	.	18	.	.
Richmond	06/06/03	7956	Roadside1	866	TS	F	175	Y	.
Richmond	07/06/03	7956	Roadside2	873	CG	F	23	Y	.
Richmond	07/06/03	7956	Roadside2	521	PL	M	20	Y	.
Conroy	08/06/03	6580	Roadside1	nm	CG	M	16	.	.
Conroy	08/06/03	6580	Interior	nm	CG	F	20	.	.
Conroy	08/06/03	6580	Roadside1	958	PL	F	24	Y	.
Conroy	08/06/03	6580	Roadside1	982	PL	M	18	Y	.

Appendix A cont...

Location	Date	Traffic Volume	Grid	Tag	Species	Sex	Mass	Recaptured	Where
Conroy	08/06/03	6580	Interior	989	PL	M	26	Y	.
Conroy	08/06/03	6580	Roadside1	994	PL	F	18	.	.
Conroy	08/06/03	6580	Interior	nm	TH	F	26	.	.
Conroy	08/06/03	6580	Roadside2	915	TS	F	124	.	.
Conroy	08/06/03	6580	Roadside1	961	TS	M	94	Y	.
Highway 7	16/06/03	14700	Interior	721	CG	F	16	.	.
Highway 7	16/06/03	14700	Roadside2	nm	CG	F	24	.	.
Highway 7	16/06/03	14700	Roadside2	638	PL	M	23	Y	.
Highway 7	16/06/03	14700	Roadside2	949	PL	M	32	Y	within
Highway 7	16/06/03	14700	Interior	950	PL	F	25	Y	within
Highway 7	16/06/03	14700	Roadside2	901	TH	F	150	.	.
Highway 7	17/06/03	14700	Roadside2	745	CG	F	16	.	.
Highway 7	17/06/03	14700	Roadside2	902	CG	M	26	Y	.
Highway 7	17/06/03	14700	Roadside1	639	PL	F	26	Y	.
Highway 7	18/06/03	14700	Roadside2	940	CG	M	14	Y	.
Highway 7	18/06/03	14700	Roadside2	903	PL	M	16	.	.
Highway 7	18/06/03	14700	Roadside2	942	PL	F	24	.	.
Highway 7	19/06/03	14700	Interior	746	PL	F	13	.	.
Highway 7	19/06/03	14700	Roadside1	936	PL	M	26	.	.
Highway 7	20/06/03	14700	Interior	923	PL	M	26	Y	.
Highway 7	20/06/03	14700	Roadside1	927	PL	M	18	Y	.
Highway 7	21/06/03	14700	Roadside2	943	CG	M	16	.	.
Highway 7	21/06/03	14700	Roadside1	nm	PL	M	14	.	.
Highway 7	21/06/03	14700	Roadside2	nm	PL	F	11	.	.
Highway 7	21/06/03	14700	Roadside2	nm	PL	F	21	.	.
Highway 7	21/06/03	14700	Interior	nm	PL	F	32	.	.
Highway 7	21/06/03	14700	Interior	nm	PL	M	21	.	.
Moodie	24/06/03	3078	Interior	976	PL	F	24	Y	.
Moodie	24/06/03	3078	Interior	998	PL	M	17	Y	.
Moodie	24/06/03	3078	Roadside2	nm	PL	.	.	.	.
Moodie	24/06/03	3078	Roadside2	904	TH	M	174	Y	.
Moodie	24/06/03	3078	Roadside1	905	TH	F	180	.	.
Moodie	24/06/03	3078	Roadside1	906	TS	F	68	Y	.
Moodie	24/06/03	3078	Roadside1	931	TS	F	74	Y	within
Moodie	24/06/03	3078	Interior	932	TS	F	82	Y	.
Moodie	24/06/03	3078	Interior	935	TS	M	100	Y	.
Moodie	24/06/03	3078	Roadside1	977	TS	F	94	Y	within
Moodie	24/06/03	3078	Roadside1	978	TS	M	92	Y	within
Moodie	24/06/03	3078	Roadside2	979	TS	F	70	Y	.
Moodie	24/06/03	3078	Roadside1	980	TS	F	64	Y	within
Moodie	25/06/03	3078	Roadside2	919	PL	M	20	Y	.
Moodie	25/06/03	3078	Roadside1	908	TS	M	64	Y	within
Moodie	25/06/03	3078	Roadside1	909	TS	F	120	Y	within
Moodie	25/06/03	3078	Roadside1	920	TS	F	145	Y	within
Moodie	25/06/03	3078	Interior	981	TS	F	130	.	.
Moodie	25/06/03	3078	Roadside2	994	TS	F	68	.	.

Appendix A cont...

Location	Date	Traffic Volume	Grid	Tag	Species	Sex	Mass	Recaptured	Where
Moodie	26/06/03	3078	Roadside2	922	PL	F	24	Y	.
Moodie	26/06/03	3078	Roadside2	996	PL	M	22	.	.
Moodie	26/06/03	3078	Interior	934	TS	M	80	Y	.
Moodie	26/06/03	3078	Interior	990	TS	F	102	.	.
Moodie	27/06/03	3078	Interior	986	PL	F	19	Y	.
Moodie	27/06/03	3078	Interior	984	TS	M	96	Y	.
Moodie	27/06/03	3078	Interior	995	TS	F	68	.	.
Moodie	27/06/03	3078	Interior	997	TS	M	100	.	.
Moodie	27/06/03	3078	Roadside2	999	TS	F	62	Y	.
Moodie	28/06/03	3078	Roadside2	nm	PL	F	25	.	.
Moodie	28/06/03	3078	Roadside1	nm	TS	F	100	.	.
Moodie	28/06/03	3078	Roadside1	nm	TS	F	74	.	.
Moodie	28/06/03	3078	Roadside1	nm	TS	F	120	.	.
Moodie	28/06/03	3078	Interior	nm	TS	F	120	Y	.
Conroy	07/08/03	6580	Interior	nm	FS	M	100	.	.
Conroy	07/08/03	6580	Roadside1	980	PL	F	38	Y	.
Conroy	07/08/03	6580	Interior	991	PL	M	28	Y	.
Conroy	07/08/03	6580	Roadside1	995	PL	F	26	Y	.
Conroy	07/08/03	6580	Roadside2	914	TS	M	300	Y	.
Conroy	08/08/03	6580	Interior	979	PL	F	24	Y	.
Conroy	08/08/03	6580	Roadside1	988	PL	M	16	.	.

Appendix B. Data for trapping protocol two. Locations are names of sites used in 2002 and 2003. Traffic volume is average annual daily traffic volumes. Individuals received a unique tag number. Animals were translocated either across roads (AR) or within the patch (WP). Animals that were recaptured within the 6 night trapping session for each site were recorded as returning. Ts: *Tamias scurius*, PL: *Peromyscus leucopus*.

Location	Date Translocated	Date Recaptured	Traffic Volume	Tag	Species	Sex	Mass	Translocated	Return
WHC 2002	09/05/02	.	13423	1120	TS	M	100	AR	N
WHC 2002	09/05/02	.	13423	1140	PL	M	22	AR	N
WHC 2002	10/05/02	11/05/02	13423	1101	TS	F	86	AR	Y
WHC 2002	11/05/02	12/05/02	13423	1102	TS	F	90	WP	Y
Davidson	19/05/02	.	1670	1187	TS	F	90	AR	N
Davidson	22/05/02	24/05/02	1670	1006	TS	M	100	WP	Y
Davidson	24/05/02	25/05/02	1670	1161	TS	M	98	AR	Y
Mer Bleu	01/06/02	.	47	1162	TS	F	130	AR	N
Mer Bleu	03/06/02	.	47	1137	TS	M	112	AR	N
Mer Bleu	04/06/02	.	47	1163	TS	M	90	WP	N
Mer Bleu	04/06/02	05/06/02	47	1108	TS	F	100	WP	Y
Moodie 2002	14/06/02	15/06/02	3025	1172	PL	M	28	AR	Y
Moodie 2002	14/06/02	.	3025	1190	TS	M	108	WP	N
Slack	22/06/02	.	2677	1192	TS	F	100	AR	N
Slack	22/06/02	23/06/02	2677	1168	TS	M	104	SS	Y
Slack	24/06/02	25/06/02	2677	1111	TS	F	110	WP	Y
Slack	24/06/02	24/06/02	2677	1152	TS	M	111	WP	Y
Slack	25/06/02	26/06/02	2677	1194	TS	M	92	WP	Y
Slack	27/06/02	27/06/02	2677	1151	TS	M	110	AR	Y
Lester 2002	15/07/02	16/07/02	7760	273	TS	M	100	AR	Y
Lester 2002	15/07/02	17/07/02	7760	274	TS	F	94	WP	Y
Lester 2002	15/07/02	16/07/02	7760	300	PL	F	20	WP	Y
Lester 2002	17/07/02	19/07/02	7760	299	PL	M	22	AR	Y
Lester 2002	19/07/02	.	7760	203	PL	M	20	AR	N
Lester 2002	19/07/02	19/07/02	7760	272	PL	M	16	WP	Y
Slack B	29/07/02	31/07/02	2923	210	PL	F	23	WP	Y
Slack B	31/07/02	.	2923	202	TS	F	87	AR	N
Slack B	31/07/02	.	2923	257	PL	M	25	WP	N
Timm	05/08/02	06/08/02	2346	454	PL	M	17	AR	Y
Timm	06/08/02	07/08/02	2346	405	PL	M	19	AR	Y
Timm	06/08/02	07/08/02	2346	417	PL	M	20	AR	Y
Timm	07/08/02	08/08/02	2346	406	PL	F	15	WP	Y
Timm	08/08/02	09/08/02	2346	457	PL	M	18	WP	Y
Richmond	15/08/02	16/08/02	5827	419	PL	M	25	WP	Y
Richmond	17/08/02	.	5827	476	TS	F	99	AR	N
Richmond	17/08/02	18/08/02	5827	448	TS	F	85	WP	Y
Richmond	18/08/02	19/08/02	5827	486	TS	M	100	AR	Y
Moodie	03/06/03	04/06/03	6519	888	PL	F	20	AR	Y
Moodie	03/06/03	04/06/03	6519	898	TS	F	100	AR	Y
Moodie	03/06/03	04/06/03	6519	899	PL	M	26	AR	Y
Moodie	04/06/03	05/06/03	6519	889	PL	F	18	SS	Y

Appendix B cont...

Location	Date Translocated	Date Recaptured	Traffic Volume	Tag	Species	Sex	Mass	Translocated	Return
Moodie	04/06/03	.	6519	868	PL	F	10	WP	N
Moodie	08/06/03	.	6519	865	PL	F	47	WP	N
Moodie	09/06/03	12/06/03	780	647	PL	M	24	WP	Y
Moodie	10/06/03	11/06/03	780	632	TS	M	82	AR	Y
Moodie	10/06/03	11/06/03	780	635	TS	M	85	AR	Y
Moodie	10/06/03	12/06/03	780	860	PL	M	23	WP	Y
Moodie	11/06/03	.	780	863	PL	M	23	WP	N
Moodie	11/06/03	11/06/03	780	636	TS	M	90	WP	Y
Moodie	11/06/03	12/06/03	780	637	TS	M	87	WP	Y
Moodie	12/06/03	.	780	861	TS	M	140	AR	N
Moodie	12/06/03	.	780	646	PL	M	22	WP	N
Moodie	12/06/03	13/06/03	780	862	TS	M	110	WP	Y
Moodie	13/06/03	14/06/03	780	638	TS	M	90	WP	Y
WHC	01/07/03	.	15433	2988	TS	F	104	AR	N
WHC	01/07/03	.	15433	2991	PL	F	20	AR	N
WHC	01/07/03	.	15433	2992	PL	M	24	AR	N
WHC	01/07/03	.	15433	2982	TS	F	68	WP	N
WHC	02/07/03	03/07/03	15433	2652	TS	M	66	WP	Y
Highway 7	15/07/03	.	13500	666	PL	M	24	AR	N
Highway 7	15/07/03	16/07/03	13500	668	PL	F	24	AR	Y
Moores	15/07/03	17/07/03	14700	665	PL	F	27	AR	Y
Highway 7	15/07/03	19/07/03	13500	667	PL	M	26	WP	Y
Moores	15/07/03	15/07/03	14700	662	PL	F	23	WP	Y
Highway 7	16/07/03	.	13500	659	PL	F	31	AR	N
Moores	16/07/03	17/07/03	14700	239	PL	F	26	AR	Y
Moores	16/07/03	18/07/03	14700	657	PL	M	22	AR	Y
Moores	16/7/03	.	14700	1436	PL	F	24	WP	N
Highway 7	16/7/03	17/07/03	13500	669	PL	F	25	WP	Y
Highway 7	16/7/03	17/07/03	13500	1416	TS	F	105	WP	Y
Moores	16/07/03	19/07/03	14700	664	PL	M	23	WP	Y
Moores	16/7/03	17/07/03	14700	1433	PL	F	29	WP	Y
Moores	16/7/03	19/07/03	14700	1442	PL	M	10	WP	Y
Highway 7	17/07/03	.	13500	660	TS	F	95	AR	N
Highway 7	17/7/03	.	13500	1415	TS	F	104	AR	N
Highway 7	17/7/03	.	13500	1433	TS		76	AR	N
Highway 7	17/07/03	18/07/03	13500	663	TS	M	90	AR	Y
Highway 7	17/7/03	18/07/03	13500	1429	TS	M	81	AR	Y
Moores	17/7/03	18/07/03	14700	654	PL	M	15	WP	Y
Highway 7	18/07/03	.	13500	971	PL	F	28	AR	N
Highway 7	18/07/03	.	13500	2951	PL	F	31	AR	N
Moores	18/07/03	.	14700	1431	TS	M	110	AR	N
Moores	18/07/03	19/07/03	14700	653	PL	M	20	AR	Y
Moores	18/07/03	19/07/03	14700	1432	PL	F	28	AR	Y
Moores	18/07/03	.	14700	652	PL	F	27	WP	N
Highway 7	18/07/03	19/07/03	13500	2993	TS	M	95	WP	Y
Moores	18/07/03	19/07/03	14700	658	PL	M	30	WP	Y

Appendix B cont...

Location	Date Translocated	Date Recaptured	Traffic Volume	Tag	Species	Sex	Mass	Translocated	Return
Moores	18/07/03	19/07/03	14700	661	PL	F	19	WP	Y
Lester	29/07/03	.	8254	3985	PL	M	18	WP	N
Lester	29/07/03	30/07/03	8254	2969	PL	M	17	WP	Y
Lester	31/07/03	.	8254	3997	PL	F	18	WP	N

Appendix C. Data for trapping protocol three. Traffic volume is the sum of the AADT for each of the roads that are between the home and destination patches. Edge-to-edge distance was measured between home and destination sites using a GIS based application or field marking tape. Individuals were marked with a unique tag. Animals that were recaptured within the 6 night trapping session for each site were recorded as returned. PL: *Peromyscus leucopus*, TS: *Tamias striatus*.

Location	Road Number	Traffic Volume	Distance (m)	Tag	Return	Species
2nd Line n. of Phelan Rd	0	0	10.4	2501	N	TS
2nd Line n. of Phelan Rd	0	0	10.4	2168	Y	PL
2nd Line n. of Phelan Rd	2	0	10.4	2169	Y	TS
2nd Line n. of Phelan Rd	2	0	10.4	2172	Y	PL
3rd Line s. of Roger Stevens Rd	0	0	82	2174	Y	PL
3rd Line s. of Roger Stevens Rd	0	0	82	2175	Y	TS
3rd Line s. of Roger Stevens Rd	0	0	82	2180	Y	TS
3rd Line s. of Roger Stevens Rd	0	0	82	2503	Y	PL
3rd Line s. of Roger Stevens Rd	1	0	82	2194	N	TS
3rd Line s. of Roger Stevens Rd	1	0	82	2516	N	PL
3rd Line s. of Roger Stevens Rd	1	0	82	2504	N	TS
3rd Line s. of Roger Stevens Rd	1	0	82	132	N	PL
3rd Line s. of Roger Stevens Rd	2	0	82	2195	N	PL
4th Line s. of Carsonby Rd	2	0	82	2507	N	TS
Blanchfield Rd	1	0	90.5	2550	N	TS
Blanchfield Rd	3	0	90.5	2558	N	TS
McCordick Road	2	0	94.9	166	N	PL
McCordick Road	2	0	94.9	167	N	TS
McCordick Road	2	0	94.9	178	N	PL
McCordick Road	2	0	94.9	187	N	TS
McCordick Road	2	0	94.9	194	N	PL
2nd Line s. of Hwy 72	1	0	112.4	206	Y	TS
2nd Line s. of Hwy 72	1	0	112.4	234	Y	PL
2nd Line s. of Hwy 72	2	0	112.4	209	N	PL
2nd Line s. of Hwy 72	2	0	112.4	219	N	PL
Airport	0	0	126.8	2147	Y	PL
Airport	0	0	126.8	2156	Y	TS
Airport	1	0	126.8	2148	N	TS
Airport	1	0	126.8	2161	N	TS
John Shaw Road	1	0	128.5	2578	N	TS
John Shaw Road	1	0	128.5	2579	N	PL
John Shaw Road	1	0	128.5	2590	N	TS
John Shaw Road	1	0	128.5	2594	N	PL
John Shaw Road	1	0	128.5	2597	N	PL
Spratt 2	0	0	135.8	2160	N	PL
Spratt 2	0	0	135.8	2140	Y	PL
Blanchfield Rd	1	0	175.6	2534	N	TS
Blanchfield Rd	1	0	175.6	2551	N	TS
Blanchfield Rd	1	0	175.6	2559	N	PL
Blanchfield Rd	1	0	175.6	2560	N	TS

Appendix C cont...

Location	Road Number	Traffic Volume	Distance (m)	Tag	Return	Species
Airport	1	0	193.4	2154	N	TS
Airport	1	0	193.4	2159	N	PL
Airport	1	0	193.4	2164	N	TS
3rd Line s. of Carsonby Rd	0	0	264	103	Y	PL
3rd Line s. of Carsonby Rd	0	0	264	118	Y	PL
McCordick Road	1	0	294.7	175	N	PL
McCordick Road	1	0	294.7	176	N	TS
McCordick Road	2	0	294.7	193	N	PL
2nd Line s. of Roger Stevens	1	0	338.3	203	Y	PL
2nd Line s. of Roger Stevens	2	0	338.3	231	N	PL
2nd Line s. of Roger Stevens	2	0	338.3	237	N	PL
3rd Line s. of Bankfield Rd	0	0	347	70	Y	TS
3rd Line s. of Bankfield Rd	1	0	347	71	N	PL
3rd Line s. of Bankfield Rd	1	0	347	112	N	PL
Jake Street, Osgoode	0	0	455.5	262	N	PL
Jake Street, Osgoode	0	0	455.5	269	N	TS
Jake Street, Osgoode	1	0	455.5	246	N	PL
Jake Street, Osgoode	1	0	455.5	270	N	TS
Jake Street, Osgoode	1	0	455.5	290	N	PL
Mohr's Road	0	0	488.4	2577	N	PL
Mohr's Road	0	0	488.4	2586	N	TS
Mohr's Road	0	0	488.4	84	N	TS
Mohr's Road	1	0	488.4	50	Y	PL
Mohr's Road	0	0	533.3	94	N	PL
Mohr's Road	1	0	533.3	2576	N	PL
Mohr's Road	1	0	533.3	2585	N	TS
Mohr's Road	1	0	533.3	2599	N	PL
Mohr's Road	1	0	533.3	2587	Y	TS
2nd Line at Dalmeny Road	0	0	655.3	251	N	PL
2nd Line at Dalmeny Road	0	0	655.3	278	N	TS
2nd Line at Dalmeny Road	0	0	655.3	291	N	PL
2nd Line at Dalmeny Road	0	0	655.3	256	Y	PL
Jake Street, Osgoode	1	0	663.3	260	N	PL
Jake Street, Osgoode	1	0	663.3	265	N	TS
Jake Street, Osgoode	1	0	663.3	255	N	PL
Jake Street, Osgoode	1	0	663.3	274	N	TS
Jake Street, Osgoode	1	0	663.3	288	N	PL
Jake Street, Osgoode	2	0	880.3	2583	N	TS
John Shaw Road	2	0	880.3	2591	N	PL
John Shaw Road	2	0	880.3	91	N	TS
John Shaw Road	1	0	880.6	2580	N	PL
John Shaw Road	2	0	897.4	169	N	TS
McCordick Road	2	0	897.4	173	N	PL
McCordick Road	2	0	897.4	184	N	PL
McCordick Road	2	0	897.4	195	N	PL
McCordick Road	1	0	953.6	277	N	PL

Appendix C cont...

Location	Road Number	Traffic Volume	Distance (m)	Tag	Return	Species
2nd Line at Dalmeny Road	1	0	953.6	281	N	TS
2nd Line at Dalmeny Road	1	0	1025	2564	N	PL
Limebank at Highschool	1	0	1025	2570	N	PL
Limebank at Highschool	1	0	1369	2565	N	PL
Limebank at Highschool	1	0	1369	2571	N	PL
Limebank at Highschool	0	10	248.6	136	N	PL
4th Line s. of Carsonby Rd	0	10	248.6	158	N	PL
4th Line s. of Carsonby Rd	0	10	248.6	128	N	PL
4th Line s. of Carsonby Rd	0	10	248.6	146	N	PL
4th Line s. of Carsonby Rd	0	10	248.6	140	N	PL
4th Line s. of Carsonby Rd	1	10	781.6	160	N	PL
3rd Line n. of Hwy 72	1	10	781.6	190	N	PL
3rd Line n. of Hwy 72	1	32	10.4	192	N	TS
3rd Line n. of Hwy 72	1	32	10.4	198	N	PL
3rd Line n. of Hwy 72	2	32	10.4	156	Y	PL
3rd Line n. of Hwy 72	2	32	10.4	180	Y	PL
3rd Line n. of Hwy 72	1	32	958.5	65	N	TS
3rd Line s. of Carsonby Rd	1	32	958.5	67	N	PL
3rd Line s. of Carsonby Rd	1	32	958.5	106	N	PL
3rd Line s. of Carsonby Rd	1	33	649.8	2533	N	TS
Cabin Rd	1	33	649.8	2546	N	PL
Cabin Rd	1	33	649.8	2547	N	TS
Cabin Rd	1	33	649.8	2553	N	TS
Cabin Rd	1	33	649.8	2520	Y	PL
Cabin Rd	1	33	649.8	2531	Y	PL
Cabin Rd	3	33	649.8	2525	N	TS
Cabin Rd	4	33	649.8	2529	N	TS
Cabin Rd	1	50	302.5	233	N	PL
2nd Line s. of Roger Stevens	1	50	302.5	240	N	PL
2nd Line s. of Roger Stevens	2	50	302.5	201	N	PL
2nd Line s. of Roger Stevens	2	50	302.5	223	N	PL
2nd Line s. of Roger Stevens	0	50	478.6	2566	N	TS
Spratt 1	1	50	478.6	2574	Y	PL
Spratt 1	0	50	894.4	2141	N	PL
Spratt 2	0	50	894.4	2145	N	PL
Spratt 2	0	50	894.4	2135	Y	PL
Spratt 2	0	53	233.2	2142	N	PL
Spratt 2	0	53	233.2	2143	N	PL
Spratt 2	0	53	233.2	2165	N	PL
Spratt 2	1	53	233.2	2135	Y	PL
Spratt 2	1	53	233.2	2146	Y	PL
Spratt 2	1	53	233.2	2138	Y	PL
Spratt 2	0	82	333.1	225	Y	PL
2nd Line s. of Roger Stevens	1	82	333.1	202	N	PL
2nd Line s. of Roger Stevens	1	82	333.1	236	N	PL
2nd Line s. of Roger Stevens	2	82	333.1	241	N	PL

Appendix C cont...

Location	Road Number	Traffic Volume	Distance (m)	Tag	Return	Species
2nd Line s. of Roger Stevens	0	83	638.4	200	N	PL
2nd Line s. of Roger Stevens	0	83	638.4	204	N	PL
2nd Line s. of Roger Stevens	2	83	638.4	232	N	PL
2nd Line s. of Roger Stevens	2	83	638.4	239	N	PL
2nd Line s. of Roger Stevens	2	85	54.6	58	N	TS
3rd Line s. of Bankfield Rd	2	85	54.6	59	N	PL
3rd Line s. of Bankfield Rd	2	85	54.6	102	N	PL
3rd Line s. of Bankfield Rd	0	85	308.5	100	Y	PL
3rd Line s. of Bankfield Rd	0	85	308.5	52	Y	TS
3rd Line s. of Bankfield Rd	0	85	308.5	72	Y	PL
3rd Line s. of Bankfield Rd	2	85	308.5	114	N	PL
3rd Line s. of Bankfield Rd	0	85	992.9	61	N	PL
3rd Line s. of Bankfield Rd	0	85	992.9	62	N	TS
3rd Line s. of Bankfield Rd	0	85	992.9	111	N	PL
3rd Line s. of Bankfield Rd	1	120	627.9	142	N	PL
4th Line n. of Carsonby Rd	2	120	627.9	135	N	PL
4th Line n. of Carsonby Rd	2	122	60.8	2199	N	TS
2nd Line n. of Phelan Rd	2	122	60.8	2510	N	PL
2nd Line n. of Phelan Rd	0	151	984.1	69	Y	PL
3rd Line s. of Carsonby Rd	1	151	984.1	68	N	TS
3rd Line s. of Carsonby Rd	1	151	984.1	116	N	PL
3rd Line s. of Carsonby Rd	0	153	484.4	2167	N	PL
2nd Line n. of Phelan Rd	1	153	484.4	2505	N	TS
2nd Line n. of Phelan Rd	2	153	484.4	2171	Y	TS
2nd Line n. of Phelan Rd	2	153	484.4	2192	Y	PL
2nd Line n. of Phelan Rd	0	168	41.8	217	N	TS
2nd Line s. of Hwy 72	0	168	41.8	218	N	PL
2nd Line s. of Hwy 72	0	168	41.8	228	Y	PL
2nd Line s. of Hwy 72	1	168	141.4	212	Y	TS
2nd Line s. of Hwy 72	1	168	141.4	214	Y	PL
2nd Line s. of Hwy 72	1	168	141.4	220	Y	PL
2nd Line s. of Hwy 72	2	168	141.4	235	N	PL
2nd Line s. of Hwy 72	1	182	17.9	155	N	PL
3rd Line n. of Hwy 72	1	182	17.9	161	N	PL
3rd Line n. of Hwy 72	1	182	17.9	197	N	PL
3rd Line n. of Hwy 72	1	182	17.9	182	Y	TS
3rd Line n. of Hwy 72	1	182	48.7	2177	N	TS
3rd Line s. of Roger Stevens Rd	1	182	48.7	2181	N	TS
3rd Line s. of Roger Stevens Rd	1	182	48.7	2197	N	PL
3rd Line s. of Roger Stevens Rd	1	182	48.7	2508	N	TS
3rd Line s. of Roger Stevens Rd	1	182	48.7	2518	N	PL
3rd Line s. of Roger Stevens Rd	1	182	48.7	2179	Y	PL
3rd Line s. of Roger Stevens Rd	1	182	48.7	2196	Y	TS
3rd Line s. of Roger Stevens Rd	1	182	48.7	2189	Y	PL
3rd Line s. of Roger Stevens Rd	1	182	48.7	2186	Y	TS
3rd Line s. of Roger Stevens Rd	0	182	422.9	2183	N	PL

Appendix C cont...

Location	Road Number	Traffic Volume	Distance (m)	Tag	Return	Species
3rd Line s. of Roger Stevens Rd	0	182	422.9	2185	N	PL
3rd Line s. of Roger Stevens Rd	0	182	422.9	2517	N	TS
3rd Line s. of Roger Stevens Rd	0	182	422.9	2187	Y	TS
3rd Line s. of Roger Stevens Rd	1	182	422.9	2178	N	TS
3rd Line s. of Roger Stevens Rd	1	182	422.9	2193	N	PL
3rd Line s. of Roger Stevens Rd	1	182	422.9	2198	N	TS
3rd Line s. of Roger Stevens Rd	0	192	10.4	159	Y	PL
3rd Line n. of Hwy 72	1	192	10.4	181	N	PL
3rd Line n. of Hwy 72	1	216	584.6	174	N	PL
McCordick Road	1	216	584.6	185	N	PL
McCordick Road	1	216	584.6	196	N	PL
McCordick Road	2	216	584.6	172	N	TS
McCordick Road	0	298	10.4	2535	Y	PL
Blanchfield Rd	1	298	10.4	2556	N	TS
Blanchfield Rd	1	298	10.4	2543	Y	TS
Blanchfield Rd	1	298	10.4	2561	Y	TS
Blanchfield Rd	1	298	53.2	2544	N	TS
Blanchfield Rd	1	298	53.2	2557	N	TS
Blanchfield Rd	1	365	10.4	2575	Y	PL
Mohr's Road	1	365	10.4	2588	Y	PL
Mohr's Road	0	614	235.6	2149	Y	TS
Airport	0	614	235.6	2151	Y	PL
Airport	0	614	235.6	2157	Y	TS
Airport	1	614	235.6	2162	N	TS
Airport	1	688	494.7	23	N	PL
3rd Line s. of Carsonby Rd	1	688	494.7	117	N	PL
3rd Line s. of Carsonby Rd	1	874	112.7	2150	N	TS
Airport	1	874	112.7	2158	N	TS
Airport	1	874	112.7	2163	N	TS
Airport	1	903	314.9	2589	N	TS
Airport	1	903	314.9	2592	N	PL
John Shaw Road	1	903	314.9	2596	N	PL
John Shaw Road	1	1047	474.1	267	Y	PL
John Shaw Road	2	1047	474.1	243	N	PL
Jake Street, Osgoode	2	1047	474.1	247	N	PL
Jake Street, Osgoode	2	1047	474.1	261	N	TS
Jake Street, Osgoode	2	1047	474.1	273	N	PL
Jake Street, Osgoode	0	1047	671.2	268	N	PL
Jake Street, Osgoode	0	1047	671.2	272	N	TS
Jake Street, Osgoode	0	1047	671.2	284	N	PL
Jake Street, Osgoode	1	1047	671.2	244	N	PL
Jake Street, Osgoode	1	1047	671.2	248	N	PL
Jake Street, Osgoode	1	1047	671.2	264	N	TS
Jake Street, Osgoode	2	1107	224.9	2581	N	PL
Jake Street, Osgoode	2	1107	224.9	2584	N	TS
John Shaw Road	2	1107	224.9	2595	N	PL

Appendix C cont...

Location	Road Number	Traffic Volume	Distance (m)	Tag	Return	Species
John Shaw Road	2	1107	224.9	95	N	TS
John Shaw Road	0	1498	175.8	253	N	PL
John Shaw Road	0	1498	175.8	257	Y	PL
2nd Line at Dalmeny Road	1	1498	175.8	280	N	TS
2nd Line at Dalmeny Road	0	2024	2.375	121	Y	TS
2nd Line at Dalmeny Road	1	2024	2.375	122	N	PL
4th Line n. of Carsonby Rd	1	2024	15.4	138	N	PL
4th Line n. of Carsonby Rd	1	2024	194.7	149	N	TS
4th Line n. of Carsonby Rd	2	2024	194.7	126	N	TS
4th Line n. of Carsonby Rd	2	2024	194.7	147	N	PL
4th Line s. of Carsonby Rd	0	2024	353.8	139	N	PL
4th Line s. of Carsonby Rd	0	2024	353.8	154	N	PL
4th Line s. of Carsonby Rd	0	2024	353.8	127	N	PL
4th Line s. of Carsonby Rd	0	2024	353.8	129	N	TS
4th Line s. of Carsonby Rd	0	2024	353.8	133	N	PL
4th Line s. of Carsonby Rd	0	2024	353.8	145	N	PL
Limebank at Highschool	1	2047	694.6	2567	N	PL
Limebank at Highschool	1	2047	694.6	2573	N	PL
4th Line n. of Carsonby Rd	1	2144	1212	134	N	PL
4th Line s. of Carsonby Rd	1	2203	707.5	137	N	PL
4th Line s. of Carsonby Rd	1	2203	707.5	153	N	PL
4th Line s. of Carsonby Rd	1	2203	707.5	131	N	PL
4th Line s. of Carsonby Rd	1	2203	707.5	141	N	PL
Cabin Rd	1	3077	721.7	2521	N	PL
Cabin Rd	1	3077	721.7	2526	N	TS
Cabin Rd	1	3077	721.7	2532	N	PL
Cabin Rd	1	3077	721.7	2536	N	TS
Cabin Rd	1	3077	721.7	2540	N	TS
Cabin Rd	1	3077	721.7	2548	N	TS
Cabin Rd	1	3077	721.7	2554	N	PL
Moodie	1	3078	50	641	N	TS
Moodie	1	3078	50	644	N	TS
Moodie	1	3078	50	647	N	TS
Moodie	1	3078	50	648	N	TS
Moodie	1	3078	50	865	N	PL
Moodie	1	3078	50	895	N	PL
Moodie	1	3078	50	924	N	TS
Moodie	1	3078	50	641	Y	TS
Moodie	1	3078	50	648	Y	TS
Moodie	1	3078	50	865	Y	PL
Moodie	1	3078	50	865	Y	PL
2nd Line at Dalmeny Road	2	3181	660.6	249	N	PL
2nd Line at Dalmeny Road	2	3181	660.6	254	N	PL
2nd Line at Dalmeny Road	2	3181	660.6	275	N	TS
2nd Line at Dalmeny Road	2	3181	660.6	283	N	TS
2nd Line at Dalmeny Road	2	3181	660.6	286	N	PL

Appendix C cont...

Location	Road Number	Traffic Volume	Distance (m)	Tag	Return	Species
Cabin Rd	0	4300	798.9	2523	N	PL
Cabin Rd	0	4300	798.9	2528	N	TS
Cabin Rd	1	4300	798.9	2538	N	PL
Cabin Rd	1	4300	798.9	2539	N	TS
Cabin Rd	1	4300	798.9	2545	N	TS
Cabin Rd	1	4300	798.9	2552	N	TS
Cabin Rd	0	4300	926.7	2541	N	TS
Cabin Rd	0	4300	926.7	2549	N	TS
Cabin Rd	0	4300	926.7	2555	N	PL
Cabin Rd	2	4300	926.7	2524	N	PL
Cabin Rd	2	4300	926.7	2527	N	TS
Cabin Rd	2	4300	926.7	2530	N	TS
Cabin Rd	2	4300	969.7	2522	N	PL
Limebank at Highschool	1	6837	105.1	2562	N	PL
Limebank at Highschool	1	6837	105.1	2568	N	PL
Lester	1	8254	30	2973	Y	PL
Lester	1	8254	40	1434	N	PL
Lester	1	8254	40	2965	N	PL
Lester	1	8254	50	2963	N	PL
Lester	1	8254	60	2964	Y	TS
Lester	1	8254	60	2970	Y	TS
Lester	1	8254	90	2968	N	TS
Lester	1	8254	100	3976	N	PL
Lester	1	8254	100	2973	Y	PL
Highway 7	1	10300	30	2912	N	PL
Highway 7	1	10300	50	2674	Y	PL
Highway 7	1	10300	75	2672	Y	PL
Highway 7	1	10300	100	2711	N	PL
Highway 7	1	10300	150	2913	N	PL
2nd Line s. of Hwy 72	2	12005	543	215	N	PL
2nd Line s. of Hwy 72	2	12005	543	216	N	TS
2nd Line s. of Hwy 72	2	12005	543	221	N	PL
2nd Line s. of Hwy 72	2	12005	543	242	N	PL
West Hunt Club	1	13423	60	845	N	PL
West Hunt Club	1	13423	60	846	N	PL
West Hunt Club	1	13423	60	847	N	TS
West Hunt Club	1	13423	60	848	N	TS
2nd Line n. of Phelan Rd	1	15035	10.4	2166	N	PL
2nd Line n. of Phelan Rd	1	15035	10.4	2191	N	TS
2nd Line n. of Phelan Rd	1	15035	10.4	2509	N	PL

Appendix D. Sample data manipulation for mean heading.

Mean Bearing: Direction of movement.

Example Path – the road was always zeroed so the heading read North-South long the length of the road.

Heading(°) from North	Cos ϕ	Sin ϕ
180	-1.000	0.000
190	-0.985	-0.174
160	-0.940	0.342
160	-0.940	0.342
200	-0.940	-0.342
160	-0.940	0.342
200	-0.940	-0.342
200	-0.940	-0.342
220	-0.766	-0.643
250	-0.342	-0.940
260	-0.174	-0.985
.	.	.
.	.	.
300	0.500	-0.866
250	-0.342	-0.940
300	0.500	-0.866
310	0.643	-0.766
10	0.985	0.174
Σ	-15.092	-15.156

Appendix E continued...

Each angle was represented by an x,y coordinate in a Cartesian plane. Mean bearing was calculated by taking the inverse of tan of the sum of y values divided by the sum of x values.

$$x' = (\cos \phi_1 + \cos \phi_2 + \dots + \cos \phi_n)$$

$$x' = (-15.092)$$

$$y' = (\sin \phi_1 + \sin \phi_2 + \dots + \sin \phi_n)$$

$$y' = (-15.156)$$

When x' is greater than 0:

$$\text{Mean bearing} = \arctan (y' / x')$$

When x' is less than 0:

$$\text{Mean Bearing} = 180 + \arctan (y' / x')$$

Therefore, the mean bearing of the example path is:

$$\text{Mean Bearing} = 180 + (-15.156 / -15.092)$$

$$\text{Mean Bearing} = 225^\circ$$