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Eastern Hognose Snakes (*Heterodon platirhinos*) Avoid Crossing Paved Roads, but Not Unpaved Roads

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Roads can directly impact animal populations by increasing the risk of mortality; however, a more subtle ecological effect may lie in the way roads impede gene flow by creating barriers to animal movement. We investigated the effect a road network, containing both paved and unpaved surfaces, has on the movement patterns of the Eastern Hognose Snake (*Heterodon platirhinos*) in the Long Point region of Ontario, Canada by radio-tracking 17 adult snakes over two years. We used telemetry data collected in the field to infer the minimum number of road crossings made by snakes, and random walk simulations to estimate the number of road crossings snakes would have made if they moved randomly in relation to roads. Comparing the inferred and expected number of crossings allowed us to test the hypothesis that roads constrain movements because snakes avoid crossing them. Overall, the road network did not impede snake movements. When examined separately, however, we showed that road substrate affected movement: snakes avoided crossing paved roads while they crossed sand roads readily. Male and female snakes crossed roads at the same frequency. While the risk of road mortality is reduced by road avoidance, such avoidance of paved roads may contribute to the genetic isolation and further decline of this species-at-risk.

THERE is a growing body of evidence suggesting that road infrastructure has a negative impact on wildlife and is a driving force behind the global loss of biodiversity (Fahrig, 2003; Benítez-López et al., 2010; Tremblay and St. Clair, 2011). Studies on many groups of animals, including large and small mammals (Ford and Fahrig, 2008; Long et al., 2010; Zurcher et al., 2010), amphibians and reptiles (Findlay and Houlahan, 1997; Vos and Chardon, 1998; Row et al., 2007), birds (Reijnen et al., 1995; Kociolek et al., 2011), and invertebrates (Seibert and Conover, 1991) have demonstrated the detrimental effects roads have on wildlife. Fewer amphibians exist in wetlands adjacent to roads (Findlay and Houlahan, 1997; Vos and Chardon, 1998). Reijen et al. (1995) suggested that the noise from roads results in decreased bird densities in roadside habitat. Mammals and reptiles have been found to alter movement and migration patterns to avoid crossing roads (Zurcher et al., 2010), but also suffer from road mortality where crossing occurs (Row et al., 2007). Row et al. (2007) showed that road mortality alone was sufficient to explain a localized population decline in a large-bodied snake. When roads cause changes in animal movement patterns, they may restrict access to necessary resources like water, breeding and nesting grounds as well as food supply. While these challenges pose immediate negative consequences to animals, the barrier effect roads have on gene flow are subtler. If roads are avoided, or if individuals are unable to cross roads and survive, animal populations may become genetically isolated resulting in low genetic diversity and inbreeding depression (Holderegger and Di Giulio, 2010). Reptiles and amphibians have the highest risk of road mortality of any terrestrial animal group (Ashley and Robinson, 1996; Andrews and Gibbons, 2005).

Males and females often have divergent ecological needs, thus movement patterns within a species should reflect theses differences in behavior (e.g., Blouin-Demers and Weatherhead, 2001; Sillero, 2008; Kuykendall and Keller, 2011). If different patterns of movement exist, then rates of road mortality may be different between the sexes. Many studies have focused on quantifying road mortality and the effect it has on population viability, but few have focused on intraspecific variation in road mortality (but see Row et al., 2007; Andrews and Gibbons, 2008; Rees et al., 2009). If one sex is more susceptible to road mortality, demographics of the population can change quickly and lead to declines. Road mortality was found to be higher among male Massasauga Rattlesnakes (*Sistrurus catenatus*) compared to females, and mortalities were concentrated in August when males travel more widely in search of mates (Shepard et al., 2008). Row et al. (2007) demonstrated that road mortality of female ratsnakes (*Elaphe obsoleta*) had a much more severe impact on the population than that of males. It is therefore imperative that we measure the impact road networks have on the spatial ecology of animals, especially species that are threatened, so that the risk of road mortality and genetic isolation may be mitigated.

The goal of this study was to test the hypothesis that movements of the Eastern Hognose Snake (*Heterodon platirhinos*), a species classified as threatened by the Committee on the Status of Endangered Wildlife in Canada, are constrained because the snakes avoid crossing roads. We used movement data from a two-year radio-telemetry study to determine whether roads are crossed less often than expected by chance by male and female snakes. We also examined whether paved roads were avoided more than unpaved roads.

MATERIALS AND METHODS

Study area and study species.—*Heterodon platirhinos* is a large-bodied snake (up to 125 cm in total length; Michener and Lazell, 1989) and, in Canada, found only in southern Ontario. We conducted this study from May 2009 to October 2010 in the Long Point Region of Ontario, Canada (42°42′N, 80°28′W). The study area consisted of two separate properties ca. 1035 ha and 500 ha comprised mainly of oak savannah, mixed forest, old-field, shallow wetlands, and pine stands with sandy soils. The first property is bisected by two sand roads and is bordered by

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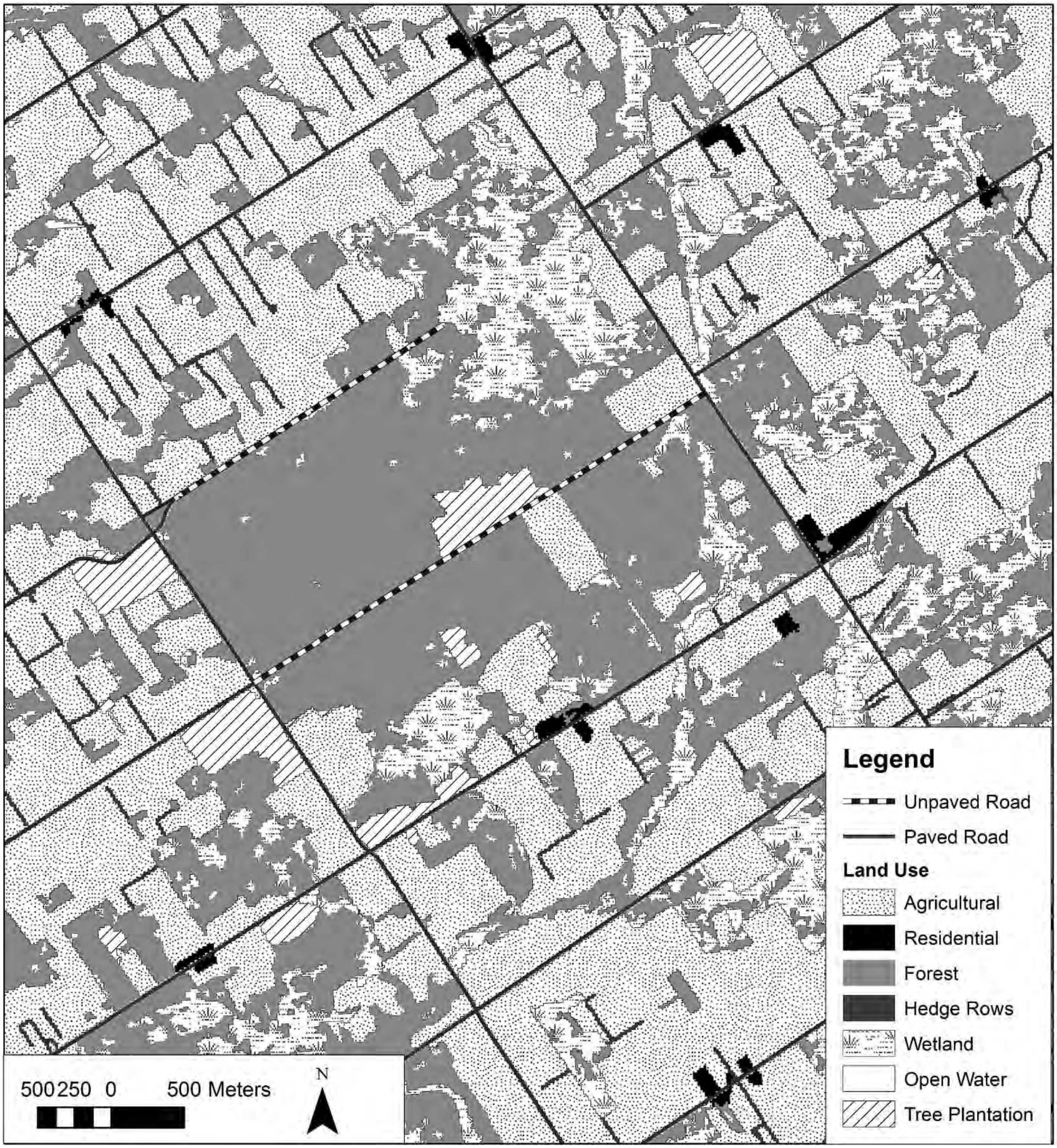

Fig. 1. Habitat composition and road network in the Long Point Region of Ontario, Canada, where road avoidance by Eastern Hognose Snakes (*Heterodon platirhinos*) was studied.

paved roads on three sides (Fig. 1). The second property is also bisected by several sand and paved roads. Speed limits along these roads range from 50–80 km/h and the annual average daily traffic (AADT) volume for surrounding roads ranges from 6,350–10,350 vehicles/day (Ministry of Transportation of Ontario, 2007).

Snakes were captured opportunistically throughout the active season. We surgically implanted radio-transmitters in a total of 25 adult snakes (17 females, 8 males) and tracked them for periods ranging from several weeks to two years. Several snakes were lost to predation, so we used the movement patterns of 17 individuals (12 females, 5 males) that were tracked over a complete active season for our analyses. Individuals with radio-transmitters were located on average every five days during peak activity season (1 May to 31 August). At each location, the Universal

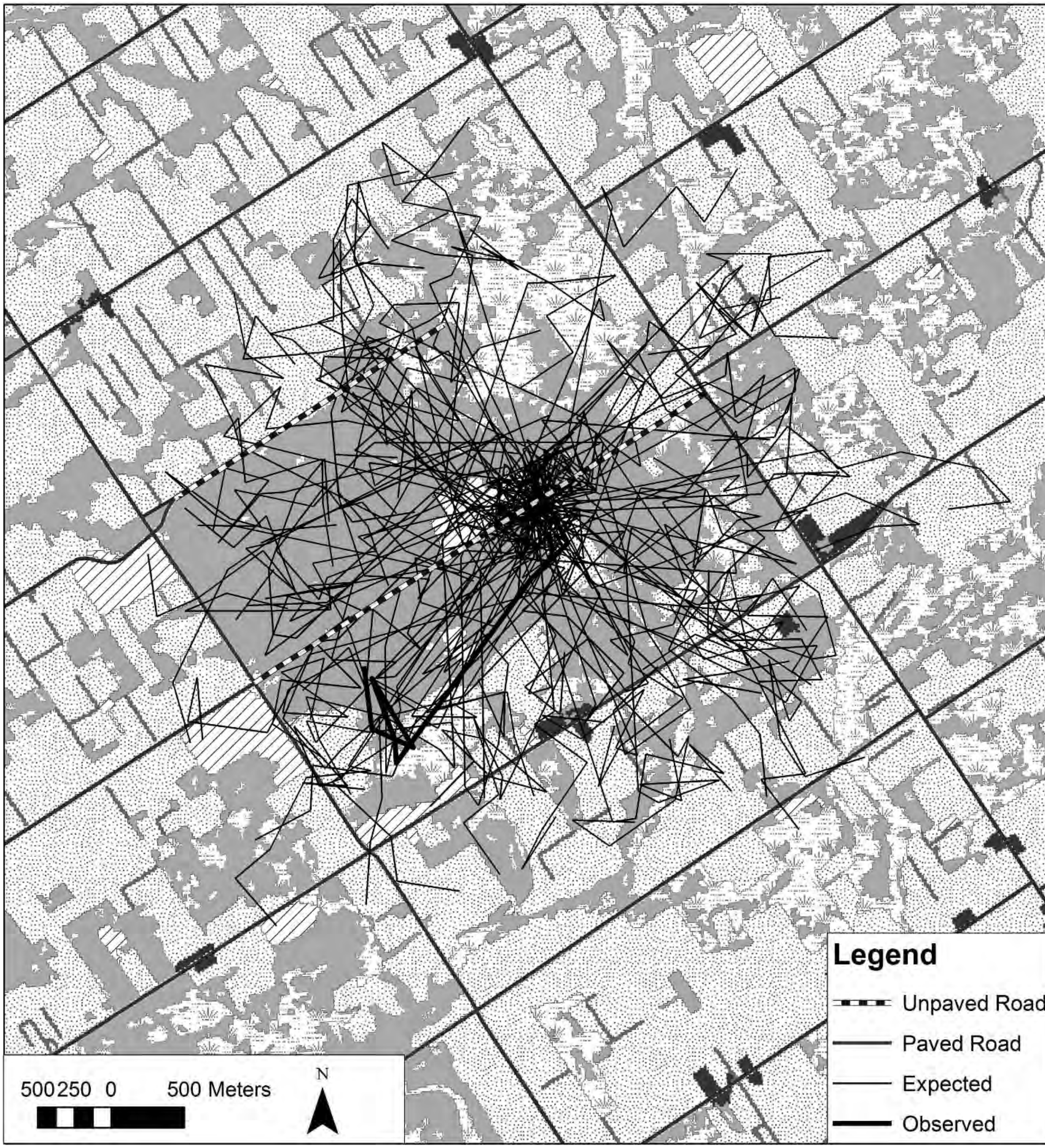

Fig. 2. Inferred and expected pathways across paved and unpaved roads of one Eastern Hognose Snake (*Heterodon platirhinos*) in the Long Point Region of Ontario, Canada based on 25 unique telemetry locations.

Transverse Mercator (UTM) coordinates were recorded using a GPSmap76Cx portable GPS unit (Garmin International Inc., Olathe, KS, www.garmin.com) at an accuracy of <4 m.

Road avoidance.—We estimated road avoidance for each individual by comparing the inferred minimum number of road crossings made by the individual (the number of times a straight line linking two successive locations bisected a road) to the number of road crossings it would have made given a random course. We generated 100 'random walk' movement paths for each individual snake (Klingenbock et al., 2000; Row et al., 2007) using the Animal Movement Extension (Hooge and Hooge, 2001) in ArcView 3.2 (Environmental Systems Research Institute, Redlands, CA, www.esri.com). Each random movement course started in the same location as the real snake to which it was paired and had the same chronological series of distances moved, but we randomized the bearing at which the pathway

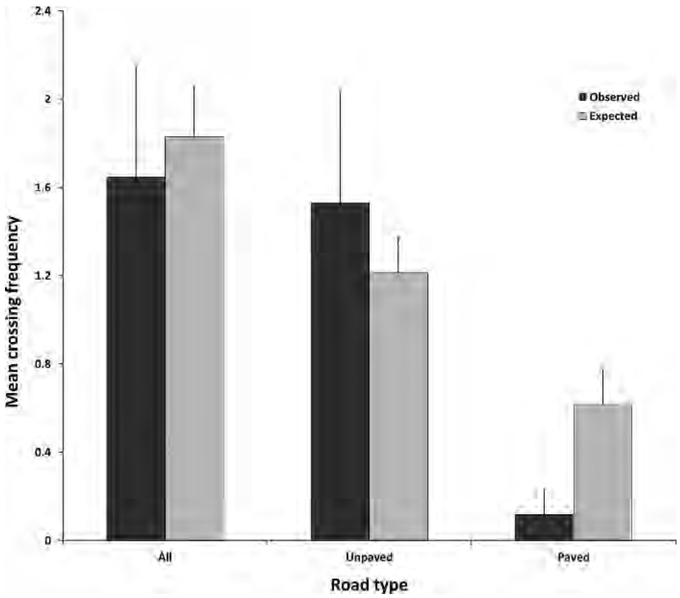

Fig. 3. Mean (± SE) observed and expected road crossings over unpaved and paved roads by the Eastern Hognose Snake (*Heterodon platirhinos*) in the Long Point Region of Ontario, Canada (*n* = 17 snakes).

turned at each location (Fig. 2). This set of 100 random pathways, along with the true snake movement paths, were then intersected with the entire road network to count the number of road crossings. We also intersected the paved and unpaved road network separately to see if substrate plays a role in road avoidance.

We compared road avoidance between the sexes by subtracting the observed crossing value from the mean expected value for each individual and performing a non-parametric ANOVA (Wilcoxon signed-rank test) on the differences. To test for individual road avoidance, we created a distribution of road crossings for each individual from its 100 'random walk' pathways (expected crossings) and compared the actual pathway (inferred crossings) to this distribution. We deemed a snake to avoid roads significantly when its inferred number of crossings was less than the 5% percentile of the distribution of expected crossings. The number of snakes who significantly avoided roads was tallied, and we used a sign-test to determine whether roads were avoided significantly at the population level.

RESULTS

The minimum convex polygon home range size for the 17 Eastern Hognose Snakes was 39.4 ± 6.3 ha. There was no significant difference in the degree of road avoidance between the sexes ($R^2 = 0.002$, $F_{1,15} = 0.02$, $P = 0.88$); therefore, we pooled the sexes for further analyses. *Heterodon platirhinos* crossed roads an average of 1.65 ± 0.51 times per season (maximum number of crossings = 6), whereas snakes moving randomly would have traversed roads an average of 1.88 ± 0.21 times per season (maximum number of crossings = 10, Fig. 3). Snakes crossed paved roads on average 0.12 ± 0.12 times per season, while randomly moving snakes would have crossed 0.62 ± 0.16 times. Snakes crossed unpaved roads on average 1.52 ± 0.50 times per season, while randomly moving snakes would have crossed 1.21 ± 0.16 times.

Overall the 17 snakes did not significantly avoid crossing roads (sign test $P > 0.10$), but the number of inferred crossings was significantly less than the number of expected crossings for more than half of the snakes (11 out of 17 snakes). When we repeated the analysis separately for paved and unpaved roads, we found that overall snakes did not avoid crossing unpaved roads (sign test $P > 0.10$; the number of inferred crossings was significantly less than the number of expected crossings for ten out of 17 snakes), but they did avoid crossing paved roads (sign test $P = 0.0001$: the number of inferred crossings was significantly less than the number of expected crossings for 16 out of 17 snakes).

DISCUSSION

Several studies have documented road avoidance in reptiles (Klingenbock et al., 2000; Koenig et al., 2001; Andrews and Gibbons, 2005), but others have found that large snakes may not avoid crossing roads (Row et al., 2007). Andrews and Gibbons (2008) showed that the largest individuals of a species are more likely to be hit and killed on roads. We found that roughly half the Eastern Hognose Snakes we followed via radio-telemetry avoided crossing unpaved roads, but almost all avoided crossing paved roads. This suggests that, unsurprisingly, all roads are not equal in their effect on wildlife movement.

We anticipated a difference between the frequency of male and female road crossings due to their differences in reproductive ecology (e.g., Blouin-Demers and Weatherhead, 2002), as documented by Bonnet et al. (1999). The inferred rate of overall crossings was, however, similar for both sexes but modest sample sizes (especially of males) reduced our ability to detect a difference if it indeed existed. Male home ranges were slightly smaller than female home ranges, but not significantly so (33.3 ± 11.9 ha, 42.0 ± 7.6 ha, respectively).

Paved roads are markedly avoided by *H. platirhinos*, which should in theory reduce road mortality but increase population isolation, while unpaved roads are avoided less, which should result in increased road mortality but decreased population isolation if a sufficient number of snakes succeed in traversing the road without being killed. Because *H. platirhinos* is diurnal in Ontario, its chances of crossing a road without being killed are diminished. Avoidance of paved roads by *H. platirhinos* would exacerbate fragmentation effects and contribute to genetic isolation of sub-populations.

The distribution of *H. platirhinos* is divided into two distinct areas in Canada: the southwestern Ontario region and the Wasaga–Oak Ridge Moraine–Peterborough region (Oldham and Weller, 2000). It is currently unknown whether any gene flow exists between these populations, but given the extensive road network and our results showing road-crossing avoidance it appears unlikely. Wildlife underpasses have been shown to reduce mortalities along highways especially when fencing is also present (Woltz et al., 2008; McCollister and van Manen, 2010). As the Eastern Hognose does appear to avoid crossing paved roads, populations may benefit from the construction of wildlife culverts and underpasses if indeed these structures are used by *H. platirhinos*.

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