No Effect of Road Density on Snake Abundance in Suburban Ottawa, Canada

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I. Abstract

Roads negatively affect many animal species. Snakes are particularly susceptible to roads, with increased mortality observed in habitats with roads compared to natural habitats. Therefore, we should find fewer snakes in areas with higher road densities. I sampled snakes in field habitats using plywood coverboards from June to October and found two species of snakes: *Thamnophis sirtalis* (garter snakes) and *Storeria occipitomaculata* (red-bellied snakes). I calculated road density with a Geographic Information System. The abundance of garter snakes, red-bellied snakes, and both species combined were not significantly affected by road density. The lack of effects of road density may be due to small sample size and lack of sites without any roads. This study provides additional information on the effects of roads on snakes and invites further studies to understand how snakes are affected by roads, leading to valuable for conservation research.

II. Acknowledgements

I would like to thank my supervisor Gabriel Blouin-Demers for giving me the opportunity to pursue this study. His excellent suggestions and assistance with this project are invaluable and appreciated. I would like to thank Tippawan McKillip for accompanying me on almost every field day. She made this project even more enjoyable, and her help was extremely appreciated. I would like to thank my mother Michelle Beaudoin for sourcing a majority of the plywood used for this study and I would like to thank my father George Matsoukas for his interest and help with this study. I would also like to thank my grandfather Wayne Beaudoin for allowing me to use his vehicle for the entire field season. Finally, I would like to thank Peter Ruiter and his family for allowing me access to his farm for this study. Thank you everyone!

1. Introduction

Many animals are negatively affected by roads. Amphibians, snakes, freshwater turtles, and ground nesting birds have been observed less often as traffic levels and impervious surface area increase in the landscape (Shepard et al., 2008; Sutherland et al., 2009). Roads also affect species diversity. Sites closer to urban areas have lower species richness and evenness than rural habitats (Sullivan et al., 2016). In addition, as the area of a habitat decreases, the species most sensitive to fragmentation are likely to disappear from the habitat (Hager, 1998). The effects of fragmentation are seen commonly in reptiles, with the most abundant species in natural areas being rare in fragmented habitats (Mac Nally & Brown, 2001). Reptile abundance is also one-third lower in modified habitats compared with unmodified habitats (Doherty et al., 2020). In this study, I will examine the effects of roads on snakes in Ottawa Canada.

Snakes are one of the most affected taxa by roads. Eastern hognose snakes, eastern milk snakes, and eastern massasauga rattlesnakes avoid paved roads (Shepard et al., 2008; Robson et al., 2011; Maddalena et al., 2020). This suggests roads represent barriers to snakes, negatively impacting their movement. In addition, survival rates of eastern indigo snakes were greatly reduced along highways in suburbs compared to conservation core areas (Breininger et al., 2012). Mitrovich et al. (2018) found that coachwhip snakes occupy urbanized and fragmented sites 64 times less and have ten times greater odds of extinction compared to larger connected sites. These studies support the idea that roads represent strong barriers to snakes and suggest that fewer snakes will be found in areas with paved roads due to the roads negatively impacting snake movement and survival.

Coverboards are commonly used to sample snakes. Coverboards can be used to measure the abundance of snakes, as they may reveal species not detected by other techniques (Ryan et al., 2002). Materials with high heat conductivity such as asphalt shingles, tin roofing, and plywood are ideal for snake coverboards as they have relatively high heat conductivity and snakes hide under the warm boards for thermoregulation (Carfagno & Weatherhead, 2006). In the Ottawa region, snakes are also more abundant in old field locations than in forests due to higher thermal quality of the fields (Retamal Diaz & Blouin-Demers 2018). This means that using coverboards in old fields should be a productive way to sample snakes. There are two common snake species in Ottawa: *Thamnophis sirtalis* (garter snakes) and *Storeria occipitomaculata* (red-bellied snakes) and these will thus be the species of interest in my study.

To determine a meaningful area to measure road density around each habitat, a buffer area must be determined. Fyson & Blouin-Demers (2020) tested buffer areas between 300 m and 4000 m to determine the scale of maximum effect of road density on the presence of Blanding's turtles in wetlands around Ottawa. In addition, Findlay & Houlahan (1997) tested buffer areas for reptiles and amphibians in southeastern Ontario between 250 m and 2000 m and found that species were negatively affected by roads up to 2 km from the wetland. Here, I will use an intermediate value, 1000 m, as the buffer distance to measure road density.

The pattern of interest that I wish to explain is the spatial variation in snake abundance in Ottawa. My hypothesis is that snakes are negatively affected by roads. Therefore, my prediction is that I should observe fewer snakes at sites surrounded by more roads. My study can contribute to management efforts by determining the effects of roads on snakes in Ottawa.

2. Materials and Methods

Field Data Collection

I chose twelve old field habitats to represent a gradient of road densities in Ottawa, Ontario, Canada (Figure 1). At each site, I placed three cover boards to sample snakes, for a total of 36 coverboards deployed. Coverboards were 60 cm x 60 cm (Halliday & Blouin-Demers, 2015) and made from either thin single sheet plywood or thicker layered plywood. Ten fields had two thick boards and one thin board, and two fields had one thick board and two thin boards. This controlled for snakes potentially preferring one board type over the other. I placed coverboards at each site incrementally. Initially, I placed one coverboard at each site until enough plywood was obtained for a second coverboard at each site. Once an additional twelve coverboards were prepared, I placed a second coverboard at each site on the same day. Finally, when an additional twelve coverboards were prepared, I placed a third coverboard at each site on the same day again, one month after the initial coverboards were placed. Coverboards were spaced approximately 7.5 m apart from each other.

I collected data on 28 field days from June to October 2020. I observed two species of snakes: *Thamnophis sirtalis* (garter snakes) and *Storeria occipitomaculata* (red-bellied snakes).

I visited the fields approximately twice per week in a different order each field day to avoid introducing a potential confounding effect of time of day. I sampled fields on mostly warm sunny days, however, I also sampled fields on some warm overcast days to allow for a larger data set. On each field day, I sampled all twelve sites. I lifted each coverboard and counted the snakes. I also recorded snakes opportunistically along the paths to reach the coverboards. Finally, I recorded a small number of deceased snakes.

Road Density Calculation

I calculated road density in QGIS 3.16.3 using the OpenStreetMap coordinate reference system projection (EPSG:3857 - WGS 84 / Pseudo-Mercator – Projected). I located the twelve sites and generated a circular area around each site. The area of the circle was 3.14 km^2. I measured the paved roads in each area and calculated road density by dividing the length of roads of each site by the buffer area. The twelve sites ranged in road density from 0.46 km/km^2 to 8.00 km/km^2 (Figure 1).

Statistical Analyses

I preformed six linear regressions in Microsoft Excel (Analysis ToolPak Add-in). The first linear regression was to determine the relationship between road density and the number of live snakes found, and the second linear regression was to determine the relationship between road density and the total number of snakes found. The third linear regression was to determine the relationship between road density and the number of live garter snakes found, and the fourth linear regression was to determine the relationship between road density and the total number garter snakes found. Finally, the fifth linear regression was to determine the relationship between road density and the number of live red-bellied snakes found, and the sixth linear regression was to determine the relationship between road density and the total number of red-bellied snakes found. I used the significance level $\alpha < 0.05$.

3. Results

I found 135 snakes: 63 (46.7%) garter snakes and 72 (53.3%) red-bellied snakes. I found 78 (57.8%) snakes under the coverboards and 51 (37.8%) snakes outside the coverboards nearby. I found 5 (3.7%) dead snakes outside the coverboards (2 garter snakes and 3 red-bellied Snakes) and 1 (0.7%) dead red-bellied snake under a coverboard. I found red-bellied snakes mostly under the coverboards, with 61 (84.7%) snakes found under the coverboards and 7 (9.7%) snakes found outside the coverboards. I found garter snakes mostly outside of the coverboards, with 44 (69.8%) snakes found outside the coverboards and 17 (27.0%) snakes found under the coverboards.

I found no significant effect of road density on snake abundance. For both snake species combined, I found no significant effect of road density on either the live snakes and the total of live and deceased snakes. Road density had a slightly stronger effect on the number of live snakes found, but this effect was not significant ($R^2 = 0.034$, Figure 2; $p = 0.567$, Table 1). Road density had a weaker effect on the total number of snakes found, and the effect was again not significant ($R^2 = 0.031$, Figure 2; $p = 0.587$, Table 1).

I also found no significant effect of road density on garter snake abundance. Road density had a slightly stronger effect on the number of live garter snakes found, but this effect was not significant (R^2 = 0.025, Figure 3; p = 0.622, Table 1). Road density had a weaker effect on the total garter snakes found, and the effect was again not significant (R^2 = 0.024, Figure 3; p = 0.631, Table 1).

Finally, I also found no significant effect of road density on red-bellied snake abundance. Road density had a slightly stronger effect on the number of live red-bellied snakes found, but this effect was not significant (R^2 = 0.019, Figure 4; p = 0.668, Table 1). Road density had a weaker effect on the total red-bellied snakes found, and the effect was again not significant (R^2 = 0.016, Figure 4; p = 0.698, Table 1).

4. Discussion

I expected to observe fewer snakes as road density increased to support my hypothesis that snakes are negatively affected by increasing road density. However, I found no significant effects of road density on snake abundance for garter snakes, red-bellied snakes, or for both species combined. Previous studies have shown that snakes are negatively affected by roads due to avoidance behaviours and increased mortality (Shepard et al., 2008; Robson et al., 2011; Breininger et al., 2012; Maddalena et al., 2020). It has also been observed that increasing the road density by 0.2 km/km^2 within a 2 km buffer area leads to an approximately 20% decline in reptile and amphibian species richness in southeastern Ontario (Findlay & Houlahan, 1997). With many previous studies contradicting my results, sources of errors must be present and will be discussed.

The non-significant results across my study could be due to several factors. First, my sample size is small. With 12 sites, I had low statistical power to detect differences even if they existed. The chance of discovering real effects is low and false negatives are more likely to occur (Button et al., 2013). Increasing the sample size by adding additional sites will increase the statistical power.

Second, some coverboards were not placed effectively. In the fall, I found snakes on the path to coverboards at sites where I had never found snakes before. This increase in observations in fall has been observed previously with some snakes increasing their home range area in the fall (Brito, 2003), including garter snakes (Shonfield et al., 2019). This suggests that snakes were present in the area around the site but did not find or use the coverboards. If I placed coverboards in a suboptimal location, then the snakes that were present in the habitat did not find or use the coverboards. As a result, my observations at these sites are much lower than the true number of snakes in the habitat. To reduce the chances of this occurring, I recommend choosing better site locations and increasing the number of boards per site. This will increase the chances of snakes finding boards, and lead to better estimates of snake abundance.

Finally, my choice of locations was not optimal to answer my question because I had a limited range of variation in road density. My sites do not fully reflect the landscape that I was trying to investigate to determine the spatial variation of snake abundance in Ottawa. I chose no truly natural sites, resulting in all study populations potentially being negatively impacted by roads. Roads contribute to habitat isolation (Mader, 1984) that has been observed to decrease the abundance (Mac Nally & Brown, 2001; Doherty et al., 2020) and species richness (Hager, 1998; Sullivan et al., 2016) of animals, including colubrid snakes (Mitrovich et al., 2018). In addition, most of the sites I chose are in suburban areas where studies have observed high mortality rates in snakes (Breininger et al., 2012). The lack of truly natural sites that are not negatively impacted by roads further weakens the effects of road density on snakes found. In the future, I recommend choosing some truly natural sites that are less impacted by roads to increase the range of variation in road density.

In conclusion, my study suggests that road density does not affect snake abundance in Ottawa. Previous studies have shown that snakes are negatively affected by roads due to avoidance behaviours and increased mortality. The lack of road effects in my study could be due to a small sample size, ineffective placement of coverboards, and improper site location choice. I recommend increasing the number of sites, increasing the number of coverboards in better locations, and choosing some truly natural sites that are less impacted by roads. My study provides additional information on the effects of roads on snakes in Ottawa and represents an area of research that can be expanded upon to further understand how snakes are affected by roads, leading to valuable areas for management efforts.

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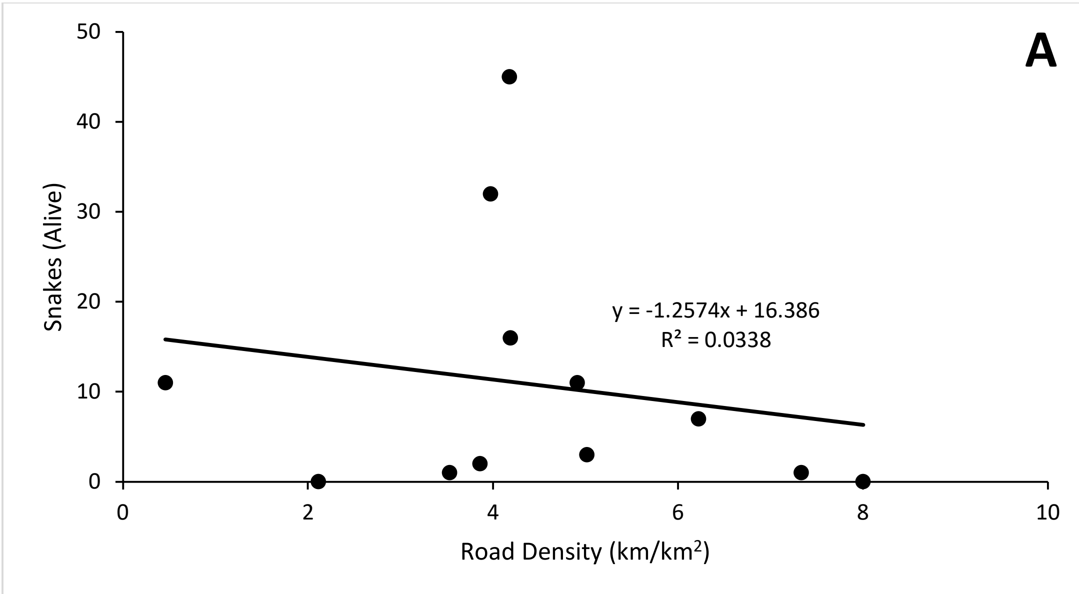
Appendix

Table 1. Statistical results for linear regressions. The abundance of garter snakes (*Thamnophis sirtalis*) and red-bellied snakes (*Storeria occipitomaculata*) were compared to road density. n = 12 sites in Ottawa, Ontario, Canada. Significance level α < 0.05.

Linear Regression	R^2	df	F - value	p - value
Alive Snakes ~ Road Density	0.034	10	0.350	0.567
Total Snakes ~ Road Density	0.031	10	0.316	0.587
Alive Garter Snakes ~ Road Density	0.025	10	0.259	0.622
Total Garter Snakes ~ Road Density	0.024	10	0.245	0.631
Alive Red-Bellied Snakes ~ Road Density	0.019	10	0.195	0.668
Total Red-Bellied Snakes ~ Road Density	0.016	10	0.159	0.698

Figure 1. Locations and buffer areas of study sites around Ottawa, Ontario, Canada where the effect of road density on snake abundance was studied. Mapping done in QGIS 3.16.3 using the OpenStreetMap coordinate reference system projection (EPSG:3857 - WGS 84 / Pseudo-Mercator – Projected). n = 12 site locations. Buffer area of each site represents 3.14 km^2.



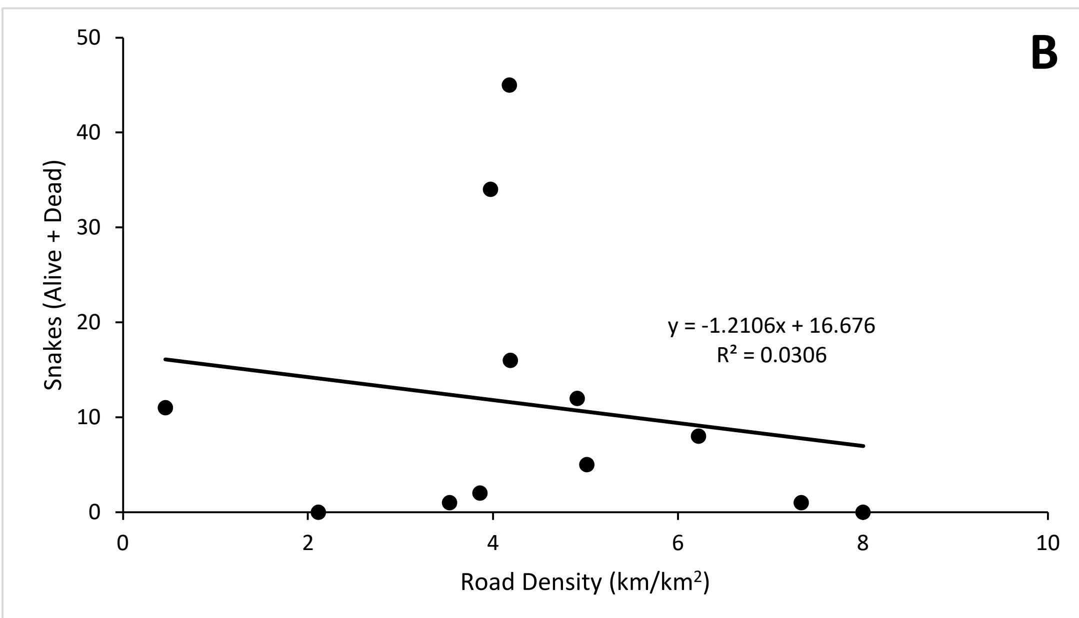


Figure 2. The number of snakes observed as a function of road density at 12 sites in Ottawa, Canada. Snakes represent both *Thamnophis sirtalis* (garter snakes) and *Storeria occipitomaculata* (red-bellied snakes). Panel A represents the alive snakes found at each site (n = 129, p = 0.567) and panel B represents both the alive and dead snakes found at each site (n = 135, p = 0.587).

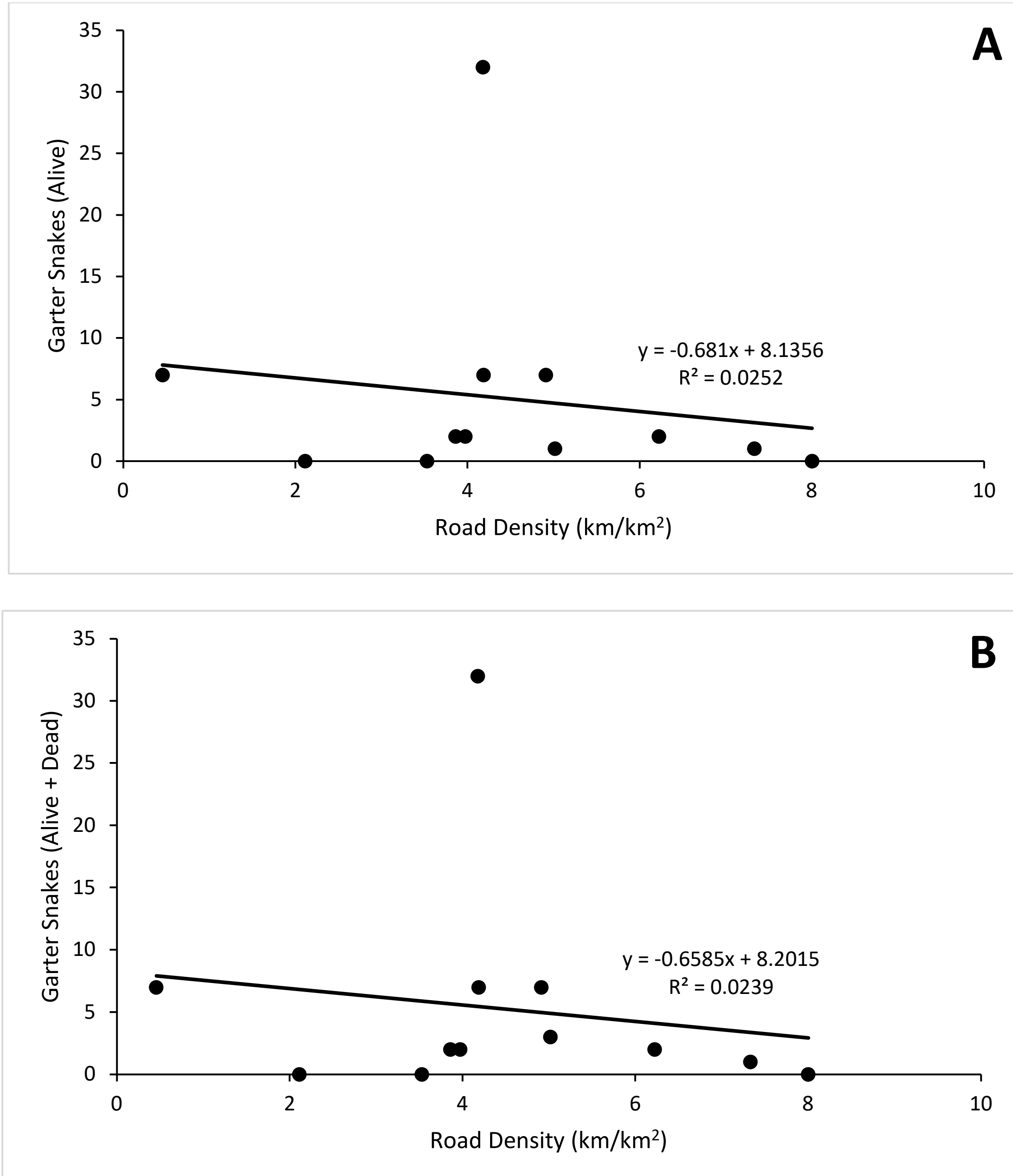
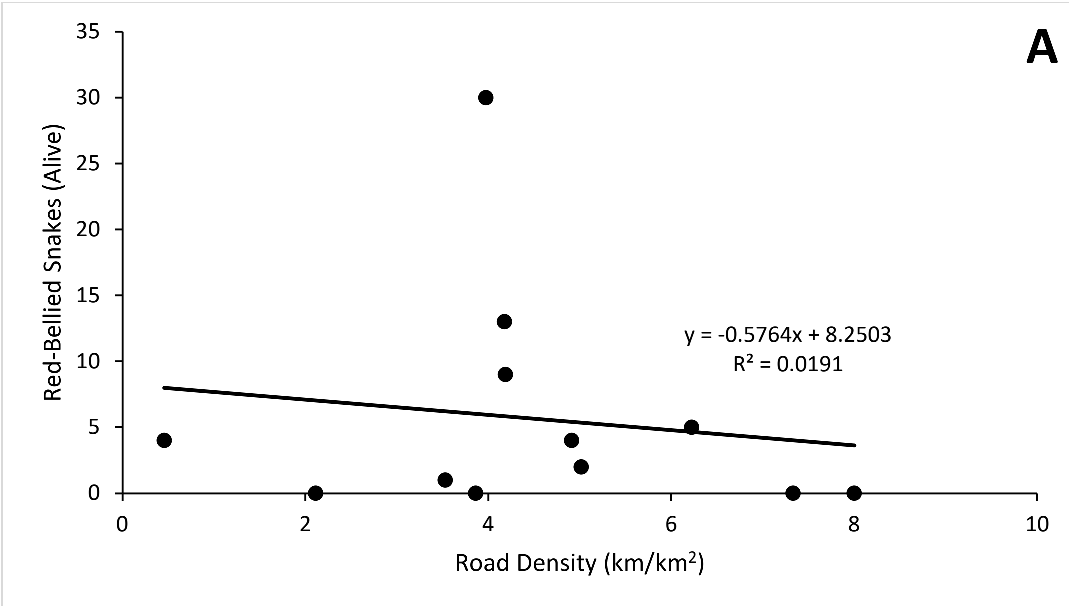


Figure 3. The number of *Thamnophis sirtalis* (garter snakes) observed as a function of road density at 12 sites in Ottawa, Canada. Panel A represents the alive garter snakes found at each site (n = 61, p = 0.622) and panel B represents both the alive and dead garter snakes found at each site (n = 63, p = 0.631).



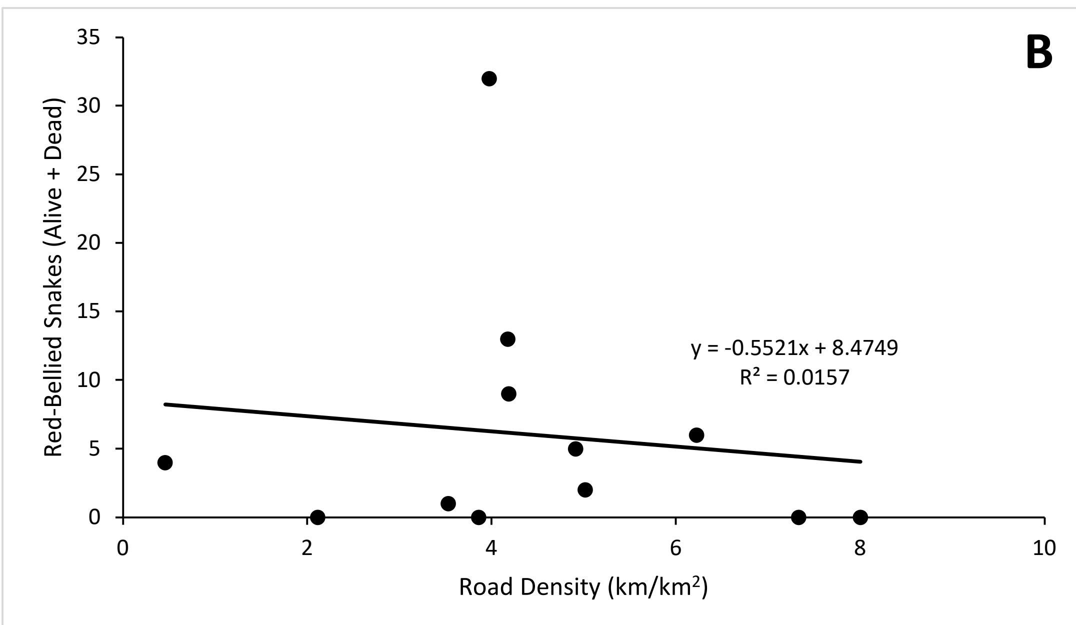


Figure 4. The number of *Storeria occipitomaculata* (red-bellied snakes) observed as a function of road density at 12 sites in Ottawa, Canada. Panel A represents the alive red-bellied snakes found at each site (n = 68, p = 0.668) and panel B represents both the alive and dead red-bellied snakes found at each site (n = 72, p = 0.698).