

Which fence works best? An animal behavioral study that explores the effectiveness of solid plastic VS. mesh when used as a mitigation measure to reduce road mortality for herpetofauna.

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1. ABSTRACT

Fencing is one of the most effective mitigation measures used to reduce road-kill, however little is known regarding the most suitable fence materials to exclude herpetofauna from roads, with a lot of concerns surrounding the safety and effectiveness of mesh fencing. This research attempts to address this knowledge gap by evaluating the effectiveness of mesh and solid plastic fencing (Animex) for use as mitigation tools to protect wildlife near roads.

This behavioral study explores the reactions of various herpetofauna when placed in an enclosure comprising two sides of steel mesh fencing (1/4 inch) and two sides of solid plastic fencing (Animex). The activity that was recorded and compared during the observations included:

- a. Time spent within each fence zone
- b. Physical interactions with the fencing
- c. Climbing or escape attempts
- d. Correlations between behaviors and other variables

The results showed that the herpetofauna groups spent a greater proportion of time along the mesh fencing, with all study groups attempting to escape the mesh fencing during at least double as many trials as the solid plastic fencing. All species except Midland painted turtles successfully escaped the mesh fencing but no species escaped the solid plastic fencing. Based upon behaviors exhibited by the herpetofauna during the trials it was concluded that mesh fencing has the potential to cause injury to animals that come into contact with it due to the risk of laceration and/or entanglement proposed by the wire strands.

As the goals of exclusion fencing are not only to keep animals off the road but also to funnel animals safely to wildlife crossing structures, this study concludes that solid plastic is the most appropriate material for use as exclusion or drift fencing for the species studied. Conversely, mesh fencing will hinder the funneling of herpetofauna towards wildlife crossings or into adjacent habitat due to the associated additional risk of injury, delay and/or escape.

2. INTRODUCTION

It is important to understand the impacts affecting wildlife populations and overall ecosystem health, particularly those associated with human development and infrastructure. Roads have been important to human society since the mass production of vehicles began, with the demand for better roads and routes increasing with economic growth. Approximately 90% of the land surface can now be accessed by travelling only 48 hours via road or rails from the closest city (Frissell & Trombulak, 1999; Van der Ree *et al.*, 2015).

Roads affect terrestrial and aquatic ecosystems in 7 ways: (1) increased mortality from road construction; (2) increased mortality from collision with vehicles; (3) modification of animal behavior; (4) alteration of the physical environment; (5) alteration of the chemical environment; (6) spread of exotic species; and (7) increased alteration and use of habitats by humans (Frissell & Trombulak, 1999; Van der Ree *et al.*, 2015).

Road traffic kills hundreds of millions of animals every year, negatively affecting populations of species in different parts of the world (Rytwinski *et al.*, 2016). The species groups most abundantly killed by vehicular collision are amphibians, whilst reptiles also incur high road mortality. (Glista *et al.*, 2007; Huijser *et al.*, 2009; Colino-Rabanal & Lizana, 2012). It is believed that road-kill could be contributing to global amphibian and reptile decline (Glista *et al.*, 2007; Baker *et al.*, 2015).

The main contributing factors as to why herpetofauna are one of the most abundantly killed animal groups on roads are that by nature they often travel *en masse* during migration, and that negative human attitudes exist towards them, resulting in individuals being targeted by drivers (Glista *et al.*, 2007; Crawford & Andrews, 2016). Despite recent changes in such public attitudes to, in particular, turtle road mortality (Crawford & Andrews, 2016), the concerning issue regarding turtles is that these species suffer a bigger decline than other animals. This is because in comparison with other herpetofauna, turtle populations take longer to recover; therefore road-kill affects the population on a larger scale than to other animals (Horne *et al.*, 2003; Baxter-Gilbert *et al.*, 2015).

Roads built through or near wetlands cause significant mortality of reptiles and amphibians and create barriers to migration, dispersal and gene flow (Aresco, 2005; Jackson & Fahrig, 2011). Wetlands require a landscape approach to conservation, which considers not only the quality of wetlands and nearby terrestrial habitats, but also the provision of safe corridors for wildlife to disperse through wetlands or, if possible, to identify alternative routes (Aresco, 2005; Roe *et al.*, 2005; Van der Ree *et al.*, 2015).

Rytwinski *et al.*, (2016) states that there are more than 40 types of road mitigation measures available to reduce wildlife mortality on roads, but that fencing, with or without wildlife crossing structures, is the most efficient. Fences can provide *in situ* wildlife protection, facilitate the reintroduction of species at risk, and serve dual educational and research functions (Dickman, 2011). Many types of exclusion structures exist, however little research has addressed what fencing types work best to exclude herpetofauna from roads (Aresco, 2005; Glista *et al.*, 2007; Waltz *et al.*, 2008; Baxter-Gilbert, *et al.*, 2015). This lack of research represents a concern, as functional and cost-effective conservation measures are critical to the recovery of susceptible populations. This is why, as Van der Ree *et al.*, (2015) states, studies investigating road impacts, which provide easily accessible conclusions and recommendations to decision makers, are imperative to road ecology, with a good experimental design vital to evaluate the effectiveness of road mitigation measures.

Aresco (2005) reported that a continuously monitored silt fencing results in a substantial, although not total, reduction in road mortality. However, Baxter-Gilbert *et al.*, (2015) concludes that neither silt fencing nor mesh fencing were effective as herpetofauna were able to climb or escape easily. The Association of Wetland Stewardship for Clayoquot and Barklet Sounds (2014) study illustrated that amphibians, particularly those with toe pads, are able to climb mesh fencing in order to escape from an exclusion area. Whilst Langan (2011) concluded that mesh fencing can be effective when considering turtles, Ferronato *et al.*, (2014) identified that turtle species were the most negatively affected by the mesh fencing, particularly associated with entanglement, but with impacts on snakes and lizards also moderate. Neither Ferronato *et al.* (2014) nor Crosswhite *et al.*, (1999) subsequently recommend mesh as a suitable fence material. Conversely, Long & Robley (2004) state that despite mesh fencing causing deaths, such occurrences are infrequent

(Walmsley, 2015) and, therefore, the ecological benefits of using mesh outweigh the negatives.

As a result of the identified potential negative effects associated with the use of mesh fencing, some scientists have recommended smooth solid plastic sheets as an alternative, or at least the use of a harder opaque material. Geotextiles such as silt fencing are considered to require high levels of maintenance due to regular tearing and fast degeneration, (Kruidering *et al.*, 2005; Clevenger & Huijser, 2011; Baxter-Gilbert *et al.*, 2015). Hence, this paper aims to address the knowledge gap associated with the effectiveness of mesh vs. solid plastic fencing and their respective usage as a mitigation tool for herpetofauna conservation.

3. METHODOLOGY

A good experimental design is imperative in evaluating the effectiveness of road mitigation measures (Van der Ree *et al.*, 2015). In order to demonstrate the potential benefit of using solid plastic over mesh fencing, an enclosed 25m² area was installed with two sides comprising steel mesh fencing and two sides solid plastic (*Animex*). The mesh fencing had an aperture of ¼ inch as recommended by Johnson (1989).

The study area was located at Scales Nature Park (SNP), a private property in Orillia, Ontario, Canada. The frog and snake individuals involved in the study comprised wild individuals captured a maximum of 8km from the study site. The frog and snake species used do not hold legal protection status; a trained field surveyor who held fishing and hunting licences therefore undertook capture. Native turtles in Ontario are specially protected or listed as species at risk; thus all turtles used in the study were captive individuals procured from SNP with the permission of their animal care department.

The square enclosure was installed in a grassy area between a road and forest. The grass was cut within the enclosure to ensure ease of observation.

The trials were carried out in June and July of 2016, with the opposing sides of the fence enclosure switched halfway through the trials to reduce bias associated with the landscape and shadows cast by the sun. The trials were conducted whenever wild

individuals were available, and were therefore dependent upon weather conditions, with each individual caught at least 2 hours before the start of the trial. Snakes were released back to the same location within 24 hours and frogs within 12 hours. All the species used for these trials commonly inhabit the land within SNP. The number of individuals used for the study was dependent upon the number of unique individuals found within the local population, with a maximum of 20 individuals per group. To prevent repeated captures of the same individuals during surveying individuals were measured, sexed and subject to photo-recognition. Although one snake individual was used during two trials, it was considered that a one-month period between participations was a suitably long interval to prevent memory of the experience (Mauro & Jayne, 2016).

16 snakes, 20 frogs and 14 turtles were placed individually into the enclosure at corner where the mesh and solid plastic fences converged and monitored for one hour. Plywood sheets were deployed for cover near both corners where the mesh and solid plastic fencing joined, and a 1m² vernal pool was constructed at the center of the enclosure to offer shelter and replicate natural habitat as much as possible.

The wild individuals were captured in the least harmful way for the individual and the local ecosystem. Individuals were only handled when captured and being photographed. Any habitat that was disturbed during the capturing process, such as logs being turned over, was replaced. All wild individuals were hand-caught. The snake group included 15 different individuals, including one recapture of the most common snake in Ontario (the Eastern garter snake (*Thamnophis sirtalis*) (Logier, 1967)), and one Red-bellied snake (*Storeria occipitomaculata*). The frog group included 20 individuals. The study species represented two of the most common frog species in Ontario (Fisher *et al.*, 2007), and included 18 Green frogs (*Lithobates clamitans*) and two Northern leopard frogs (*Lithobates pipiens*). The captive-kept turtle group consisted of seven Midland painted turtles (*Chrysemys picta*) and seven Snapping turtles (*Chelydra serpentina*).

The time of day that each of the groups were studied varied based on the species' most active time of day, as follows. Although frogs are more active later in the day, limitations associated with the availability of natural light resulted in a slightly earlier time being used for this species group (Pechmann & Semlitsch, 1986; Todd & Winne, 2006).

The frog trials began 1/2 hour before sunset and ended 1/2 hour after sunset. Only one trial was conducted per 24-hour period.

Conversely each snake and turtle individual participated in two trials per day; one in the morning and one in the evening. As Edwards (2005) states, Midland painted turtles (*Chrysemys picta*) are most active between 10:00 and 19:00. Several tests were undertaken with the snake group to determine the hours most closely related to the temperature conditions that Peterson (1987) states. The chosen start times were between two and two and a half hours after sunrise and before sunset respectively.

During the trials the surveyor remained either on the opposite side of the enclosure to the observed animal or in a place where they would not be visible to reduce disturbance to the natural behavior of the herpetofauna. The only exceptions to this occurred when taking photos or videos to document the individual's behavior or to capture an individual if it escaped. All escapees were replaced at the same location inside the enclosure from where they escaped. The behavior and location of all the individuals was monitored and recorded once per minute.

For the purpose of this study any behaviors relating to the attempt of breaching the fences was recorded for all species groups and both fence types, which included actions such as climbing and digging. If any escapes were the direct result of design flaws, such as a result of fence collapse or via the use of fixings to climb the fence, these incidences were not recorded or analysed. This was because it was considered to be a consequence of the installation method rather than the type of material.

Some secondary behaviors were recorded that could result in delays to the safe movement of herpetofauna to wildlife crossing structures in real situations; such behavior was also recorded during the study. These behaviors were specific to each group and, in the case of the turtle and snake groups, relevant to each fence type. Each group behaved in a different way towards the mesh fencing: for the snake group it was observed that if they continuously tested the fence with their snout, it considerably delayed their movement along it. Regarding the turtle group, the amount of times that individuals walked along the mesh fence whilst testing it with their front limbs was recorded. The

frog group expressed the same type of behavior; jumping, in its interaction with both fences. The number of times that each individual jumped at each fence was recorded. In addition, the action of searching for cover in the shade of the solid plastic was recorded specifically for snakes and turtles as behavior only demonstrated towards solid plastic fencing. Such behavior was also recorded, as it is possible that the shade created by solid plastic fencing could also cause delay to the funnelling of herpetofauna safely to wildlife crossing structures. An individual was considered to be basking or searching for shade when they spent more than three minutes in the sun or shade respectively without moving during sunny weather.

The recorded location of the individual during the trial depended on which fence zone they were in. The fence zones were defined to be within 40cm of each fence line; everything outside of this was considered to lie between zones. Weather conditions, including air and ground temperatures, were also recorded at the beginning and end of each trial. The mean air and ground temperatures for each trial were subsequently calculated to determine whether these affected the results (Gibson & Falls, 1979).

After compiling the data, Microsoft Excel was used to calculate a correlation matrix for the studied variables: amount of time spent in each fence zone; number of fence breaches and climbing attempts; number of interactions with the fence; collected data with each studied individual; and climatic factors of each trial.

4. RESULTS

The study sought to observe the behavior of a range of herpetofaunal species to demonstrate which fence material is the most efficient type for road mitigation purposes. The aim was to test which fence type would result in delays associated with the safe funnelling of herpetofauna to wildlife crossing structures, whilst also observing the amount of escape attempts and physical interactions individuals demonstrated towards the two different materials. During the study, 20 wild frogs, 17 wild snakes and 14 captive turtles were studied within the mixed fence enclosure.

a. Time spent within each fence zone

As illustrated in Figure 1, the percentage of time for all groups spent in the mesh fencing zone exceeds that spent in the solid plastic zone and between the two zones. During the 82 hours observed, all groups spent 60% of the time within the mesh fencing zone, 18% within the solid plastic zone and 22% between both.

If the results are analyzed by group, turtles and snakes spent 56% of the time within the mesh fence zone. The turtles spent nearly twice as much time in the solid plastic fence zone than between the fence zones, whilst snakes demonstrated the opposite. In comparison, the frog group spent 73% of the time in the mesh fence zone and only 6% in the solid plastic zone. Once an individual frog reached the mesh fence it rarely left; it was observed to remain close to the mesh fence or seen to search for cover in the long grass.

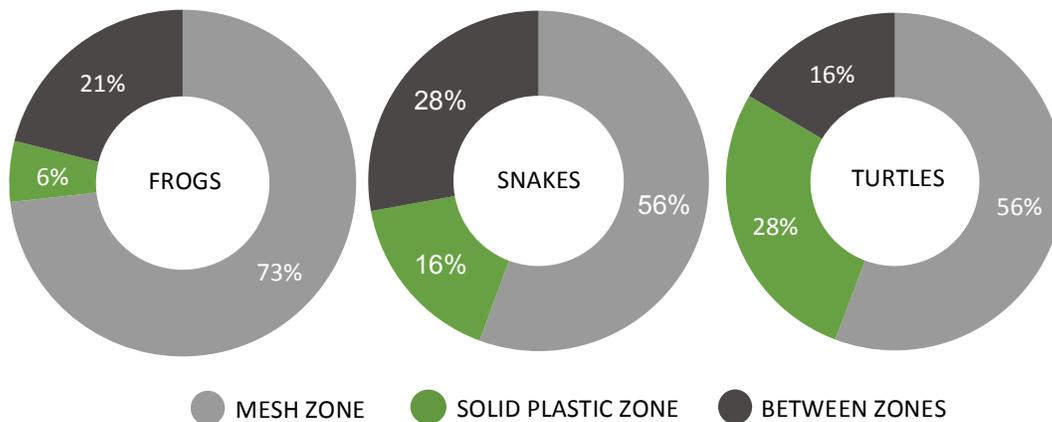


Figure 1. Percentage of time spent per zone relative to time spent in enclosure, per trial per group.

b. Physical interactions

To further understand the results, physical interactions with the two fence types were also observed. Each herpetofauna group expressed a different physical interaction with the fences relative to their natural style of movement. This was observed to determine whether this could result in physical harm or delay the movement of individuals in safely reaching a wildlife crossing structure. Figure 2 illustrates the specific physical interactions of each group towards the two types of fencing materials.

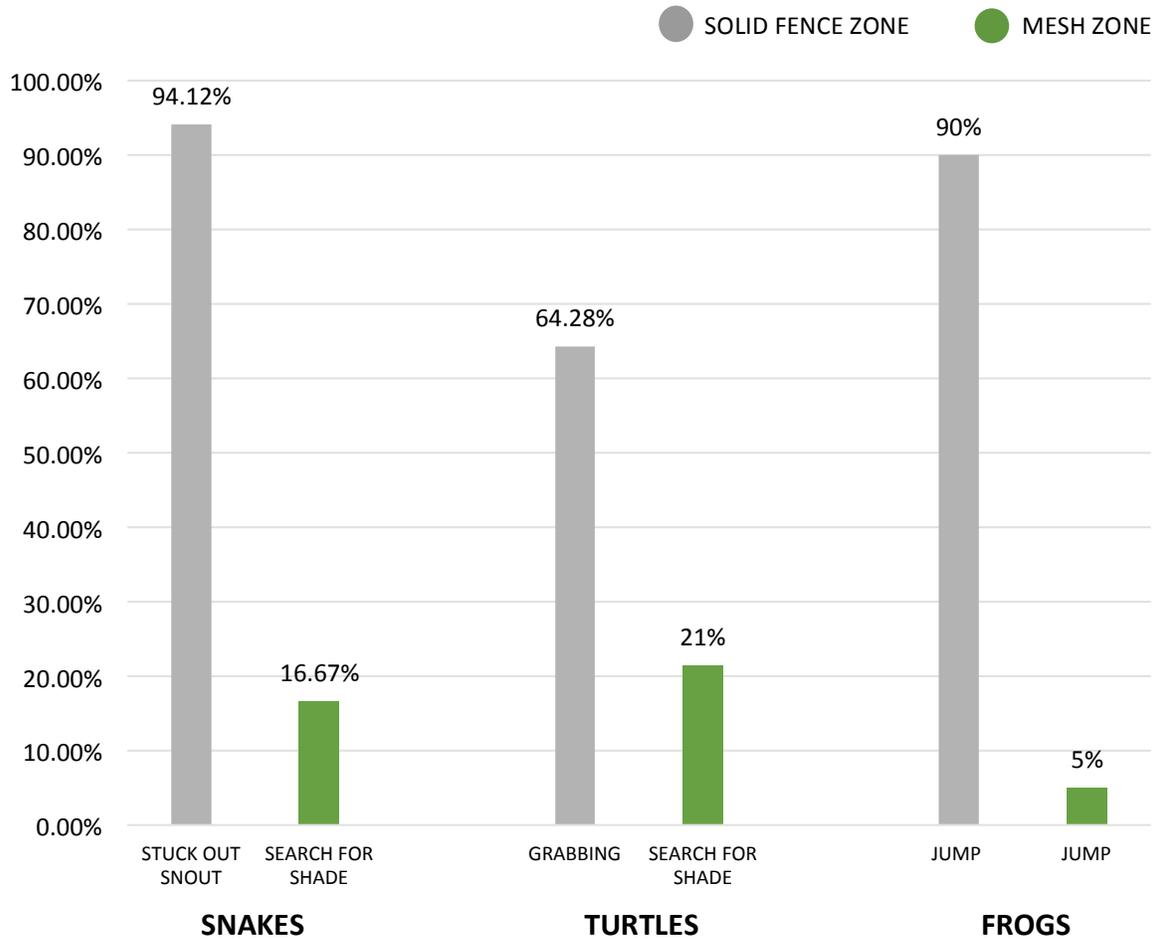


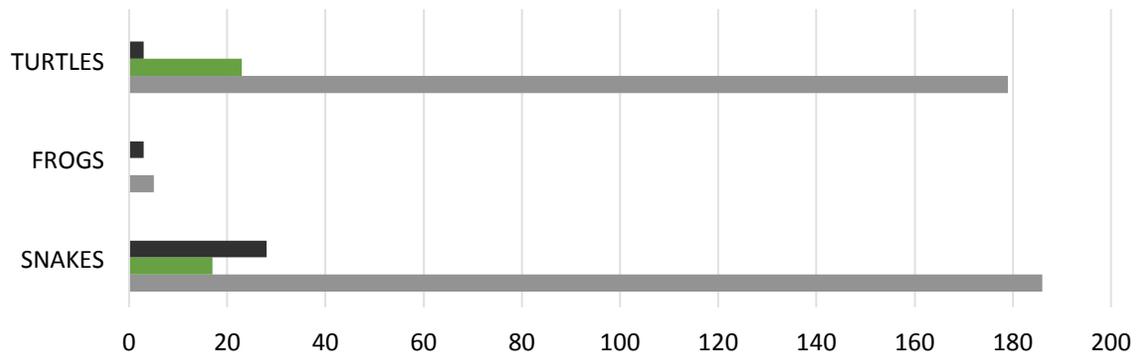
Figure 2. Summary of the behavioral interactions demonstrated by the herpetofauna towards each fence type.

In 64.28% of the turtle trials, the individuals were seen to test the mesh material by using their claws to grab the fence. In contrast, during 21% of the trials the turtles stayed three or more minutes under cover or in the shade cast by the solid plastic fencing. In the snake group such interactions only occurred in 16.7% of the trials, however in 94.1% of the trials snakes were seen to extend their snouts through the mesh fencing at least once. The biggest difference in the interactions between the two fence types was demonstrated by the frog group. Although frogs jumped at the solid plastic fencing in 5% of the trials, they jumped at the mesh fence in 90% of the trials. Further, when the frogs were released in the corner where the mesh and solid plastic fence zone converged, they immediately jumped at the mesh fencing in the majority of instances.

Finally, all study groups demonstrated greater than 40% more attempts to escape the mesh fencing by climbing or jumping at the fence as opposed to the solid plastic material.

c. Climbing and breaching the fences

As illustrated in Figure 3 all animals groups attempted to climb the mesh fencing more than the solid plastic material. Furthermore, Table 1 shows that in 7% of the trials the turtles attempted to climb the solid plastic fencing more than three times, whereas nearly 50% of the turtle and snake trials revealed they tried to climbed the mesh fence on at least three different occasions. All species other than Midland painted turtle successfully escaped over the mesh fencing (Table 1); however, no species successfully escaped over the solid plastic material. Moreover, in 34 hours of trials, three snakes escaped 28 times through the mesh whilst turtles, in 28 hours, and frogs, in 20 hours, escaped three times each. This resulted in 8.8%, 7.1 % and 10% of the trials respectively. The frog group was the only group that did not attempt to climb the solid plastic fencing.



| | TURTLES | FROGS | SNAKES |
|---------------------------------|---------|-------|--------|
| Escaped solid plastic | 0 | 0 | 0 |
| Escaped mesh | 3 | 3 | 28 |
| Attempts to climb solid plastic | 23 | 0 | 17 |
| Attempts to climb mesh | 179 | 5 | 186 |

Figure 3. Summary of the number of breaches / climbing attempts per fence type by herpetofauna group.

Table 1: Comparison between both fence types showing percentages of climbing attempts by herpetofauna group and breaches by species.

| Group | > 3 climbing attempts mesh fencing | > 3 climbing attempts solid plastic fencing | % of trials in which species successfully escaped mesh fencing | |
|---------|------------------------------------|---|--|------------|
| SNAKES | 47.1% | 0% | EAGA 6.3% | RBSN 50.0% |
| TURTLES | 50.0% | 7.1 | MPTU 0% | SNTU 14.3% |
| FROGS | 0% | 0% | GRFR 5.6% | NLFR 50.0% |

d. Correlations between behaviors and other variables

It was revealed that snakes are the herpetofauna group most likely to result in harm associated with the mesh fencing. If a snake’s body is a similar diameter to the gap between mesh strands then their head can get stuck; this occurred in 8% of the snake trials (Table 2).

Table2: A summary of the correlations between behavioral response, weather and herpetological group specific variables by each herpetofauna group.

| Correlation between behaviors and/or location | FROG | SNAKE | TURTLE |
|--|-------|-------|--------|
| Time in mesh fence zone (MIN) w/ time outside (MIN) | -0.93 | -0.91 | - |
| Head stuck in mesh fence with length of snake | - | -0.57 | - |
| Escape mesh fence w/ length of snake OR frog attempts to climb mesh | 0.83 | -0.56 | - |
| Time spent in mesh fence w/ sticking its snout out or testing mesh | - | 0.55 | 0.69 |
| Time spent within solid plastic fence zone w/ time in shade or cover | - | - | 0.52 |

Table 2 illustrates a strong negative correlation between the time snakes and frogs spent within the mesh fence zone and the time between both fences; however, there is no correlation with the amount of time spent in the solid plastic fence zone. Nevertheless, a moderate correlation can be observed between turtles spending time in the solid plastic fencing zone and trying to search for shade or cover. Where turtles and snakes tried to escape or test the mesh fence there is a moderate probability that they would spend more time near the mesh fence than the solid fence or in between the two. Despite during these trials the amount of time that the herpetofauna spent at the different fence zones was not correlated to the temperature, in the case of the snakes the amount of time spent between both fence types was moderately correlated to the mean air and ground temperatures.

In all cases of escape, the turtles and frogs climbed vertically up the mesh fence by clinging to the small gage wire fencing with their limbs, whereas snakes escaped through the 1/4" inch aperture between mesh strands. As Table 2 shows, the size of the snake correlates with successfully escaping the mesh or getting their head temporary stuck in it; consequently only the juvenile Eastern garter snakes and Red-bellied snakes were able to escape in this way.

5. DISCUSSION

To understand which fencing material is more effective as a mitigation measure for herpetofauna road mortality, we have to understand that turtles' and frogs' strongest sense is eyesight, whilst snakes' strongest sense is smell (Biersner & Melzack, 1966; Ernst & Ernst, 2003; Moldowan *et al.*, 2015). Multiple studies demonstrate how snakes follow chemical cues to find their hibernacula or food source. Mesh fencing allows chemical cues from conspecifics and food to diffuse across it; therefore a reptile is highly likely to try to persist along a mesh fence line, which could result in entanglement. Conversely solid plastic fencing would likely diffuse chemical cues, reducing the occurrence of reptiles following fence lines and therefore being encouraged to seek alternative routes or food sources (Lemaster *et al.*, 2000; Cooper Jr. & Perez-Mellado, 2001). Moreover, this research demonstrates that even though snakes and turtles tried to climb both types of fencing, they persistently tried to climb mesh fencing, whilst turtles only occasionally attempted to climb the solid plastic and at a lower frequency than the mesh. This could result in herpetofauna spending increased time attempting to breach mesh fencing rather than being guided to wildlife crossing structures. Hence, if herpetofauna take longer to reach wildlife crossings, potential risks from roads such as pollution, vibration, noise, illegal collection, predation, persecution and desiccation/dehydration due to the microclimate and the change of habitat close to the road could be increased (Ferronato *et al.*, 2014; Kimberley *et al.*, 2015).

The conclusions of this study correspond with Brennan *et al.*, (2005) in that solid fencing produces a microclimate, however the correlation for the turtles demonstrated in this study highlights that the amount of time individuals spend at the solid plastic fence depends upon the individual's necessity to find shade, or inversely to the amount of time they spent interacting with the mesh fencing. To reduce any study bias associated with

the impact of shade on the decision-making of the herpetofauna, the opposite fences were switched in the enclosure halfway through the trials for all study groups.

This study highlights the inefficiency of mesh fencing as a suitable mitigation measure for conservation due to the fact that turtles, frogs and snakes are all able to escape over or through it (Crosswhite *et al.*, 1999; Baxter-Gilbert *et al.*, 2015). Thus, this paper corresponds with the findings of Aresco (2005), Iuell *et al.*, (2011) and Baxter-Gilbert *et al.*, (2015) in that not all fence types are effective in road mortality mitigation. In contrast, this research conflicts with the findings of Baxter-Gilbert *et al.*, (2015), who concluded that plastic fences are easily breached by many reptile species, since none of the species studied in this experiment were able to escape the solid plastic fencing. It should therefore be noted that the type of plastic fencing and its design in this instance comprised specifically fabricated sheets of high-density polyethylene (*Animex*). The solid plastic is completely smooth, which appeared to prevent herpetofauna from gaining purchase, as well as preventing entanglement.

Since this study only used one gauge ($\frac{1}{4}$ inch) of steel mesh fence, further studies with other gauges and materials are recommended to effectively demonstrate whether herpetofauna would still demonstrate higher escape attempts associated with mesh rather than solid plastic fencing. Following the findings of this study, it is expected that herpetofauna would likely still expend more effort into escaping mesh fencing rather than solid plastic material regardless of the gauge size or material as they could still see and smell through it.

Interactions with the fence, time in each fence zone and breaching the fences were all related to each other. Therefore, if the herpetofauna spent more time near one fence they would have more interactions with it, increasing the possibility of finding a way to breach it or reducing the possibility of them safely reaching a wildlife crossing structure or being diverted into adjacent habitat. When a frog tried to climb the fence during the trial, there was a 60% probability that it would successfully escape over the mesh fence. This study therefore agrees with Kruidering *et al.*, (2005) and Clevenger & Huijser, (2011) in recommending the use of smooth plastic sheets rather than mesh materials in fencing for these species.

A number of studies do not correspond to the findings recorded at SNP; for example Langen (2011) concluded that mesh fencing is effective when used to reduce Herpetofauna road-kill. In contrast, however, the study was conducted with tortoises rather than freshwater turtles, with results also demonstrating that the number of road-kills would be reduced but not completely mitigated. In our study two out of seven Snapping turtles managed to escape over the mesh and one did so twice. Furthermore, one of these individuals was considered to be approximately the average size of a reproductive female (Congdon *et al.*, 1987).

Although the percentage of time spent at each fence type is closer with turtles than any of the other herpetofauna group, they still spent almost twice as much time within the mesh fence zone than the solid plastic fence zone. This highlights that herpetofauna would not be so easily encouraged towards a wildlife crossing structure by the mesh fencing as they would do by solid plastic fencing. This could cause collateral damage to some herpetofauna such as: getting their limbs stuck and escaping entanglement, harm associated with repeated jumping at the fence (as in the case of the frogs), as well as increased potential risks from being close to roads as previously explained.

Further study is recommended to determine whether herpetofauna would behave the same way if they were placed in front of a long fence line instead of within an enclosure. This would hopefully reveal whether the percentage of time spent within each fence zone would vary, or if interactions would correlate.

Colino-Rabanal & Lizana (2012) state that a fence designed for amphibians and reptiles to reduce mortality on a road is drastically needed. Using solid plastic fencing rather than mixed-construction materials such as geotextiles and mesh as mitigation measure for herpetofauna appears to be an appropriate and effective solution to this requirement. It should, however, be remembered that for any fence to be effective its installation must be carefully considered, with its effectiveness carefully monitored post-installation to ensure its ongoing effectiveness. Monitoring should cover not only structural integrity but also functional integrity (Kimberly *et al.*, 2015; Van der Ree *et al.*, 2015).

This study had some limitations, such as potential human error whilst correctly identifying which fence zones the herpetofauna were in. This was minimized by clearly marking the perimeter of the fence zones at the pre-determined distance of 40cm from each fence material.

This study monitored the same individual twice per day in the same enclosure; therefore, as would likely occur outside of the enclosure (Mauro & Jayne, 2016), some snakes appeared to be able to form short-term associations. To reduce this error during the analysis all the trials were collated, rather than separating the morning trials from the evening ones.

6. CONCLUSION

This study sought to investigate the behavioral responses of amphibian and reptile groups when interacting with two different types of commonly used exclusion and drift fencing: steel mesh (1/4 inch) and solid plastic (Animex). This study has demonstrated that herpetofauna spend increased time near to and/or express greater interest towards physically interacting with mesh fencing as opposed to solid plastic fencing. This concurs with Kruidering *et al.*, (2005) and Clevenger & Huijser, (2011) by highlighting that because the goal of exclusion fencing is not only to keep animals off roads, but also to funnel animals safely to wildlife crossing structures, mesh fencing is not an effective choice of fencing when compared to solid plastic. Herpetofauna are not as easily directed towards the wildlife crossings by mesh due to additional risk of injury, escape and delay. Hence, if herpetofauna take longer to reach wildlife crossing structures it could increase the potential risks associated with roads such as pollution, vibration, noise, illegal collection, predation, persecution and desiccation/dehydration due to the microclimate and the change of habitat close to the road (Ferronato *et al.* 2014; Kimberley *et al.*, 2015)

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8. REFERENCES

- a. Animex Fencing. 2016. [Cited 09 January 2018]. United Kingdom. Available from: www.animexfencing.com/about-us.
- b. Aresco M.J. Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a North Florida lake. *Journal of Wildlife Management* 2005; 69(2): 549-560pp.
- c. Association of Wetland Stewards for Clayoquot and Barkley Sounds. Announcing The SPLAT Project Amphibian Tunnel Blog. 2014 Oct 3 [Cited 09 January 2018]. Canada. Available from: www.splatfrogunnel.blogspot.co.uk/.
- d. Baker *S.J.*, Dreslik M.J., Wylie D.B., Phillips C.A. Sources of mortality in the endangered eastern massasauga (*sistrurus catenatus*) in illinois. *Herpetological conservation and biology*, 2015; 11(2): 335–343pp.
- e. Baxter-Gilbert J.H. The Long Road Ahead: Understanding Road-related Threats to Reptiles and Testing if Current Mitigation Measures are Effective at Minimizing Impacts. Unpublished Master thesis. Laurentian University, Sudbury, Ontario. 2014; Forthcoming.
- f. Baxter-Gilbert J.H., Riley J.L., Lesbarrères D., Litzgus J.D. Mitigating Reptile Road Mortality: Fence Failures Compromise Ecopassage Effectiveness. *PLoS ONE*. 2015;10(3): e0120537. doi:10.1371/journal.pone.0120537
- g. Biersner R., Melzack R. Approach-avoidance responses to visual stimuli in frogs. *Experimental Neurology*. 1966; 15 (4): 418-424pp.
- h. Brennan K.E.C., Majer J.D., Moir M.L. Refining sampling protocols for inventorying invertebrate biodiversity: Influence of drift-fence length and pitfall trap diameter on spiders 2005.
- i. Canadian Council on Animal Care. CCAC guidelines on: procurement of animals used in science, 2007. [Cited 09 January 2018]. Canada. Available from: www.ccac.ca/Documents/Standards/Guidelines/Procurement.pdf.

- j. Clevenger, A.P., M.P. Huijser. Wildlife Crossing Structure Handbook Design and Evaluation in North America. Department of Transportation, Federal Highway Administration, Washington D.C., USA. 2011.
- k. Colino-Rabanal V.J., Lizana M. Herpetofauna and roads: a review. *Basic and Applied Herpetology*. 2012; 26: 5-31pp.
- l. Congdon J.D., Breitenbach G.L., van Loben Sels R.C., Tinkle D.W. Reproduction and Nesting Ecology of Snapping Turtles (*Chelydra serpentina*) in Southeastern Michigan. *Herpetologica*. 1987; 43 (1): 39-54pp.
- m. Cooper Jr W.E., Perez-Mellado V. 2001. Location of fruit using only airborne odor cues by a lizard. *Physiology and Behavior*. 2001; 74(3): 339-432pp.
- n. Crowford B.A. and Andrews K.M. Drivers' attitudes toward wildlife-vehicle collisions with reptiles and other taxa. *Animal conservation*. 2016; 19(5): 444-450pp.
- o. Crosswhite D.L., Fox S.F., Thill R.E. Comparison of Methods for Monitoring Reptiles and Amphibians in Upland Forests of the Ouachita Mountains. *Okla. Acad. Sci*. 1999; 79:45-50pp.
- p. Dickman C. R. Fences or ferals? Benefits and costs of conservation fencing in Australia. *Fencing for conservation*. 2011; 43–63 pp.
- q. Ernst C.H., Ernst E.M. Snakes of the United States and Canada. China: Published by Smithsonian Institution; 2003.
- r. Ferronato B.O., Roe J.H., Georges A. Reptile bycatch in a pest-exclusion fence established for wildlife reintroductions. *Journal for Nature Conservation*. 2014; 22: 577–585pp.
- s. Fisher C., Joynt A., Brooks R.J. Reptiles and Amphibians of Canada. China: Published by Lone Pine; 2007.
- t. Frissell C., Trombulak S. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. *Conservation Biology*. 1999; 14 (1): 18-30pp.

- u. Gibson A.R., Falls J.B. Thermal biology of the common garter snake *Thamnophis sirtalis* (L.). I. Temporal variation, environmental effects and sex. 1979.
- v. Glista D.J., DeVault T.L., DeWoody J.A. Vertebrate road mortality predominantly impacts amphibians. *Herpetological Conservation and Biology*. 2007; 3(1):77-87pp.
- w. Horne B.D., Brawman R.J., Moore M.J.C., Seigel R.A. Reproductive and Nesting Ecology of the Yellow-Blotched Map Turtle, *Graptemys flavimaculata*: Implications for Conservation and Management. *Copeia*. 2003 (4): 729-738pp.
- x. Huijser M. P., Duffield J. W., Clevenger A.P., Ament R.J., McGowen P.T. Cost-benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada; a decision support tool. *Ecology and Society*. 2009; 14(2): 15pp.
- y. Iuell B., Bekker G.J., Cuperus R., Dufek J., Fry G., Hicks C., Hlaváč V., Keller V., Rosell C., Sangwine T., Tørsløv N., Wandall B. *Wildlife and traffic, A European Handbook for Identifying Conflicts and Designing Solutions*. UK: KNNV Publishers; 2003.
- z. Jackson N.D., Fahrig L. Relative effects of road mortality and decreased connectivity on population genetic diversity. *Biological conservation*. 2011; 144(12): 3143-3148pp.
- aa. Johnson R.J. G89-908 Controlling Snake Problems Around Homes. Historical Materials from University of Nebraska-Lincoln Extension. 1989.
- bb. Kimberley M.A., Nanjappa P., Riley S.P.D. *Roads and Ecological Infrastructure: Concepts and Applications for Small Animals*. Published in association with The wildlife society by Johns Hopkins university Press, Baltimore. Printed in Unites States of America; 2015.
- cc. Kruidering A.M., Veenbaas G., Kleijberg R., Koot G., Rosloot Y., Van Jaarsveld E. *Leidraad faunavoorzieningen bij wegen*. Rijkswaterstaat, Dienst Weg-en Waterbouwkunde, Delft, The Netherlands; 2005

- dd. Langen T.A. Design considerations and effectiveness of fencing for turtles: three case studies along northeastern New York state highways. Proceedings of the 2011 International Conference on Ecology and Transportation. In press. 2011; Forthcoming.
- ee. Lemaster M.P., Moore I.T., Mason R.T. Conspecific trailing behavior of red-sided garter snakes, *Thamnophis sirtalis parietalis*, in the natural environment. *Animal Behavior*. 2000; 61(4): 827 – 833pp.
- ff. Logier E.B.S. The snakes of Ontario. Royal Ontario Museum Division of Zoology and Palaeontology. 2nd ed. Canada: Toronto and Buffalo: University of Toronto Press; 1967.
- gg. Long K., Robley A. Cost Effective Feral Animal Exclusion Fencing for areas of high conservation value in Australia, The Department of the Environment and Heritage [Online]. 2004. Available from: www.environment.gov.au/system/files/resources/b39c119e-c58a-4473-9507-db68da31a95c/files/fencing.pdf. [Cited 09 January 2018].
- hh. Mauro A.A., Jayne C.B. Perch compliance and experience affect destination choice of brown tree snakes (*Boiga irregularis*). *Zoology*. 2016; 119 (2): 113-118pp.
- ii. Moldowan P.D., Keevil M.G., Mills P.B., Brooks R.J., Litzgus J.D. Diet and Feeding Behavior of Snapping Turtles (*Chelydra serpentina*) and Midland Painted Turtles (*Chrysemys picta marginata*) in Algonquin Provincial Park, Ontario. *The Canadian field-naturalist*. 2015; 129: 403-408pp.
- jj. Pechmann J.H.K., Semlitsch R.D. Diel activity patterns in the breeding migrations of winter-breeding anurans. *Canadian Journal of Zoology*, 1986; 64(5): 1116-1120pp.
- kk. Peterson C. R. 1987, Daily Variation in the Body Temperatures of Free-Ranging Garter Snakes. *Ecology*, 68 (1): 160–169pp.

- ll. Rytwinski T., Soanes K., Jaeger J.A.G., Fahrig L., Findlay C.S., Houlihan J., Van der Ree R., Van der Grift E.A. How Effective Is Road Mitigation at Reducing Road-Kill? A Meta-Analysis. PLOS ONE. 2016; 11(11): e0166941. doi:10.1371/journal.pone.0166941.
- mm. Roe J.H., Gibson J., Kingsbury B.A. Beyond the wetland border: Estimating the impact of roads for two species of water snakes. Biological conservation. 2005; 130 (2): 161-168pp
- nn. Scales Nature Park 2018. [Cited 9 January 2018]. In Canada. Available from: www.scalesnaturepark.ca.
- oo. Todd B.D. & Winne C.T. Ontogenetic and interspecific variation in timing of movement and responses to climatic factors during migrations by pond-breeding amphibians. Canadian Journal of Zoology. 2006; 84(5): 715-722 pp.
- pp. TWP. 2014. [Cited 03 April 2017]. Choose your mesh by project. Snake control mesh. Available from: www.twpinc.com/wire-mesh-by-project/pest-control/snake-control-mesh.
- qq. Van der Ree R., Smith D.J. and Grilo C. Handbook of road ecology. Uk: Published by John Wiley & Sons.LTD; 2015.
- rr. Walmsley H. 2015. [Cited 09 January 2018]. Conservation fences killing native species at Mulligans Flat in Canberra's north. Australia: Published by ABC News. Available from: www.abc.net.au/news/2015-02-17/trapped-reptiles-at-mulligans-flat/6126630.
- ss. Waltz H.W., Gibs J.P., Ducey P.K. Road crossing structures for amphibians and reptiles: Informing design through behavioral analysis. Biological conservation. 2008; 141 (11): 2745-2750 pp