Action: Creating overpasses and underpasses to influence species richness

Key messages

- While flying animals have previously been overlooked in overpass effectiveness studies, one study focusing on bats[2] and two studies focusing on birds[3,6] have revealed that species richness of bats and birds differ between overpasses and surrounding forests. Some species were not observed crossing the open road and only crossed using the overpass.
- One study focusing on birds[3] found that larger birds (mean weight of 110 grams) more commonly crossed the open road, but smaller birds (mean weight 15 grams) were more likely to cross using the overpass. Species that are known to inhibit the forest interior were also detected using the overpass.
- One study in Australia[4] found that rope bridges effectively act as overpasses for strictly arboreal species. However, when the use of the rope overpasses was compared to the use of a nearby natural canopy crossing, it was determined that the natural canopy was preferred to the man-made overpass.
- In Queensland, Australia, a one-lane road was upgraded into a two-lane road with four underpasses. A study[5] found that the overall roadkill declined, but a greater number of rainforest bird species were killed on the road in the year following the upgrade.
- Two studies, one located in Poland[1] and one in Australia[8], have found that invasive and non-native species are often the first to use an overpass or underpass and are commonly found on the crossing structure thereafter. These species included the European hare *Lepus europaeus*, the house dog *Canis lupus familiaris,* and the house cat *Felis catus*.
- One study in Banff National Park[9] determined that structural attributes of overpasses and underpasses were correlated with the use by different species. Grizzly bears, wolves, and elk favored tall, wide, and short crossing structures, while black bears and pumas preferred more constricted structures.

Background information

As the world continues to develop, more roads and highways are constructed to facilitate easy access to developing areas. While roads are essential to economic development and infrastructure expansion (Malkoc 2019), they can pose detrimental consequences to the wildlife that inhabit the area in which it is built. Habitats are fragmented when roads are constructed through them, which can create barriers to animal dispersal (Pell 2016). Roads can disrupt the movement of animals by preventing daily passage between forest fragments and negatively impacting seasonal movement patterns (Benitez et al. 2010). Animals that reside in close proximity to roads also face the direct threat of road mortality due to collisions with vehicles (Coffin et al. 2007). All of these issues caused by road construction, including roadkill, habitat fragmentation, and movement barriers can lead to the separation and isolation of animal populations on either side of the road. The persistence of this separation of animal populations can threaten the health and longevity of these populations (Pell 2016). Often the ecological effects caused by roads depend on the taxa of species living near the road, the level of traffic on the road, and the structure and dimension of the road (Garcia-Gonzalez 2012). The negative effects of fragmentation caused by roads and highways on wildlife populations have been recognized, but little action has been made in order to mitigate these ecological impacts (Glista et al. 2009). However, these ecological concerns have gained greater recognition in recent years, and methods to mitigate these issues have become a major area of research (Fahrig et al. 2009).

Governmental agencies, road authorities, and environmental advocates have recently become interested in designing and constructing various structures that will allow the safe passage of animals under or over roads. These structures are usually fauna underpasses and overpasses and have increasingly been incorporated into plans to build new roads or upgrade old roads (Mata et al. 2008). Fauna overpass and vegetated land bridges are the largest of these crossing structures (Beckmann et al. 2010). Even though overpasses are the most structurally challenging (Beckmann et al. 2010) and expensive of the crossing structures to build, they have become abundant throughout the world (Corlatti et al. 2009). Vegetated overpasses and underpasses are a favorable form of crossing structure because they present the potential to create continuous transitions between habitats bisected by roads (Jones & Pickvance 2013).

In the United States, Australia, and Europe, especially in France which has erected over 200 overpasses, overpass crossing structures have become common practice for mitigating the negative effects of roads (Corlatti et al. 2009). Likewise, vegetated underpasses, such as tunnels or culverts underneath roads, have become an increasingly popular method of mitigating road effects (McCollister & Van Manen 2010). The goal of both of these crossing structures is to reduce road mortality, remove barrier effects created by roads, and allow movement of species between fragmented habitat areas to enable gene flow within a population and increase species richness (Pell 2016). Although overpasses and underpasses have become increasingly used, studies to measure their effectiveness at improving connectivity between fragmented habitats have not become common practice (Mata et al. 2008). It is critical that more research and evaluation is done on the effectiveness of wildlife crossing structures such as overpasses and underpasses, as they cost a large amount of money, time, and effort to construct (Corlatti et al. 2009).

Supporting Evidence from Individual Studies

1. A 50 meter wide by 225 meter long overpass was constructed over an expressway in central Poland (Krauze-Gryz & Gryz 2016). Immediately after the completion of the overpass, a six-month-long study was performed to determine which species of medium and large mammals crossed the overpass and how long after completion animals began to cross it. The overpass was surveyed every two weeks, and the tracks of eleven different species of medium and large mammals were detected. During the first survey, five species were detected: European hare *Lepus europaeus*, Red fox *Vulpes vulpes*, House cat *Felis sylvestris catus*, House dog *Canis familiaris*, and Roe deer *Capreolus capreolus*.

Wild boar *Sus scrofa* tracks were found on the second survey, Martens *Marten spp.* tracks on the fourth, moose *Alces alces* tracks on the sixth, Red deer *Cervus elaphus* on the seventh, European badger *Meles meles* tracks on the eighth, and Fallow deer *Dama dama* tracks on the ninth survey (5 months after overpass completion). European hare tracks were most numerous at five tracks found per survey, but Red fox tracks were recorded at every survey. Tracks of the European hare, Red fox, House dog, and Roe deer were most frequently recorded per survey. Tracks of all species of ungulates and lagomorphs that live in the surrounding habitat were recorded on the overpass. Tracks of the Red deer were only recorded once. Tracks of all eleven species were found within six months of the completion of the overpass.

2. A vegetated overpass was constructed over a four-lane road in Brisbane, Queensland, Australia (McGregor et al. 2017). A seven-month-long study was performed in order to evaluate the effect of the 70 meter long by 20 meter wide overpass on microbat species in the surrounding habitats. During two consecutive nights of each of the seven months, eight transects were walked while bat echolocation calls were recorded and later used to determine the species that made the calls. The walking transects were either "road transects," located at the unvegetated roadside near the overpass, or "overpass transects," located at the roadside near the overpass. Two stationary points were monitored at the apex of the overpass to determine species richness on the overpass. In total, nine different microbat species were identified, along with two "species groups" that contained calls that could not be narrowed down to a single species. While the species richness of the overpass and the forest were equal at eleven different bat species, more bat activity was detected on the overpass than in the surrounding forest areas. On the overpass, 726 total calls were detected, while only 379 and 402 calls were detected in the forest on either side of the overpass. Also, higher bat activity and species richness were found at the roadside where the overpass was located than at the unvegetated roadside.

3. A two-year-long study took place in Brisbane, Queensland, Australia, in order to evaluate the effects of a vegetated overpass on the species richness of birds crossing a four-lane road (Jones and Pickvance 2013). Birds used the overpass by crossing the road either within the foliage of the overpass or by flying above the overpass. The species of birds observed crossing the open road varied from the species that crossed over the overpass. Significantly more bush bird species flew over the overpass than the road. Of the 31 species recorded crossing using the overpass, 22 of these species were not recorded crossing the open road. Statistically greater species richness was observed of the birds crossing the overpass than over the road; two times as many species were detected crossing with the overpass. Larger birds with a mean weight of 110 grams crossed the open road, while smaller birds with a median weight of 15 grams crossed the overpass. Bushland species most frequently used the overpass. Species that are regarded as being

sensitive to disturbances were detected using the overpass, as well as species that inhabit the forest interior.

4. In the rainforests of Queensland, Australia, two types of rope overpasses were set up over a two-lane road to provide a crossing method for arboreal rainforest species (Goosem et al. 2005). The first type of overpass was a 50 x 50 centimeter rope tunnel that was 14 meters long and at the height of 7 meters above the road. The second overpass type was a rope ladder. Two ladders were created, one with a width of 50 centimeters and the other with a width of 25 centimeters. To determine which species used the rope overpasses, scat and hair were collected. A collection net caught scat falling from the rope tunnel, while a PVC pipe caught scat from the rope ladders. Tape was used to collect hair from the animals using the rope overpasses. Infrared cameras were periodically set up on the overpasses. The study focused on eight arboreal species, including ringtail possum species, other arboreal possum species, the tree-kangaroo, and melomys. After five years of monitoring, all target species were found using at least one of the rope overpasses. However, when the use of the rope overpasses was compared to the use of a natural canopy crossing, it was determined that the natural canopy was preferred. Although, most species used the rope overpasses when no natural crossing was available. It was five months after the competition of the overpasses before any animals were pictured using the overpasses.

5. A one-lane road was reconstructed into a two-lane road, and four faunal underpasses were built underneath the road in Queensland, Australia (Goosem et al. 2005). The structure of the underpasses included steel arches that were 2.4 meters tall and 3.7 meters wide at the base with concrete floors covered with soil, leaves, and branches. The underpasses included poles and ropes designed to provide protection for smaller species. Researchers compared the amount of roadkill found before and after the reconstruction of the road. Before the reconstruction, the most common species to be found as roadkill were feral and grassland species, and rainforest species almost never were. After the construction, there was a decrease in the number of grassland amphibian casualties seen, but an increase in the number of rainforest bird species casualties. This increase in fatalities of rainforest bird species was seen one year after road reconstruction but then decreased the following year. Even though the road more than doubled in width, the inclusion of the underpasses led to an overall decrease in average weekly road mortality; 70 pre-reconstruction, 56 in the first 12-month period, and 43 in the second 12-month period. Sand tracks and infrared cameras were used to determine which species were using the underpasses. Bandicoots and pademelons, both of which are rainforest species, were most often observed using the underpass. The brushtail possum, rodents, brush turkeys, and feral cats were also a common occurrence in the underpass.

6. A one-year study was performed on a 15 meter overpass over a four-lane road in Brisbane, Australia (Pell 2016). Sixteen nine-hour observations were conducted in order to compare bird species composition on the overpass and in the surrounding forests. Also, the bird crossing rate at the overpass was compared with the bird crossing rate over a 20 meter and a 90 meter road. The main species groups that crossed the road using the overpass included small forest insectivores and honeyeaters, 1.17 and 0.94 crossing per hour, respectively. Large forest insectivores crossed less often at 0.27 crossing per hour, and generalists rarely crossed at 0.03 crossings per hour. Birds could cross the road using the overpass in two different methods: either through the foliage or flying at canopy height. Small forest insectivores were only found crossing within the foliage, while honeyeaters and larger insectivores used both methods. Seven of the 13 species of small forest insectivores that were observed crossing via the overpass were never observed crossing the open road. Species richness was significantly higher on the overpass than in the neighboring forests, an average of 2.5 species/ten-minute survey on the overpass and 1.7 species/ten-minute survey in the forests. When comparing the number of species that crossed at the overpass (2.19 species/hour) with the number that crossed the open road (2.50 species/hour), no significant difference was found. However, there were significant differences in which species groups crossed the overpass and open road. For instance, large forest insectivores were more likely to cross the open road than use the overpass.

7. A study was conducted looking at the effectiveness of the overpasses and underpasses of a four-lane road in Brisbane, Australia (McGregor 2016). The road has one overpass, two underpasses, and arboreal overpass ladders. This study used animal trapping, cameras, sand tracking, and bat call recording to compare the species composition of the surrounding forest and the crossing passages. Overall, 90 species were identified in the forest. It was determined that 100% of the bat species, 70% of the mammal species and 74% of the herpetofauna species found in the forest used the overpass, while only 45% of the mammal species and 13% of the herpetofauna species used the underpass. A total of 29 herpetofauna species were observed on and within one kilometer of the overpass, while ten of these species were found only in the forest and not on the overpass. 60% of the herpetofauna species were observed using the overpass, and species diversity of the overpass was not significantly different from species diversity of the forest. Each year an average of 2.2 new species began using the overpass. Species richness of bats on the overpass was higher than in the forest. The earliest species observed using the passages were invasive species, including the European hare *Lepus europapaeus*, which was the first animal seen on the overpass.

8. In Victoria, Australia, a 70 meter wide underpass was constructed under a freeway (Abson & Lawrence 2003). A 12-month study took place to determine the species

richness of the animals using the underpass compared with that of the surrounding forest. Sampling methods included direct observation, audio recordings, trapping, and collection of hair and scat. A total of 116 different species, including reptiles, amphibians, birds, and mammals, were detected in the study area, with 79 of these species found using the underpass. While it was not expected for possums and gliders to use the underpass, four of the seven total detected species in this group were found using the underpass. The authors suggest that the inclusion of rope bridges in the vegetation would allow for greater use of the underpass by arboreal species such as gliders. Only 59 percent of the observed bird species were seen using the underpass, while 86 percent of amphibians, 100 percent of macropods, and 63 percent of observed reptiles were seen in the underpass. Three commonly detected mammals using the underpass were non-native predators, including cats *Felis catus*, dogs *Canis lupus familiaris*, and foxes *Vulpes vulpes.* However, an analysis of the scat of these predators showed that they are not only preying on species found in the underpass, but also on species not found in the underpass, indicating that their hunting is independent of the underpass.

9. A 34-month study examining 13 wildlife crossing structures in Banff National Park, Alberta was performed to determine which attributes of crossing structures were correlated with the use of these structures by specific species and species groups (Clevenger & Waltho 2004). These wildlife structures included 11 underpasses of varying structural attributes and size and two 50 meter wide overpasses. Tracks left in sand strips at the ends of each crossing structure were used to determine which species used them. For black bear *Ursus americanus* use of the passages, structural attributes that were positively correlated included distance to nearest drainage and structure length, while structure openness was negatively associated. For grizzly bears *Ursus arctors*, wolves *Canis lupus*, elk *Cervus elaphus*, and deer *Odocoileus* sp., crossing structures that were tall, wide, and short in length encouraged passage. Crossing structures with more constricted attributes were favored by black bears and cougars *Puma concolor.* The highest correlated attribute that was associated with cougar usage was the distance to coverage, which was a negative correlation. The results also reveal that human presence at the crossing structures was not as correlated with the passage of certain species as the structural attributes of the crossing structures.

Conclusions and Recommendations

Overall, overpasses and underpasses appear to be effectively used by a large proportion of the species present in a habitat fragmented by a road. The inclusion of rope bridges should be considered when designing a new crossing structure, as this allows arboreal species that would not cross over the ground surface of the overpass or underpass to cross the road (Goosem et al. 2005). Before a new crossing structure is constructed, extensive studies should be done on the species composition of the surrounding forests, so that any changes in species richness caused by the implementation of the crossing structure can be calculated. When evaluating the effectiveness of an overpass or underpass, it is important not to exclude flying species such as birds and bats, as their tendency to cross a road can be impacted by a crossing structure (Pell 2016, McGregor et al. 2017). Invasive and non-native species make use of the crossing structures, so these species need to be closely monitored when a new overpass or underpass is constructed (Krauze-Gryz & Gryz 2016, Abson et al. 2003). If multiple crossing structures are being built for a road, then varying the structural attributes of each overpass or underpass would allow for a greater number of species to cross the road, as species have different preferences for the structure of the overpass or underpass (Clevenger & Waltho 2004). However, if only one crossing structure is being constructed, then an overpass should be constructed if financially feasible because a greater number of species were observed crossing an overpass than an underpass on the same road (McGregor 2016).

Supporting Studies

1. Krauze-Gryz, D. & Gryz J. (2016) Evaluation of a new wildlife overpass on S7 expressway (central Poland). *Annals of Warsaw University of Life Sciences – Forestry and Wood Technology*, 94, 224-230.
2. McGregor, M., Kelly, M., & Jones, D. (2017). Vegetated Fauna Overpass Disguises Road Presence and Facilitates Permeability for Forest Microbats in Brisbane, Australia. *Frontiers in Ecology and Evolution*, 5: 153.
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