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Evaluating the Success and Monitoring the Usage of Wildlife Crossing Structures in Bedminster, NJ

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Abstract

Expanding road networks are detrimental to the populations of many reptile and amphibian species. The fragmenting of the landscape creates barriers, separating the populations of native organisms from the necessary resources. Wildlife crossing structures can be beneficial in aiding the movement of amphibians and reptiles across previously installed wildlife crossing culvert in Bedminster, New Jersey. The wildlife crossing culverts are located underneath River Road, which forms a barrier between the woods on one side of the road and the ponds on the other side. We used a combination of wildlife cameras and pitfall traps to determine the usage and success of the wildlife crossing culvert during a peak migration period of amphibians and reptiles. From March 31, 2017 through June 13, 2017, pitfall traps and wildlife cameras were monitored daily to determine the successful usage of the wildlife crossing culvert during migrations from the woods to the breeding ponds, and then returning from the breeding ponds to the woods. During this time period a total of 102 animals were found utilizing the wildlife crossing culvert. The cameras and pitfall traps revealed that the wildlife crossing culverts were most commonly used by amphibians, reptiles and small mammals when migrating to or from the woods and ponds. This study found the most effective method of monitoring usage of the wildlife crossing culvert was a combination of time-interval cameras and pitfall traps in a structure which is accompanied by angled fencing, directing the organisms into the culvert. Cameras were most effective in monitoring the larger amphibians and larger mammals, while pitfall traps were more effective in monitoring smaller amphibians and mammals.

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by

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Introduction

Roads have a detrimental effect on ecosystems. As the global population increases, the road network increases. From 2000 to 2010 the United States population increased from 281.4 million people to 308.7 million (Sullivan and Yen 2013). In these ten years alone, twelve million kilometers of road networks needed to be paved due to this increase in population (Mandle et al. 2015). As population increases, more road networking is established to continue connecting people to necessary resources. Between 1942 and 2010, road density nearly doubled (from 0.67 km/km^2 to 1.22 km/km^2) (Newman et al. 2014). While expanding road networking, forest and wildlife habitat were fragmented. This ultimately alters the structures and functions of ecosystems (Newman et al. 2014). In a study done in Turkey, researchers used geographical information systems (GIS) to note the structure of land use and land cover of Istanbul. The study documented the impacts of expanding urbanization on the dynamics of land use and land cover patterns in Istanbul. Although the population continued to increase over the last 31 years, reforestation has increased the forested areas by 5387.3 hectares. In order for the reforestation to be successful, the configuration of the land needs to remain less fragmented (Cakir et al. 2008).

An estimated 15-20% of the United States was impacted by the building of roads through ecological habitats (Foreman and Alexander 1998). While roads function as barriers and affect many species, amphibians and reptiles are particularly vulnerable (Pontoppidan and Nachman 2013). More than 65% of the total recorded road mortalities consist of amphibians (Beebee 2013). When new roadways are built, they are constructed through habitats that can be common to both amphibians and reptiles. Therefore, the likelihood of road mortality increases for these animals because they are likely to be found crossing roadways to access neighboring habitats.

Amphibian and reptiles' habitats are found throughout wetlands and aquatic-terrestrial ecotones. They use these areas to mate and lay their eggs. The roads act as barriers, preventing amphibians and reptiles from accessing necessary resources while also separating them from their local population (Patrick et al 2010). When a roadway is constructed to alleviate traffic build up, its effects to wildlife habitat are frequently not considered. Although environmentalists survey the land prior to and post constructing roadways, its effects on its surrounding habitats may not appear immediately. After construction of new roadways, it can take years to recognize patterns of negative impacts on surrounding habitats (Foreman & Alexander 1998).

Susceptibility of amphibian and reptile road mortality

It is important to understand how roads affect the connectivity of the surrounding populations. Road are ecological barriers which inhibit the movement of wildlife among habitats (Downs and Horner 2012). When a new roadway is constructed within their habitat, amphibians and reptiles become at risk for road mortality. The roadway divides their habitat into isolated area. In order for amphibians to reach the other side of their habitat, they must cross the newly developed roadway.

Amphibians often migrate in masses or at similar times to breed. They often cross in large quantities, making the population as a whole, more at risk for road mortality (Gibbs and Shriver 2005). During peak migration seasons, male and female amphibians move to mate and lay their eggs (Langen et al. 2007). Amphibians survive in both wetlands and forests so it is necessary to migrate to alternate breeding grounds in water (Sutherland et al 2010). For example, *Anaxyrus americanus* (American toad) and *Lithobates sylvaticus* (green frog) move toward breeding ponds from their habitat in wooded and wetland areas between March and April depending on the temperature and rainfall (Arnfield et al. 2012). These migration routes are often intercepted by road network systems. Due to the necessity to migrate across the road surface, amphibian and reptile populations have been declining due to road mortality (McCollister and Van Manen 2009).

Urbanization and Land use effects on amphibians

Sutherland et al. (2010) studied the relationship between amphibians and road traffic. They collected data by following toads and frogs and recorded their encounter rates with road traffic. By studying varying degrees of urbanization, they found that as urbanization increased, amphibian mortality decreased. Their conclusion was that urbanization causes a depletion of suitable habitats, moving amphibians away from these areas in the first place. Amphibians do not populate urban areas because they would not thrive there successfully (Sutherland et al. 2010). Traffic stimuli such as noises and lights also drive amphibians away from urban areas due to high-volume traffic on the roadways (Pontopidan and Nachman 2013).

Sutherland et al. (2010) studied road mortality rates of amphibians specifically in urban areas. Results showed an overall decrease in road mortality with an average road mortality rate of 2 amphibians per day along a 100-km segment of road in areas where there was at least 2,048 vehicles per day. This rejected their original hypothesis that as more roads were built, an increase in road mortality of amphibians would occur. Although these numbers were lower than expected, amphibians were found to not populate urban areas regularly. Urban areas were less inhabited by amphibians because they were not suitable for amphibians to thrive. The decreased road mortality rates of amphibians in their study may be a result of the lack of amphibians existing in this area in the first place (Sutherland et al. 2010).

Sutherland et al. (2010) also compared road mortality rates in already amphibian-populated areas with road mortality rates in urban areas. Results in these amphibian-populated areas showed a positive correlation between new road construction and road mortality rates. Although these amphibian habitats may be less congested with road traffic, road mortality rates still increased in areas populated by amphibians where new roads were constructed. Data showed a mortality rate of 35 amphibians per 100 km in areas where there was less than 535 vehicles per day. These populations are at risk to decline as a result of increasing road mortality. The construction of roads in these areas impacts the large populations of amphibians inhabiting these locations (Sutherland et al. 2010).

<u>Construction of wildlife crossing structure for mitigation</u>

Wildlife crossing structures, such as culverts, can be a successful approach to preventing road mortality among migrating species (Bouchard et al. 2009). By providing wildlife crossing culverts, road mortality during peak migration waves can be greatly reduced (Dodd Jr. et al. 2003). Prior to installing a wildlife crossing structure, the first necessary step for a successful road mitigation is to determine target animals that is susceptible to road mortality and identify its highest migration period to ensure effective monitoring methods (Beebee 2013). For example, some species migrate annually in masses. Some peak migration periods take place during the early spring while others take place at the end of the spring season. Next, it is import to locate the "hot spots" or more frequented areas where the animals are crossing (Patrick et al. 2010). If it is too costly to mitigate the entire road network, focusing resources on parts of the road that are the most susceptible to animal mortality makes it easier to target those specific areas (Beebee 2013).

Another factor to be considered prior to creating the structure is predation. Pagnucco et al. (2011) studied animals within a culvert and documented impacts of predation. In their study, predation was not a reoccurring issue. The salamanders and snakes within their study were generally separated for short periods of time, which eliminated their concern for predation. The study documented approximately 2,000 crossing events where multiple species utilized the culverts with no instances of predation. This study suggested that predation is not likely to be a problem with the crossing culverts (Pagnucco et al. 2011). Once the focus animal is determined, as well as the location of its "hot spot" for migration purposes, the final step is the construction of the wildlife crossing structure. Not all wildlife crossing structures are suitable for all animals, and construction on poorly chosen sites will be ineffective (Downs and Horner 2012). When designing a wildlife crossing structure, it needs to be dependent on the animals which will be utilizing the space the most. There are many factors that must be considered when constructing a wildlife crossing structure. The culvert design should be as closely matched to the surrounding area and as natural and realistic to the surrounding landscape as it can be. The importance of creating a natural and realistic structure is vital for all animals utilizing the culvert (Beebee 2013). It is important to ensure the surrounding areas of the structure create a comfortable and safe zone for the animals. To make these structures more realistic and comfortable for the focus animals, vegetation can be added near the entrance of the culvert to depict a realistic setting for animals utilizing the culverts as a safe crossing passage (Dodd et al. 2003). Adding grates or open areas on the culvert to allow natural light helps to give the culvert a more realistic natural effect as well (Beebee 2013). Additionally, the structure's shape and size must be considered prior to construction (Beebee 2013). Larger animals require larger structures.

By selecting the proper size of the structure for the focus animal, the proper size will help make the culvert the most natural feeling. The shape will also determine the effectiveness of the structure. Both round and square shapes structures can be beneficial for different types of animals (Dodd et al. 2003). Moreover, species are also specific to certain substrates that reflect their natural landscape (Beebee 2013). Using a substrate that is the same as the surrounding area will make it more convincing for the animal to utilize the crossing structure. Some species require water in the culvert but this is not the case for most animals. If the culverts contain water, animals will not be as likely to utilize them since this is not necessary for most animals that would benefit from a culvert structure (Cunnington et al. 2014).

In order to create the most effective use of the culverts, the focus animal must locate the culverts first. When the structure blends into its surroundings, animals may not recognize this as a pathway to the other side of the road. The most effective way to direct the animals into the culverts is through exclusion fencing (Aresco 2003). This fencing goes along the road at a height that is suitable for the focus animal (Pontoppidan et al 2013). If the animal can climb over the fence or escape through the fence, then the fencing is not effective resulting in a chance for increased road mortality (Baxter-Gilbert et al. 2015).

Additionally, weather, erosion or animals can change the landscape and destroy the fencing. Therefore, the fence needs to be maintained or repaired to prevent any future animals from passing through it. To maintain the effectiveness of the fencing, it needs to be monitored on a regular basis (Dodd et al. 2003).

<u>Wildlife Crossing Project along River Road at Bedminster, NJ</u>

River Road is a two-lane road that follows an intersection where three major highways end, causing an increased amount of traffic down the road (B. Zarate, personal communication, 2016). The road was initially built through an already established ecosystem dividing the wooded area from the ponds. In 2010, the Township of Bedminster recognized a significant number of wildlife deaths on River Road; in spring 2015, the Township finalized the installment of five wildlife-crossing culverts under the road. These culverts were installed as proficient migration pathways for local animals to safely cross under the two-lane road. In addition to installing wildlife-crossing structures, the Township of Bedminster implemented exclusion fencing as part of the mitigation measure. This implementation strategy helped funnel surrounding species crossing the road to utilize the underground culverts. This mitigation approach proved success by guiding amphibians and reptiles to the mouth of the wildlife culverts instead of engaging onto the two-lane roadway. The overall goal of this study was to determine the usage and success of wildlife crossing structures at River Road in Bedminster, New Jersey.

Methods

Study Site

This study was conducted along River Road in Bedminster Township, New Jersey in the spring of 2017. Bedminster Township consists of 37% agricultural land, 37% forest land, 6% wetlands, 1% water, and 18% urban (Kratzer 2010). Following an intersection of three major highways is River Road, a two-lane road running through Stahl Natural Area. Stahl Natural area is made up of 183.5 acres bordered by the North Branch of the Raritan River. There are wetlands located to the south of River Road which provide a habitat for a variety of wildlife. Common at Stahl Natural Area are white-tailed deer, muskrats, opossums, mice, shrews, eastern box turtles, cottontail rabbits, moles, red foxes, garter snakes and milk snakes. These are found among flora such as red cedar, red maple, and oak trees as well as blackberry bushes, golden rod, wheat grass, foxtail crab grass and bluegrass (Brook 1997).

On the north side of River Road, two ponds are located within 60 meters from River Road. This is where reptiles and amphibians migrate towards during mating season to forage and lay their eggs before returning back across the road to the wetland and wooded habitats (Brook 1997). There are five culverts located at the site running underneath River Road (Figure 1). The culverts were installed by the Township of Bedminster between 2014 and 2015 and are 61 cm wide by 61 cm high and are spread 160 meters apart from each other along River Road. The location of the culverts was determined using GPS coordinates from each culvert which were then put into ArcGIS.

The culverts were each made of three concrete trench boxes, each 3 meters in length, which extended across the width of the road. (Figure 2, Figure 3) The trench boxes were accompanied on top with a metal grate top to allow natural light and elements into the culvert. Along each side of the road was drift fencing which began at the first culvert and extended to the fifth culvert. The drift fencing acted as a funnel, directing the animals into the culverts as they walked along the drift fencing.

Sampling methods

One culvert situated in the middle of the road was selected for this study. At each end of the culvert, one wildlife camera (Reconyx™ series PC900, Holmen, Wisconsin) was placed to monitor the entering or exiting of the amphibians. The cameras were inside a steel security enclosure on a pole which was inserted in the ground with the cameras angled toward the culvert floor. Cameras were on a 30 second timed interval along with the motion sensor from 8:00 PM until 6:00 AM the following day. Between 6:00 AM and 8 PM, the camera was only using motion sensor to take the pictures.

The exiting end of the culvert contained a pitfall trap (61 cm in length, 45 cm in width and 38 cm in height). The pitfall traps collected organisms crossing through the culvert allowing us to determine if the cameras were successful in monitoring the movement. We were able to see what is in the pitfall trap and then check the pictures on the cameras to see whether it triggered the camera.

The end of the culvert was where the pitfall trap contained screen fencing. The screen provided the most amount of natural light while prohibiting all species from entering the culvert from the opposite direction. This was to ensure that only the species crossing from one direction were going through the culvert. The screen was secured up against the culvert as well as into the ground to prevent any species from digging or squeezing around the fencing. The pitfall trap was documented and emptied at the end of every day during the study period (Figure 3).

The peak migration period for amphibians is in the spring and summer so that was when the study was conducted. The survey began on March 31, 2017 and continued until June 13, 2017. From March 31, 2017 until May 18, 2017 the study monitored the movement from the wooded area on the south side of River Road to the ponds on the north side of the road. The exit of the culvert on the southbound side of River Road toward the ponds was closed off using the screen fencing to prevent species from entering from the ponds. On May 19, 2017, the closed off end of the culvert was switched to allow the return migration back to the wooded area on the southbound side of River Road. The screen enclosure was moved from the northbound side to the southbound side to prevent species from entering on the wooded side heading toward the ponds. This continued until the study was concluded on June 13. 2017.

Statistical Analysis

The usage of the culverts was based on data gathered from the camera images as well as the pitfall trap captures during the migration period. The analysis of culvert usage was done using a binomial test to determine significance in completion or not completing of culvert usage. This determined whether or not the animals that were documented using the culverts successfully used the culvert as a migration corridor from one end to the other end. The comparison of species analysis was done using a chi square goodness of fit test to see if some of the species successfully used the culvert more than others. The likeliness of using the culvert was analyzed using a binomial test to determine whether the animals were more likely to use the culvert to go toward the ponds or to go toward the woods.

Results

The duration of this study was 75 consecutive days, starting on March 31, 2017 and concluding on June 13, 2017. From March 31 to May 18, 2017 (49 of the 75 consecutive days of the study) the migration of species from the woods to the breeding ponds was monitored. On day 50, the enclosure that was located on the pond side was moved to the side toward the woods. This new location prevented animals from exiting the woods. The final 25 days (May 19 June 13, 2017) were spent monitoring the return migration back to the woods from the breeding ponds.

The information in table one shows the completion of crossings from one side of the road to the other. If the organisms successfully crossed from one side of the road to the other using the culverts, then it was indicated as a successful completion. Organisms that did not successfully cross from one side of the culvert to the other did not complete the migration. The data in table 2 were gathered from a combination of the recorded observations of species in the pitfall traps as well as from the camera. If an animal was observed on both the camera and in the pitfall trap, then it was only calculated once.

There were a total of 55 amphibians that used the wildlife crossing structure as a migration pathway during the study period. Wood frogs and green frogs were difficult to differentiate between on camera so they were grouped together. A total of 37 amphibians migrated toward the breeding ponds, but 29 amphibians successfully completed the migration. When returning to the woods, 18 amphibians utilized the culvert and 15 of them successfully completed the migration back to the woods. Out of the 29 successful completions, 4 frogs were found dead throughout the study period in the pitfall traps. Their cause of death is unknown, but it is a possibility that their deaths were caused by a flying species that were able to avoid the camera.

Reptiles utilized the culvert, but not as often as the amphibians. The reptiles listed in table one consist of snapping turtles, painted turtles and garter snakes as well as various bird species (Table 1). There were a total of 13 reptiles that used the culvert, but only the snapping turtle completed the crossing to the ponds, and the garter snake was the only reptile to complete the return crossing back to the woods from the ponds. Birds were often seen on camera gathering food in the culvert but were not found using the culvert as a crossing structure.

Mammals commonly used the culvert as well. Mammals that commonly used the culvert included moles, deer mice, raccoons, red fox, weasels, chipmunks and opossum (Table 2). Moles and deer mice were the most common found utilizing the crossing structure. A total of 34 mammals were found in the culvert, 23 were moles and deer mice. Of those 23 mammals documented, 9 successfully completed a journey through the culvert toward the breeding ponds and 7 completed a journey returning toward the woods. Larger mammals such as the weasel, opossum, raccoons, and red foxes were found crossing through the culvert but not as often as the smaller mammals.

Wildlife camera images

Throughout the study, the cameras took over 180,000 photographs through motion triggered and time-interval methods. There were a total of 102 animals documented throughout the study. These animals consisted of wood frog, green frog, American toad, snapping turtle, painted turtle, garter snake, mole, deer mouse, raccoon, red fox, weasel, opossum, chipmunk and various birds.

Out of all the animals documented, 71 of them completed a migration. This included going from the woods to the ponds or from the ponds to the woods. The remaining 31 animals did not complete the migration throughout the length of the culvert in either direction. The animals that did not complete the migration throughout the culvert either turned back and returned the way they came from or they potentially escaped through the grates on the top of the culvert.

The most common species to use the culvert were the frogs and American toads. There were 24 frogs, which consisted of green frogs and wood frogs and 11 American toads that completed the migration through the entire culvert. Green frogs and wood frogs were not easily distinguishable from each other on the camera pictures making it difficult to tell them apart for classification. The next common completions throughout the culvert were from deer mice and moles with 11 and 5 completions respectively.

Culvert successes

In general, animals did use the culvert successfully as a migration corridor in order to move from one side of the road to the other without having to cross the surface of the road. Of the total successful culvert migration completions, 60% of the animals completed the commute successfully when migrating from the woods to the ponds. Only 40% of the successful completions were utilized to commute from the ponds to the woods. The difference in study periods of migration movement from ponds to woods compared to wood to ponds was taken into consideration when calculating results. The p-value when calculating with the binominal sampling formula was .65 to account for the shorter crossing period for returning to the woods. Altogether, 70% of the animals completed crossings through the culvert.

Some species successfully used the culvert more often than other species. In order to be included in these results, a species needed to successfully complete a migration at least two times. The species that utilized the culvert at least twice were wood frogs, green frogs, American toads, as well as deer mice and moles. All of the other species were excluded from these results.

Using the Chi-Square goodness of fit test, frogs were observed migrating through the culvert frequently, as well as American toads, deer mice and moles. The chi-square "goodness of fit" test observed a score of 18.21 and a p-value of 0.0004. Frogs were observed on camera more frequently using the culverts than American toads, deer mice and moles. Using a Chi-Square goodness of fit test, it was determined that there were differences amongst these species with a Chi-square score of 18.36 and a p-value of 0.0004. Of all the frogs that utilized the culverts, the most common animals observed using the culvert to get across the road were wood frogs and green frogs. Although frogs were observed migrating through the culverts more frequently using the cameras, the Chi-Square test examined the differences amongst the species studied and how often they were observed in the culvert. The successful crossings of these species suggested that the culverts were able to allow different animals' from one side of the road to the other (Figure 6, 7 and 8).

Preference of using the culvert to get to the ponds or the woods

Organisms utilized the culverts to migrate both to the ponds and to the woods. However, it was questioned as to which location species migrated more frequently to when using the culverts. After analyzing the data collected, it was established that species in this study were just as likely to use the culvert to migrate to the ponds as they were to migrate to the woods. The data showed species using the culvert to get to the ponds for 49 consecutive days successfully. After these 49 days, the culvert entrance on the pond side was opened to allow the animals to migrate back to the woods for the next 26 days. The data, found in table 2, was calculated by using the number of animals that completed the crossing to the ponds (43) compared to the total number of animals that were observed in the culvert (63). This was calculated using a binomial probability test that is 65% biased toward the ponds as a result of the study observations lasting longer for that direction. The binomial probability test resulted in a p-value of 0.69. Given this value, it was determined that species in this study are just as likely to use the culvert to migrate to the ponds as they are to migrate to the woods.

Discussion

The results of this study suggest that the culverts running underneath the roadway are a successful structure to safely allow animals to cross a road during migration seasons. Beebee (2012) found that amphibians and mammals were the most commonly affected animals that were impacted by road mortality. He also found that these mortality rates were affecting population dynamics. One of the mitigation methods suggested was to build under road culverts. In our study, amphibians, reptiles and mammals were all observed utiliziing the culvert. The smaller mammals and amphibians were forced to follow along the fence line directing them into the culvert. The culvert was effective in providing a safe crossing for smaller animals but was not effective for larger animals that were not forced into the culvert. The larger mammals were capable of crossing the road by climbing over the angled fencing.

<u>Methods of monitoring</u>

To ensure effectiveness of both the fencing and the culvert structure, monitoring methods must be able to track which animal species are using the culvert. Such methods of monitoring include direct monitoring, wildlife cameras and video surveillance, and/or track pads. Each method is beneficial but is also limited. Direct monitoring requires multiple people to watch every day to see which animals utilize the culverts. This method is time consuming and often causes species to detect the presence of humans in the area and deter them from entering the culvert (Langen et al 2007). This negates the purpose of the culvert since channeling animals to utilize the culvert is the goal to reduce road mortality. Using wildlife cameras and video surveillance is an effective method to track which species utilize the culvert. Using motion sensors on the cameras capture animals using the culvert. Unfortunately, the motion sensors only capture animals large enough to set off the sensors of the camera or animals that create enough disturbances to set off the sensors. Smaller animals, such as some amphibians smaller in size, can be difficult to capture using motion detection for these reasons (Pagnucco et al. 2011). Due to these results, motion-detecting cameras might not be an effective method when monitoring small-size amphibians.

Another method to monitor animal species using the culvert is using track pads. These pads are spread out throughout the inside of the culvert and are covered with marble dust. As species walk over it, prints are left behind that are tracked by uncovering which animals left their prints behind (Mateus et al. 2011). This is effective in knowing what types of animals are using the culvert but not specifying what species it was. Furthermore, the dust may wash away in the rain or the wind and larger prints may cover up the smaller prints. It is not suggested to use track pads as the only source of monitoring the culverts (Mateus et al. 2011).

A common method of surveying amphibians and reptiles is through the use of pitfall traps. Pitfall traps are dug into the ground so that they are even with the surface of the substrate. As an animal walks along the designated area they will fall into the trap. The pitfall traps need to be monitored frequently in order to remove any animals that end up in them. Pitfall traps can be effective in monitoring amphibians and reptiles as well as small mammals and invertebrates (McKnight et al. 2013). According to McKnight et al. (2013) the larger the pitfall traps were, the more effective they became in containing animals. A study done by Todd et al. (2007) discussed the use of pitfall traps and concluded that using multiple methods was the most effective to monitor amphibian and reptiles. While each monitoring method individually has its own successes, there are flaws in each one. Utilizing multiple methods is the most effective in capturing not only which animals are using the culvert, but also which type of species and at what time of the day. For example, using track pads and a video surveillance system allowed for the matching of prints with pictures, allowing for the most accurate information needed (Mateus et al 2011).

Effectiveness of Wildlife Camera

In this study, cameras captured some species entering the culverts but never exiting out the other side. Some of these examples included birds and larger animals. Although birds were not as susceptible to road mortality, they still utilized the culverts. Larger animals also accessed the culverts for non-migration purposes. For example, raccoons and opossums walked around in the culvert and then returned the direction that they came from. In research done by Patrick et al (2010), it was determined that animals can use culverts if a barrier can direct them to the entrance of the culvert. In this study, the cameras showed these animals walking around, sitting and eating insects in the culvert but never actually migrating and exiting out the other side (Patrick et al 2010).

Although the cameras were able to capture these larger animals, they were not always successful in capturing the smaller animals. These smaller amphibians were documented using the timed intervals but were not able to set off the motion sensor on the cameras. Using both settings on the camera in our study was effective in capturing all sizes of animals. Using the timed interval feature on the cameras enabled us to capture images that were not set off by the motion detector. Unfortunately, one of the biggest disadvantages of using a timed interval feature was the result of a large quantity of images that required processing, which can be labor intensive and time consuming. The excessive number of pictures that were taken decreased the lifespan of the batteries necessary to run the cameras; batteries were needed to be checked and changed frequently. In addition to the use of the batteries, the images also required a large amount of space on the memory card; the memory cards were needed to be emptied daily, which was also labor intensive and time consuming. Research by Pagnucco et al. (2011) also revealed how time consuming it was to assess every image taken by the camera.

There was the possibility that animals utilized the wildlife crossing structure and were not captured on camera or in the pitfall trap as well. Species such as birds could fly through the culvert above the detection of the camera and not be captured in the pitfall trap. Animals could also have utilized the culvert during the time period that the camera was not on a timed interval setting, and had also never gone into the pitfall trap. In addition, some species may have been able to escape through the grates on the top of the culvert. Although there were flaws in using this method of monitoring, this system has proven great success for monitoring animals utilizing wildlife crossing structures.

Although the cameras provided more information about the species that were not successful in completing the migration through the culvert, the pitfall trap was able to contain the smaller species which enabled us to document their success in utilizing the culvert. The pitfall trap was not large enough to contain larger mammals so these species were only documented on the camera. When used independently, camera monitoring methods or pitfall traps alone would not be as successful. For example, smaller organisms such as the juvenile *L. sylvaticus* were too small to trigger motion sensor and difficult to identify on camera. These small individuals were more successfully recorded in the traps. Utilizing both the cameras and the traps together provided better documentation to demonstrate the usage of the wildlife culvert for both smaller and larger species. This was also reflected in the study by Pagnucco et al (2011), in which they effectively collected information using the same combination of cameras and pitfall traps.

Aside from technological difficulties, another challenge that occurred during this study was the excessive flooding in the culvert in the beginning of the study. The peak migration period for amphibians takes place at the end of February through the month of March, a time where excessive flooding occurs due to snow melt (Patrick et al. 2010). Migrating species in our study headed toward water sources, areas that were prone to flooding during this time. The culverts at River Road were located near water sources making flooding a common occurrence during the beginning of spring. At points throughout the beginning of the study (April 1, 2017- April 15, 2017) the culvert had up to 20 centimeters of water in it. The flooding not only caused standing water in the culvert, but it filled in the pitfall traps which were located below the surface, eliminating any organisms from being caught in the trap. Although amphibians could swim through the culvert when necessary, species such as deer mice and other small mammals were not able to cross through the culverts when they were flooded. This occurrence would make it difficult for the culvert to be a successful crossing method during this time period.

In addition to wildlife crossing culverts, areas of high volume wildlife mortality could benefit from the placement of warning signs on the roadways. These signs will help make the public aware of the crossing of wildlife. It will also signal drivers to slow down and beware of animal crossings. Signs are the most affordable and require minimal effort, but remain the least effective (Beebee 2012). Additionally, having volunteers directing traffic and allowing amphibians to funnel through wildlife crossing structures can ensure safety of wildlife across the road (Patrick et al. 2010, Beebee 2012). Volunteers can also catch wildlife prior to crossing the roadway and release the animals to the other side. Beebee (2012) also mentioned that creating fencing structures along the roadway can help keep the majority of animals off the roadway and direct them toward safer pathways, such as an underground culvert. Combining warning signs, safety signals and volunteer groups with fencing and wildlife crossing structures, wildlife road mortality rates can decrease significantly.

Post Culvert Construction Maintenance

The wildlife culvert would have suffered more than just with flooding had it not been maintained throughout the study. For example, the drift fencing and the substrate within the culverts had to be well kept. When the rainwater carried away the substrate, it needed to be replenished. It was also necessary to inspect the grates to ensure the area was clear of debris. Aside from the culvert, the vegetation surrounding the culvert had to be maintained regularly as to not allow species to use the vegetation to gain access to the roadway.

The fencing surrounding the culvert also needs to be maintained. If the fencing was damaged, animals were able to crawl under the fence or create pathways around the fence through the gaps. Zarate (2016) found that when the fencing surrounding his culverts was not maintained, animals were able to find passage through and around the fence (personal communication). Dodd Jr. et al. (2003) suggested that it was vital to ensure that the natural habitat surrounding the wildlife culverts were not hindered either. In this study, the culvert was installed in the greenspace with natural wildlife habitats so predation was possible. A concern with these structures was how some predators might use the culverts as a trap to access the amphibian and small mammal prey. In this study, four frogs were found dead in the pitfall trap (Figure 9). Although their cause of death was unknown, it is possible that flying species, such as birds, could access the culvert while bypassing the cameras.

Conclusion

Having effective road mitigation efforts is critical in order to preserve the biodiversity. Over time, wildlife mortality on roadways has increased which seems to correlate with the increases of road networks and traffic volume. Amphibians and reptiles have been found to be especially susceptible to road mortality due to their need to migrate to and from breeding ponds and nesting locations on opposite sides of the road. When designed effectively, wildlife crossing structures can be beneficial in allowing the animal to safely get from one side of the road to the other. In this study, complete migrations of multiple species through the culverts were observed. By utilizing the culvert, the animals were provided with an alternative method to safely cross the roadway. The future monitoring plan for culverts at River Road in Bedminster, NJ requires volunteers monitoring and camera monitoring. The Township also plans to upgrade the fencing and continues ground maintenance at the site. It is important that these monitoring and maintenance practices continue in order to maximize the success of wildlife crossings, allowing amphibians and other migratory species a safe way to cross the road barrier.

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Table 1. Common name and scientific name of organisms found in the trap or on camera

Scientific Names	Common Names
Lithobates. sylvaticus	Wood Frog
Lithobates clamitans	Green Frog
Anaxyrus americanus	American Toad
Chelydra serpentina	Common Snapping Turtle
Chrysemys picta	Eastern Painted Turtle
Thamnophis sirtalis	Eastern Garter Snake
Talpidae	Mole
Peromyscus maniculatus	Deer Mouse
Procyon lotor	Raccoon
Vulpes vulpes	Red Fox
Didelphis virginiana	Opossum
Mustela frenata	Long-Tailed Weasel
Tamias striatus	Eastern Chipmunk

Table 2: Animals observed using wildlife camera or pitfall trap. If completed, the species successfully went from one end of the culvert to the opposite end. If not completed, the species entered the culvert, but then did not exit from the opposite end.

		Breeding			**Returned**			**Total**
		Completed	Incompleted	Subtotal	Completed	Incompleted	Subtotal	Number of Organisms
Amphibians	Wood/ Green Frog	20	7	27	14	3	17	44
	American Toad	9	1	10	1	0	1	11
Reptiles / Birds	Common Snapping Turtle	1	0	1	0	0	0	1
	Eastern Painted Turtle	0	1	1	0	0	0	1
	Eastern Garter Snake	0	2	2	1	2	3	5
	Birds	0	4	4	0	2	2	6
Mammals	Deer Mouse	7	1	8	4	3	7	15
	Moles	2	2	4	3	1	4	8
	Racoon	1	0	1	1	0	1	2
	Red Fox	1	1	2	1	0	1	3
	Long-Tailed Weasel	0	0	0	1	0	1	1
	Opossum	1	1	2	1	0	1	3
	Eastern Chipmunk	1	0	1	1	0	1	2
Total				63			39	102

Figure 1: Map of River Road in Bedminster (Zarate et al, 2015).

Figure 2: Culvert entrance. (61cm X 61cm). Pitfall trap (38cm (H) X 45cm (W) X 61cm (L)) installed at the culvert entrance. (Zarate et al. 2015).

Figure 3: Enclosure set up on the wood side of the road. Closing off the wood side of the road allowed for the capture of organisms returning to the woods from the breeding ponds. Enclosure was created with screen and clear plastic to allow natural light and elements to enter.

Figure 4:. Motion triggered image of *Peromyscus maniculatus* (left) and timed interval image of *Vulpes vulpes* (right) in the culvert at early morning.

Figure 5: Timed interval image of *L. clamitans* (left) and *A. americanus* (right) in the culvert at early morning. The image on the right was taken when the culvert had flooded, and animals were still using it as a corridor.

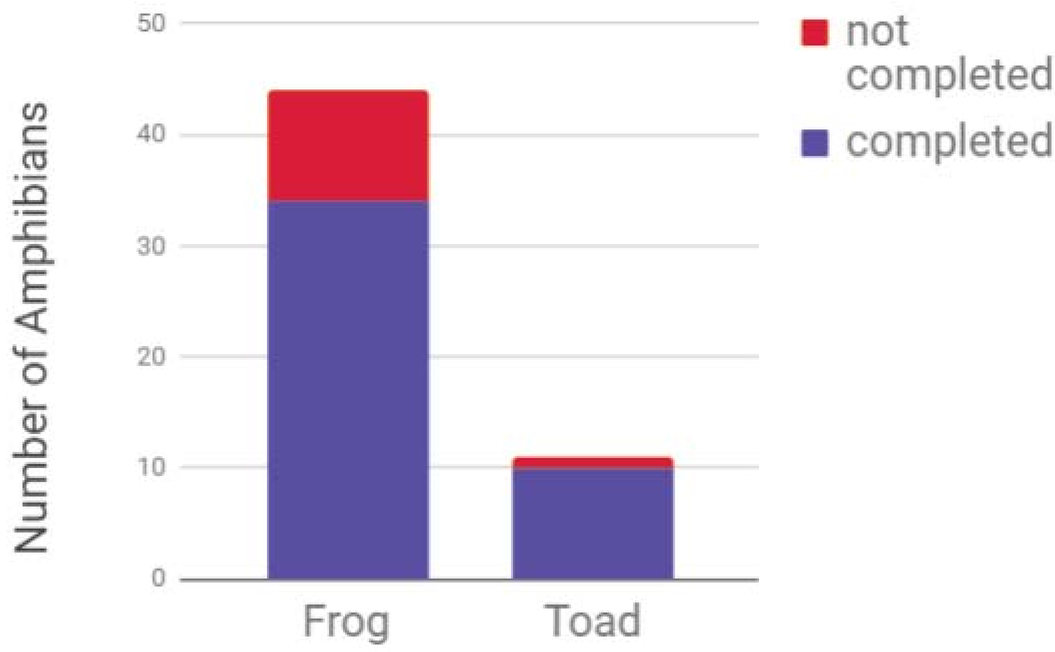

Figure 6: Culvert use by amphibians. In order for a migration to be considered complete an animal needed to go from one end of the culvert to the other.

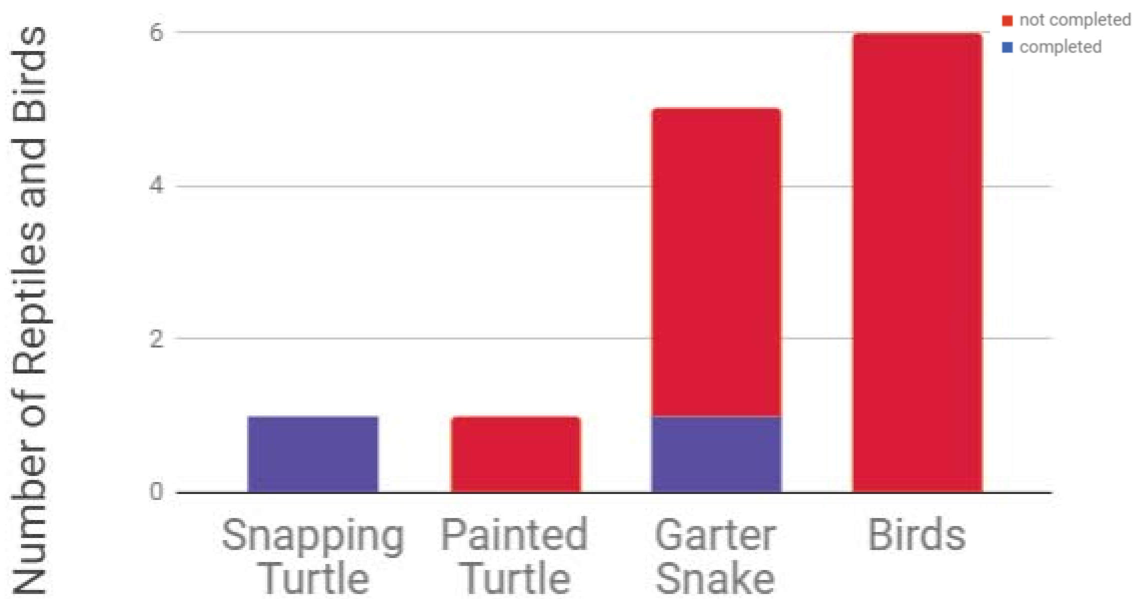

Figure 7: Culvert use by reptiles (including birds). In order for a migration to be considered complete an animal needed to go from one end of the culvert to the other.

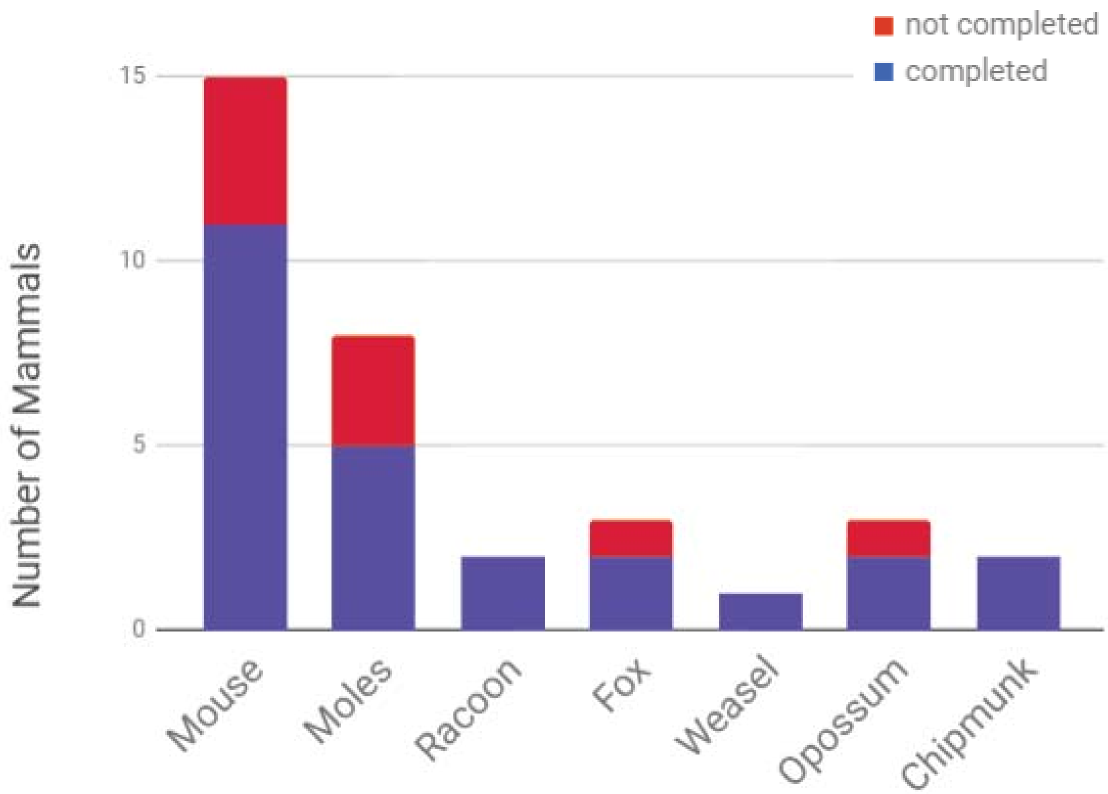

Figure 8: Culvert use by mammals. In order for a migration to be considered complete an organism needed to go from one end of the culvert to the other.

Figure 9: Four total amphibians were found dead in the pitfall trap during the study period. The cause of death was unknown.

Appendix A- Culvert Appearances of Animals

Animal	Camera 1 (Pool)		Camera 2 (Woods)		In Trap	Water Inundation
Deer Mouse	3/31/2017	12:44:00 AM	3/31/2017	12:43:00 AM	No	
Frog	3/31/2017	9:23:00 PM			No	
Mole	3/31/2017	10:12:00 PM			No	
Frog	3/31/2017	11:01:00 PM	3/31/2017	1:09:00 AM	No	
Frog			3/31/2017	5:36:00 AM	No	
Snake			3/31/2017	11:59:00 AM	No	
Frog	4/3/2017	11:59:00 AM	4/3/2017	11:08:00 AM	Yes	Under Water
American Toad	4/4/2017	1:28:00 AM	4/3/2017	11:53:00 PM	yes	Under Water
Frog	4/4/2017	1:42:00 AM	4/4/2017	12:40:00 AM	Yes	Under Water
Frog	4/4/2017	1:54:00 AM	4/4/2017	1:11:00 AM	Yes	Under Water
Frog	4/4/2017	2:04:00 AM	4/4/2017	1:26:00 AM	Yes	Under Water
American Toad	4/4/2017	3:36:00 AM	4/4/2017	1:37:00 AM	Yes	Under Water
American Toad	4/4/2017	3:39:00 AM	4/4/2017	1:54:00 AM	Yes	Under Water
Deer Mouse			4/4/2017	3:53:00 AM	Yes	Under Water
American Toad	4/4/2017	4:14:00 AM			Yes	Under Water
Frog	4/4/2017	5:09:00 AM	4/4/2017	4:24:00 AM	Yes	Under Water
American Toad			4/4/2017	4:59:00 AM	Yes	Under Water
Frog			4/4/2017	5:00:00 AM	Yes	Under Water
American Toad	4/5/2017	3:46:00 AM			Yes	Under Water
American Toad	4/5/2017	8:05:00 PM			Yes	Under Water
Frog			4/5/2017	9:00:00 PM	Yes	Under Water
Frog	4/8/2017	5:47:30 AM			Yes	

Opossum	4/11/2017	2:15:44 AM	4/11/2017	2:15:15 AM	No	
Eastern Painted Turtle			4/11/2017	12:52:35 PM	No	
American Toad			4/11/2017	9:35:30 AM	Yes	
Green Frog			4/11/2017	11:29:30 AM	Yes	
Eastern Garter Snake	4/11/2017	12:08:31 PM			No	
Bird	4/13/2017	6:09:33 PM			No	
Common Snapping Turtle	4/13/2017				Yes	
Bird			4/14/2017	1:19:21 PM	No	
Bird			4/15/2017	5:13:00 PM	No	
Mole			4/16/2017	11:00:00 PM	no	
Frog			4/17/2017	12:30:30 AM	no	
Deer Mouse			4/17/2017	2:26:48 AM	no	
Mole	4/21/2017	12:38:36 AM	4/20/2017	1:29:00 AM	yes	
Frog	4/21/2017	2:41:30 AM			no	
Frog	4/21/2017	3:55:00 AM	4/21/2017	3:52:30 AM	Yes	
Frog	4/21/2017	5:48:00 AM	4/21/2017	5:33:30 AM	Yes	
Squirrel	4/21/2017	9:24:07 AM	4/21/2017	9:24:11 AM	No	
Eastern Garter Snake			4/23/2017	11:56:50 AM	no	
Frog	4/22/2017	2:33:30 AM			No	
Deer Mouse	4/25/2017	9:45:18 PM	4/25/2017	9:43:18 PM	Yes	
Frog	4/25/2017	10:45:00 PM	4/25/2017	10:13:30 PM	Yes	
Frog	4/26/2017	12:32:00 AM	4/26/2017	1:24:30 AM	Yes	
Frog	4/26/2017	1:31:30 AM	4/26/2017	1:37:30 AM	Yes	
Frog	4/26/2017	1:45:30 AM	4/26/2017	1:39:30 AM	Yes	
Deer Mouse	4/27/2017	10:46:52 PM	4/27/2017	10:45:39 PM	Yes	
Frog	4/28/2017	11:17:30 PM			No	
Frog			4/29/2017	5:43:00 AM	yes	

Bird			4/27/2017	12:19:55 PM	No	
Eastern Chipmunk	4/30/2017	2:14:32 PM	4/30/2017	2:15:43 PM	No	
Racoon			4/30/2017	3:55:33 PM	No	
Red Fox			4/28/2017	8:52:43 PM	No	
Frog			5/6/2017	2:45:30 AM	No	
Deer Mouse			5/6/2017	11:52:53 PM	No	
Deer Mouse			5/8/2017	2:57:58 AM	No	
Deer Mouse	5/13/2017	2:41:57 AM	5/13/2017	2:40:00 AM	Yes	
Deer Mouse	5/14/2017	11:00:49 PM	5/14/2017	12:19:30 AM	Yes	
Deer Mouse	5/14/2017	11:32:47 PM	5/14/2017	10:23:00 PM	Yes	
Frog	5/18/2017	4:11:30 AM			No	
Deer Mouse			5/15/2017	9:13:03 PM	No	
Deer Mouse	5/19/2017	5:14:51 AM	5/19/2017	5:04:22 AM	Yes	
Frog			5/19/2017	3:25:00 AM	No	
Bird	5/20/2017	11:08:57 AM			No	
Deer Mouse			5/22/2017	11:56:09 PM	No	
Frog	5/25/2017	9:32:00 PM			No	
Frog	5/25/2017	10:13:30 PM			No	
Deer Mouse	5/25/2017	4:50:09 AM	5/25/2017	4:20:56 AM	No	
Deer Mouse	5/28/2017	11:41:06 AM	5/29/2017	12:29:00 AM	Yes	
Frog	5/28/2017	11:55:00 PM	5/28/2017	11:46:30 PM	Yes	
Opossum	5/29/2017	10:47:28 PM	5/29/2017	10:47:23 PM	No	
Red Fox	5/30/2017	2:40:00 AM	5/30/2017	2:40:00 AM	No	
Frog	5/31/2017	11:02:30 PM	6/1/2017	3:31:00 AM	Yes	
Eastern Garter Snake	6/2/2017				yes	

A

frog	6/4/17	10:30:00 PM			No		
Frog	6/5/17	12:17:30 AM			No		
Frog	6/5/17	1:56:30 AM			No		
Frog	6/5/17	3:08:30 AM			No		
Frog	6/5/17	3:18:30 AM			No		
Frog	6/5/17	4:20:30 AM	6/5/2017	5:28:00 AM	Yes		
Frog	6/5/17	5:23:00 AM	6/5/2017	5:28:00 AM	Yes		
Frog	6/5/17	11:54:00 PM			No		
Mole			6/6/2017	2:50:18 AM	No		
Frog	6/6/17	9:23:00 PM			No		
Deer Mouse	6/6/17	10:07:00 PM			No		
Frog	6/8/17	9:00:00 PM			No		
Racoon	6/8/17	2:13:46 AM			No		
Frog	6/9/17	9:58:30 PM			No		
Frog	6/11/2017	5:12:30 AM			No		
Bird	6/11/2017	7:24:19 AM	6/11/2017	7:24:34 AM	No		
Weasel	6/11/2017	9:02:32 AM	6/11/2017	9:02:05 AM	No		
Eastern Garter Snake	6/11/2017	8:09:00 PM			No		