Abstract
Vehicle collisions represent one of the largest anthropogenic causes of wildlife mortality. Herpetofauna are at risk for large population declines and potential extirpation as a result of a small percentage of total population mortality due to roads. Herpetofauna play an important role in wetland ecosystems and provide many ecosystem services. Ecopassages allow for the safe passage of animals under roads. The objective of this research is to identify the common elements of ecopassage developments and innovative practices that may be adopted for future application in Southern Ontario. In this paper four ecopassage case studies were used to ascertain the main features in ecopassage design and implementation. A qualitative analysis was done to highlight the major themes from each case. These themes were then compared with those present in the reference literature on ecopassages to determine their validity. In all of the case studies, the main ecopassage features were the identification of the species of importance, the identification of crossing ‘hot spots’, and the importance of fencing. The reference literature also cited the importance of mitigation and of installing ecopassages during initial road construction. Additionally, innovative approaches to ecopassage design were found in the Long Point Causeway and 1000 Islands Parkway cases. These include combining a change in driver behaviour with a change in animal behaviour and using the construction of an ecopassage as an opportunity to create a multi-use road thereby implementing multiple benefits into one development while offsetting the perceived cost and time of the project. Providing social benefits may also serve to bring the community together with their natural environment and will improve the public opinion surrounding ecopassage projects.
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Key Terms:

Ecopassage: A system that allows animals to safely travel under or over roadways.

Wildlife: the native fauna, and sometimes flora, of a region

Wildlife Crossing: structures that allow animals to cross human made barriers, commonly roads.

Ecosystem: A community of living organisms and nonliving components interacting as a system.

Habitat: The ecological or environmental area where a population of a certain species lives.

Wetland: An area that holds water either temporarily or permanently. One of the most important ecosystems in terms of ecosystem benefits.

Herpetofauna: The reptiles and amphibians of a specific region, habitat, or geological period.

Extirpation: The local extinction of a species.

Acknowledgements:

I would like to thank Professor Graham Whitelaw for all of his help and encouragement throughout this project.

I would also like to thank Dr. Ryan Danby for agreeing to be my examiner and for his help during my presentation and the later stages of this project.
Introduction:

Purpose:

The purpose of this research is to examine ecopassages through the review of case studies in order to determine opportunities for optimal key aspects of ecopassage design that may be used for application in Southern Ontario. As human development continues to expand many animals are susceptible to death on roads. Ecopassages are built in areas where there has been, or is predicted to be, a significant incidence of animal death on a road. These areas are usually associated with migratory paths or nesting areas (Coffin, 2007). The main elements of ecopassage design were examined in this paper. In order to determine these main elements, four case studies were examined; Longpoint Causeway, Ontario, CANADA; 1000 Islands Parkway, Ontario, CANADA; Paynes Prairie, Florida, USA; and Lake Jackson, Florida, USA.

Issue:

The main animals of concern are reptiles, snakes, and amphibians. Many small mammals are also killed on roads near wetlands but in much smaller numbers. Herpetofauna, which consist of the reptiles and amphibians of an area, are often the species most at risk of mortality, population decline, and local extinction when roads are built through wetlands (Jongerden, 2008; Jackson, Underpass systems for amphibians, 1996). Due to the long lifespan and late sexual maturity of many of these species there can be negative effects to local habitats if death rates are significantly increased by incidences on roads (Congdon, Dunham, & Van Loben Sels, 1993). Herpetofauna play an important role in wetland ecosystems thus roads constructed without consideration of herpetofauna vehicle interaction may negatively impact ecosystem health (Smith & Dodd, 2003). There are two main ways to reduce the deaths of
animals on roads, a change in animal behaviour and a change in driver behaviour (Garbutt, 2009). The focus of this paper is on changing animal behaviour through the use of ecopassages.

Ecopassages are a network of guide walls, tunnels and fences that allow for the safe travel of wildlife across roads (Ecopassage.org, n.d.). Ecopassages do not only include the tunnels or culverts that pass under the road but the whole system, including fences, along a roadway that prevents animals from accessing and crossing a road. They are most commonly built for smaller animals and pass under roads. The bridges that pass over roads that are most commonly used by large mammals are typically known as wildlife bridges or overpasses (Cramer & Bissonette, 2005).

Methods and Outline

This paper will begin with a literature review to provide background information and set the context for the importance of ecopassages. The case studies will be introduced and summarised. The methods used in this paper are a qualitative analysis of the scientific literature surrounding ecopassages and the grey literature associated with the case studies. The main themes and patterns were extracted from the literature and analysed using a triangulation method in order to determine the most important benefits and concerns with the implementation of ecopassages. The methods are based on Berg’s (2001) Qualitative Research Methods for the Social Sciences. In order to extract themes and patterns from the text, the qualitative analysis software NVivo was used. This software was used not only to quantify previously known themes but also to bring out new information based on the case studies that was not obvious upon first examination of the literature.
Literature Review:
Conservation Biology

Ecopassages are placed in areas where the conservation of certain species is important. For this reason, conservation biology is at the root of any study of ecopassages. Conservation biology is the branch of biology, ecology, and environmental sciences that studies the preservation of biodiversity and natural resources. It is an interdisciplinary field that deals with social and scientific issues. The term ‘Conservation Biology’ was first used as the title of a conference held at the University of California, San Diego in 1978 (Douglas, 1978).

Conservation biology is very solutions focused. The aim of many conservation biologists is to find solutions to issues concerning biodiversity and habitat loss in order to shape policy and create improvements. Conservation biologists use science and research to determine what the main issues are in a given area and how to find solutions that bring in both social and environmental values (Chan, 2008; Lackey, 2007).

When looking at the conservation of a species it is necessary to examine the habitat of that species. The spatial structure of ecosystems is as responsible for the survival or extinction of a species as predation, competition, and birth and death rates. When habitats are destroyed, species become at risk for local extinction (Hanski, 1998). Many organisms migrate to a certain extent within their habitat. This movement can be to find a mate, to find food, to nest, or even to find a suitable place to winter. It is not only important to maintain habitats but also to ensure that the habitats do not become too fragmented in order to allow for this movement (Cramer & Bissonette, 2005; Fahrig & Rytwinski, 2009).
Habitat Fragmentation

Habitat fragmentation occurs when human development creates discontinuities in the preferred living environments of organisms. These discontinuities can be as small as fences, roads, or fields and can be as large as entire cities. Habitat fragmentation occurs across the globe and is something that ecologists have been trying to understand and manage since the concept was first introduced (Harrison & Bruna, 1999).

MacArthur and Wilson (1967) were the first to offer a theory for habitat fragmentation. Their theory of island biogeography explained that the smaller the area of a habitat, the fewer the species that it could support. This theory changed the way that ecologists thought about habitats, it showed the importance of the configuration of a habitat. In order to have the most biodiversity in a protected habitat the area-to-edge ratio must be maximized and corridors must be maintained in order to improve dispersal (Harrison & Bruna, 1999).

Another important theory in habitat fragmentation is metapopulation theory (Harrison & Bruna, 1999; Hanski, 1998). This differs from island biogeography in that it assumes that there is no large area of ‘mainland’ habitat, it also focuses on one species. Due to the absence of a mainland, connection between patches of habitat is increasingly important in metapopulation theory. This theory shows that if habitats are not linked together there is a high risk of regional extinction. Both of these theories show that linkages between habitats that allow for species dispersal are important to the survival of organisms that live within fragmented habitats (Harrison & Bruna, 1999; Hanski, 1998).
The Effects of Roads

Roads are one of the greatest barriers for the dispersal and movement of animals (Harrison & Bruna, 1999; Jackson, 2000). Therefore, they present not only a physical barrier to movement but they also raise levels of noise pollution and can lead to the introduction of invasive species into habitats. They present an impact on wildlife that is disproportionate to the area that they occupy (Jackson, 2000). Roads have a twofold effect on reducing the dispersal of populations. Firstly animals may be killed while attempting to cross the road and secondly, animals may avoid the road and will thus never make the attempt to cross. Both of these effects will lead to fewer interactions with populations on the other side of the road (Fahrig & Rytwinski, 2009).

To date, studies on the effects of roads have focused on mid- to large-sized mammals and very few studies have been done on small mammals and reptiles (Rico, Kindlmann, & Sedlacek, 2007). It was thought that for the most part smaller animals had a lower risk of death on roads, would be able to find alternate ways to cross the roads, or simply that their populations would be able to sustain themselves without mixing across roads. We now know that roads can greatly affect the local survival of small mammals and reptiles (Rico, Kindlmann, & Sedlacek, 2007).

Studies on the effects of roads on animals can be difficult to find and assess due to the fact that they are usually completed by government ministries where the information is published as “grey literature” (Lesbarreres & Fahrig, 2012). Although this information is usually available to the public it can be difficult to access. The results from these studies are not often
published in scientific literature. They are for the most part not up to standards of scholarly literature and the government agencies have little incentive to try to publish them more broadly (Lesbarreres & Fahrig, 2012). It is important that more rigorous scientific research be done in the future to link ecopassages with the reduction of deaths of animals on roads (Lesbarreres & Fahrig, 2012).

**Main Species of Concern**

The main animals at risk are reptiles, snakes, and amphibians (COSEWIC, 2005; Jaarsma, van Langevelde, & Botma, 2006). Herpetofauna are the reptiles and amphibians of a specific region or habitat. Herpetofauna are often the species most at risk of mortality, population fluctuations, isolation, decline, and extirpation when roads are built through wetlands (Jongerden, 2008; Jackson, Underpass systems for amphibians, 1996)

**Case Studies**

Four case studies will be used in order to find best practices that are used in ecopassage design. They were chosen because 3 of the 4 cases are ranked within the world’s top five turtle mortality sites (Table 1). Two cases were chosen from Ontario because the goal of this research is to find best practices that may be applied in Southern Ontario. The other two cases are the top two deadliest roads in the world for turtles and by coincidence are both located in Florida, USA. Additionally, the four locations are at different stages in their implementation of ecopassages. Paynes Prairie, Florida was one of the first places to implement an ecopassage over a decade ago; Lake Jackson, Florida completed their ecopassage in 2010; The Long Point, Ontario ecopassage is currently under construction; and the 1000 Islands Parkway currently has
no plan in place for the construction of an ecopassage. By studying these four sites it is possible to examine the various stages of the implementation of an ecopassage.

**Table 1: World's Top 5 Road Mortality Sites**

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Rate Turtles Killed (per mi per yr)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2,070</td>
<td>Lake Jackson, Florida, USA</td>
</tr>
<tr>
<td>2</td>
<td>93</td>
<td>Paynes Prairie, Florida, USA</td>
</tr>
<tr>
<td>3</td>
<td>85</td>
<td>Mission Valley, Montana, USA</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>Long Point, Ontario, CANADA</td>
</tr>
<tr>
<td>5</td>
<td>37</td>
<td>Cape May, New Jersey, USA</td>
</tr>
</tbody>
</table>

This Table shows the rate of turtles killed per mile per year for the five roads in the world with the highest turtle mortality rates (Lake Jackson Ecopassage Alliance, n.d.).

The main species of concern for all four cases are amphibians and reptiles (Jaarsma, van Langevelde, & Botma, 2006) however, each case has their own species that they are trying to protect. At Paynes Prairie the four most common species found were the green tree frog (*Hyla cinerea*), Florida banded water snake (*Nerodia fasciata*), southern leopard frog (*Rana utricularia*), and green water snake (*Nerodia floridana*) (U.S. Geological Survey, 1999) At Lake Jackson the two most abundant turtle species found on the road were Yellow-Bellied Sliders (*Trachemys scripta*) (4,249) and Florida Cooters (*Pseudemys floridana*) (3,806) along with 8 other species of turtles, 34 species of other reptiles and snakes, 17 species of mammals, and 27 species of birds (Lake Jackson Ecopassage Alliance, 2008). At Long Point the main species killed on the causeway is the leopard frog however enough turtles are killed each year that Long Point has joined Lake Jackson and Paynes Prairie as one of the top 5 deadliest roads in the world for turtles (Lake Jackson Ecopassage Alliance, n.d.; Long Point World Biosphere Reserve Foundation, 2008). On the 1000 Islands Parkway there are 5 turtle species and 9 snake species. Of those, the main species of concern are the 4 turtle species and 3 snake species that are considered to be most at risk. Those are the eastern milk snake (*Lampropeltis triangulum*).
triangulum), gray rat snake (*Pantherophis spiloides*), eastern ribbon snake (*Thamnophis sauritus septentrionalis*), snapping turtle (*Chelydra serpentina*), Blanding’s turtle (*Emydoidea blandingii*), northern map turtle (*Graptemys geographica*), and eastern musk turtle (*Sternotherus odoratus*).

Paynes Prairie, Florida, USA

![Conceptual Image of the Paynes Prairie Ecopassage](http://www.lakejacksonturtles.org/ppe3.jpg)

**Figure 1: Conceptual Image of the Paynes Prairie Ecopassage**

Paynes Prairie is a freshwater marsh located in southern Alachua County in the town of Micanopy, USA. Much of the marsh lies in the Paynes Prairie State Preserve. U.S. 441 and Interstate 75 are two major north-south highways that intersect the prairie. U.S. 441 has become a commuter route and handles upwards of 10,000 cars every day. The prairie is home
to many different species including snakes, turtles, alligators, small mammals, and birds.

Unfortunately, the stretch of road where the U.S. 441 crosses over the marsh sees increased wildlife mortality (U.S. Department of the Interior: U.S. Geological Survey, 2012).

In 1998, the Florida Department of Transportation convened a study to investigate the mortality of animals on the two mile stretch of U.S. 441 where it intersects the prairie. They used input from the FDOT engineers to design a system of barrier walls and tunnels to allow for the safe passage of wildlife with an emphasis on reptiles, amphibians, and small mammals. The construction of the ecopassage and post-construction survey were completed in 2002 (U.S. Department of the Interior: U.S. Geological Survey, 2012).
Lake Jackson, Florida, USA

![Map of Lake Jackson and Little Lake Jackson](http://www.lakejacksonturtles.org/highresdesign.gif)

**FIGURE 2: MAP OF LAKE JACKSON AND LITTLE LAKE JACKSON**
Map of Lake Jackson and Little Lake Jackson being bisected by US Highway 27 showing the proposed locations of culverts and barrier walls. Photo: http://www.lakejacksonturtles.org/highresdesign.gif

Lake Jackson is a sinkhole lake located 7 miles north of Tallahassee Florida. The water levels in the lake are controlled by rain, natural runoff, and two sinkholes. During times of drought, the water level of the lake drops dramatically as the water drains through the sinkholes. In extreme cases the lake can dry up completely, an event that has happened at least 8 times in the last century. The lake is considered one of the county’s most precious natural resources and is designated as a State Aquatic Preserve and Outstanding Water Body (Lake Jackson Ecopassage Alliance, n.d.; Lake Jackson Ecopassage Alliance, 2015).
US Highway 87, a four lane highway, was built across at ¾ mile (1.2 km) section of the lake and split of the western end now known as Little Lake Jackson. Twenty-two thousand five hundred vehicles travel the road every day. When the lake dries up, 45 species of reptiles and amphibians and 17 species of mammals have been documented trying to cross the highway from Lake Jackson to Little Lake Jackson. The stretch of road that crosses the lakes is the deadliest road in the world for turtles and, without the use of ecopassages, they have only a 2% chance of successfully crossing the road without being killed. The turtle populations cannot compensate for the loss due to both natural and road caused mortality (Lake Jackson Ecopassage Alliance, n.d.).

In 2010 construction was completed on an ecopassage along the highway which has prevented wildlife from entering the road and being killed. The ecopassage consists of 4 large box culverts a guide-wall and fence system. This ecopassage has helped to restore the natural flow of water between the two separated areas of the lake. It has also reduced the amount of wildlife mortality. There has been improved road safety and the natural aesthetics of the environment have started to return to normal which will bring increased economic prosperity to the area (Lake Jackson Ecopassage Alliance, n.d.).
Long Point, Ontario, CANADA

![Aerial Photo of Long Point Causeway](http://longpointcauseway.com/introduction/what-is-the-long-point-causeway-improvement-project/)

**FIGURE 3: AERIAL PHOTO OF LONG POINT CAUSEWAY**

Long Point is a small cottage community that is connected to the town of Port Rowan and Highway 59 by the 3.8 km-long Long Point Causeway (Jongerden, 2008). The sand spit that the community of Long Point sits on and the entire wetland area form the Long Point World Biosphere Reserve (Long Point World Biosphere Reserve Foundation, 2008). The causeway was constructed in the late 1920s in order to allow access to the beaches on Long Point from the mainland. On average, 2300 car trips are made across the causeway every day from October to April with four times this number on weekends during the summer. The causeway forms the east edge of the Big Creek Marsh, a wetland located at the mouth of Big Creek at the head of Inner Bay. The 1200 ha wetland has been isolated from the shoreline and the ecosystem of Inner Bay by the causeway which hinders the movement of wildlife from one habitat to another.
and prevents the flow of water. The Big Creek Marsh acts as a natural water filter for the area but the wetland now only has one outlet into Long Point Bay. This water is no longer being properly filtered and polluted water is entering the bay (Jongerden, 2008; Long Point World Biosphere Reserve Foundation, 2008). Approximately 10,000 animals die on the causeway every year. Most of these are leopard frogs but over 99 other species of frogs, turtles, birds, snakes, and mammals die on the causeway every year (Long Point World Biosphere Reserve Foundation, 2008).

In 2006, a project began to revitalize the area along the causeway. The Long Point Causeway Improvement Plan was published in 2008 by Ecoplans Limited and outlines a proposal for improving the causeway (Jongerden, 2008). The plan consists of creating 12 culverts under the causeway to allow for the safe travel of wildlife under the road. Some of the culverts will also allow for water to flow from the marsh into Inner Bay which will help the area return to its natural state. A system of guide-walls and fences will also be installed to funnel wildlife into the culverts and away from the road. In order to construct the ecopassages the road will have to be widened which will present an opportunity to add bike trails and observation decks to the road. This plan, if completed will both help to return the environment to its natural state and will provide recreation and economic opportunities for the region (Long Point World Biosphere Reserve Foundation, 2008).
1000 Islands Parkway, Ontario, CANADA

**FIGURE 4: 1000 ISLANDS PARKWAY**
Photo: http://www.thekingshighway.ca/PHOTOS-2/hwy2S-3_lg.jpg

The 1000 Islands Parkway is a 37km long 2-lane road that runs east-west between the towns of Brockville and Gananoque, Ontario, CANADA. The parkway runs along the north shore of the St. Lawrence River and through part of the 1000 Islands National Park. Volume on the road is much higher in the summer months and traffic volume between the months of June and October varies between 1500-4000 vehicles per day (Garrah, 2012). The area surrounding the parkway is mostly wetlands, and consists of both privately owned residential property and government owned national park property. The parkway runs through the narrowest part of the Algonquin to Adirondack wildlife corridor. The A2A corridor is an important strip of land that will ensure connectivity of species between Algonquin and Adirondack national parks.
Maintaining the parkway as a safe road for animals is crucial in the overall health of the A2A corridor (Garrah, 2012).

In the area there are 5 turtle species, 4 of which are designated species at risk; and 9 snake species, 3 of which are designated species at risk (Garrah, 2012). Due to this it is important to determine a way to ensure safe passage of wildlife across the road. Since the area has a lot of private property and a large amount of driveways entering the road it may not be practical to implement a traditional ecopassage here. Other methods that include changing driver behaviour may need to be combined with wildlife culverts and fencing (Garrah, 2012). There is currently no firm ecopassage plan in place for the parkway.

Methods

In order to assess the benefits of ecopassages, the above 4 case studies and scientific literature were evaluated. The scholarly literature from multiple ecopassage studies was used as a reference for the case studies. From the literature major themes and patterns were determined. These served as the basis for the important aspects of ecopassage planning and design and contributed to the second part of the study, a systematic evaluation of each case study. The analysis of the case studies was used to draw out major themes and compare them to those found in the reference literature.

Case studies are important because they offer an opportunity to discover new issues that may not have not been discussed in the general literature surrounding ecopassages. The cases used in this paper are collective case studies which is when multiple important cases are used to allow for a better or enhanced ability to understand an issue (Berg, 2001). The four cases all
represent important ecopassage projects. They all use similar ideas however each case brings something new to ecopassage research. The findings from the case studies will help to expand the understanding of best practices for implementation of future ecopassages.

The material used for the evaluation of the case studies was comprised of grey literature and scholarly literature. For the case studies both grey literature and scholarly literature were used wherever possible. Since the study of ecopassages is relatively new, there is little grey literature available therefore the majority of the literature used for the cases was scholarly literature (Table 2). The information used was solely qualitative literature. There was an attempt made to contact the organizers of the ecopassage projects used in the case studies for any additional information however no responses were received. There was no requirement for ethics approval as all research was web-based.

**TABLE 2: SUMMARY OF SOURCES USED**

<table>
<thead>
<tr>
<th>Paynes Prairie:</th>
</tr>
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<tbody>
<tr>
<td>Lavendel, B. (2000). Putting the breaks on roadkill. <em>EBSCOhost, 133</em>(6), 9 pages. <a href="http://web.a.ebscohost.com.proxy.queensu.ca/ehost/detail/detail?sid=66ee7aff-60f5-43f1-ada7-629be4e3c707%40sessionmgr4005&amp;vid=0&amp;hid=4101&amp;bdata=JnNpdGU9UGF0aWNhbGhvbmUgZm9yYWNlLWl0ZSBQYXNzd29yZCgqYXNzd29yZCgqZnVuY3Rpb24uY29t#db=a9h&amp;AN=3938776">http://web.a.ebscohost.com.proxy.queensu.ca/ehost/detail/detail?sid=66ee7aff-60f5-43f1-ada7-629be4e3c707%40sessionmgr4005&amp;vid=0&amp;hid=4101&amp;bdata=JnNpdGU9UGF0aWNhbGhvbmUgZm9yYWNlLWl0ZSBQYXNzd29yZCgqYXNzd29yZCgqZnVuY3Rpb24uY29t#db=a9h&amp;AN=3938776</a></td>
</tr>
</tbody>
</table>
### Lake Jackson:


### Long Point Causeway:


### 1000 Islands Parkway:


### Reference Literature:


The literature was collected over a period of five months. The first search was made on October 6, 2014 and the last on March 5, 2015. The main search engine used was Google Scholar (scholar.google.com) however other engines such as Google (google.com) and Queen’s Library Summons (library.queensu.ca) were also used. The main search terms used for all search engines were ‘ecopassages,’ ‘road ecology,’ ‘conservation biology,’ and ‘wildlife crossings’ which were all searched more than once. Additionally many articles were found from the ‘Ecopassage Research Studies’ page which is archived in the ‘More Info’ category of the Longpoint Causeway Improvement Project website (http://longpointcauseway.com/category/more-info/). This webpage served as a jumping off point for more research and provided many of the articles that were used.
For the ecopassage reference information 18 sources were used (Table 2). Of these 14 were academic literature. The other 4 sources were grey literature from government sources and environmental and human rights organizations (Dockstader & Southall, 2003; Humane Society of the United States, 2009; Reptiles Canada, 2012; Casper, 2012). The articles being used are considered the most renowned in the field of ecopassage study and were chosen because they came up during multiple searches on all of the search engines used.

Five sources were used for the Lake Jackson and Paynes Prairie case studies, 4 sources were used for the Long Point case, and one source was used for the 1000 Islands Parkway case (Table 2). Two academic articles were used for each case along with the websites for the organizations running each project. For the Paynes Prairie case the 2 non-academic sources used were the Phase I and Phase II project reports completed by the US Geological Survey. For Long Point the fourth source was the Long Point Causeway Improvement Plan completed by Ecoplans Limited. For Lake Jackson the additional sources were articles by the National Wetlands Newsletter and Current Science. These sources were chosen because they represented the main information concerning each case.

All of the material used for analysis was saved in PDF format and was imported into NVivo, a data analysis software for qualitative research. The documents were then sorted into folders, one for the reference literature articles and one for each case study. This was done so that the information could be coded and analyzed for each case separately and as a whole.

Once the information was imported into the software, each folder was coded using pre-determined nodes (important themes). These nodes were decided upon based on the general
literature on ecopassages and manually reading the documents. Once this was completed, word frequency queries were done for the entire set of sources and for each individual folder. Words that were common to all folders were also created as nodes and were coded for. The main themes from each folder were then analyzed to determine which frequent words were common to all folders and which were important for only the cases.

The nodes selected for each case represent the major themes. One main issue was selected for each case to be explored further based on the significance attributed to it by the researcher, after having read the reference literature and the case study documents. The themes for each case study were triangulated against the reference literature and each other in order to ensure their validity. This means that for each case when a theme was found it was cross referenced with the existing scientific literature to determine if the theme had already been established.

**Discussion and Results**

The results from the analysis were divided into 5 sub-groups, one for each case study and one for the reference literature. Using the NVivo software the most common words were found in all of the research material (Table 3) and for each sub-group (Table 4-8). The tables outline the number of times each word was used and the weighted value of that word in the document which was determined by NVivo software during the word frequency searches. The words used in the tables represent the most frequent words used along with their root words and synonyms. For example, the word road accounts for roads and the word population also accounts for populations and populated. Additionally word clouds were created in association with each table. The word clouds give a visual representation so that the researcher and reader
can quickly identify the words that stand out and determine where those words fit in with the themes (Figure 5-10).

<table>
<thead>
<tr>
<th>Table 3: Most Common Words Used in All Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word</td>
</tr>
<tr>
<td>Roads</td>
</tr>
<tr>
<td>Turtles</td>
</tr>
<tr>
<td>Culverts</td>
</tr>
<tr>
<td>Wildlife</td>
</tr>
<tr>
<td>Species</td>
</tr>
<tr>
<td>Fencing</td>
</tr>
<tr>
<td>Mortality</td>
</tr>
<tr>
<td>Highways</td>
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</tr>
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<td>Amphibians</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4: Most Common Words Used in Reference Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word</td>
</tr>
<tr>
<td>Roads</td>
</tr>
<tr>
<td>Culverts</td>
</tr>
<tr>
<td>Species</td>
</tr>
<tr>
<td>Turtles</td>
</tr>
<tr>
<td>Wildlife</td>
</tr>
<tr>
<td>Habitat</td>
</tr>
<tr>
<td>Amphibians</td>
</tr>
<tr>
<td>Mortality</td>
</tr>
<tr>
<td>Fencing</td>
</tr>
<tr>
<td>Mitigation</td>
</tr>
</tbody>
</table>
### Table 5: Most Common Words Used in Lake Jackson

<table>
<thead>
<tr>
<th>Word</th>
<th>Number of Times Used</th>
<th>Weighted Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turtles</td>
<td>616</td>
<td>2.87</td>
</tr>
<tr>
<td>Lake</td>
<td>362</td>
<td>1.68</td>
</tr>
<tr>
<td>Fencing</td>
<td>331</td>
<td>1.54</td>
</tr>
<tr>
<td>Highway</td>
<td>326</td>
<td>1.52</td>
</tr>
<tr>
<td>Roads</td>
<td>259</td>
<td>1.20</td>
</tr>
<tr>
<td>Mortality</td>
<td>169</td>
<td>0.79</td>
</tr>
<tr>
<td>Species</td>
<td>154</td>
<td>0.72</td>
</tr>
<tr>
<td>Migrations</td>
<td>114</td>
<td>0.53</td>
</tr>
<tr>
<td>Population</td>
<td>102</td>
<td>0.47</td>
</tr>
<tr>
<td>Wildlife</td>
<td>95</td>
<td>0.44</td>
</tr>
</tbody>
</table>

### Table 6: Most Common Words Used in Paynes Prairie

<table>
<thead>
<tr>
<th>Word</th>
<th>Number of Times Used</th>
<th>Weighted Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culverts</td>
<td>215</td>
<td>1.39</td>
</tr>
<tr>
<td>Construction</td>
<td>140</td>
<td>0.90</td>
</tr>
<tr>
<td>Roads</td>
<td>131</td>
<td>0.84</td>
</tr>
<tr>
<td>Highway</td>
<td>127</td>
<td>0.82</td>
</tr>
<tr>
<td>Wildlife</td>
<td>115</td>
<td>0.74</td>
</tr>
<tr>
<td>Survey</td>
<td>111</td>
<td>0.71</td>
</tr>
<tr>
<td>Barrier</td>
<td>97</td>
<td>0.62</td>
</tr>
<tr>
<td>Mortality</td>
<td>96</td>
<td>0.62</td>
</tr>
<tr>
<td>Wall</td>
<td>83</td>
<td>0.53</td>
</tr>
<tr>
<td>Species</td>
<td>69</td>
<td>0.44</td>
</tr>
</tbody>
</table>

### Table 7: Most Common Words Used in Long Point

<table>
<thead>
<tr>
<th>Word</th>
<th>Number of Times Used</th>
<th>Weighted Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wildlife</td>
<td>363</td>
<td>1.98</td>
</tr>
<tr>
<td>Improvements</td>
<td>222</td>
<td>1.21</td>
</tr>
<tr>
<td>Roads</td>
<td>222</td>
<td>1.21</td>
</tr>
<tr>
<td>Culvert</td>
<td>166</td>
<td>0.91</td>
</tr>
<tr>
<td>Turtles</td>
<td>139</td>
<td>0.76</td>
</tr>
<tr>
<td>Fencing</td>
<td>134</td>
<td>0.93</td>
</tr>
<tr>
<td>Mortality</td>
<td>122</td>
<td>0.67</td>
</tr>
<tr>
<td>Nests</td>
<td>103</td>
<td>0.56</td>
</tr>
<tr>
<td>Species</td>
<td>99</td>
<td>0.54</td>
</tr>
</tbody>
</table>
The table and word clouds for the individual cases allow us to visualize the major issues that are found within each case. These can be compared to the most used words in the reference literature material and also to the words that are found most frequently in all of the material. Table 9 describes the words that are used in at least 4 of the sub-groups. They are ranked based on how many times they are used in total and the number of uses in each case. This enables us to see which themes are common to all sub-groups and how important they are within each sub-group. For example, ‘turtle’ is the second most common used word and is very important for the Lake Jackson case but is not important in the Long Point case and is not among the top 10 most important words for Paynes Prairie. The theme of ‘fencing’ however, is common to all cases and is used frequently.
'Wildlife’ and ‘roads’ were two of the most used words in all of the material. Protecting wildlife is the driving factor in all ecopassage projects. The central purpose of ecopassages is to aid wildlife in getting across roads (Fahrig & Rytwinski, 2009; Rico, Kindlmann, & Sedlacek, 2007; Coffin, 2007). The Lake Jackson and Paynes Prairie cases also used the word ‘highways’ frequently (326 and 127 times respectively). There is no use in installing an ecopassage where there is no large risk to crossing wildlife. Most ecopassages are placed on highways. When determining the location for ecopassages it is important to select the stretches of road that need them the most in order to reduce costs. Highways pose a much larger risk to crossing wildlife than smaller roads (Jackson, 2000; Aresco, 2003; U.S. Geological Survey, 1999).

The type of wildlife using the road is also an important theme that showed up in the reference material and in all of the case studies. Most ecopassage projects to date have focused on herpetofauna. Herpetofauna, unlike most mammals and birds, cannot consciously avoid roads (Andrews, Gibbons, & Jochimsen, 2008; Beebee, 2013). Additionally many of the areas where large amounts of roadkill are found are locations where roads have been built.
across wetlands. These areas are rich in ecosystem services and biodiversity and contain large numbers of herpetofauna (Timm, 2014).

Mitigation is an important factor in planning ecopassages. It is much more difficult and costly to rebuild roads when it is determined that ecopassages must be put into place after the road has already been there for many years. The requirement for ecopassages should be determined during the environmental assessment stage of planning (Lesbarreres & Fahrig, 2012; Beebee, 2013). Every single source analyzed for this paper mentions mitigation at least once. If all roads were constructed with the environment and animals in mind then costly retrofit projects would not need to occur.

Possibly the most important factor in the success of any ecopassage project is fencing (Cunnington, Garrah, Eberhardt, & Fahrig, 2014). As previously discussed, most reptiles and amphibians do not know how to consciously avoid roads and thus do not realize that they would be safer if they passed through a culvert instead of on the road (Andrews, Gibbons, & Jochimsen, 2008; Beebee, 2013). Without fences, there is nothing to stop animals from accessing the roads and avoiding the culverts. A major theme in terms of fencing is to install fences that angle back away from roads when they end (Jongerden, 2008; Aresco M. J., 2005) this can be seen at the road intersections on the aerial photograph of Lake Jackson (Figure 2). This ensures that the animals will be directed away from the road and cannot just go around the end of the fence. Another common practice is to build smooth walls that have a lip at the top which prevents animals from climbing over (Aresco M. J., USA and the efficacy of a temporary fence/culvert system to reduce roadkills, 2003; Barichivich & Dodd, 2002; Jongerden, 2008). All of these measures ensure that the animals will be funnelled towards the
culverts and will actually use the ecopassages (Jongerden, 2008; Sparks & Gates, 2012).

Without fences there would be no successful ecopassages (Cunnington, Garrah, Eberhardt, & Fahrig, 2014).

**Paynes Prairie**

The themes found in the Paynes Prairie case study are very similar to those in the reference material. This in part is due to the fact that the Paynes Prairie ecopassage was one of the first in North America and the hope for the project was that it would inspire construction of future projects (U.S. Geological Survey, 1999). The area has a history of high amounts of roadkill and the aim of this project was to find the best way for animals to safely cross roads. Paynes Prairie was the first ecopassage to build a concrete wall with a lip, a design that is being copied by other ecopassage projects including Long Point. The image that is used to illustrate Paynes Prairie earlier in this paper (Figure 1) was also represented on the websites for the two other case study projects as an example of a good barrier wall (Lake Jackson Ecopassage Alliance, 2015; Long Point World Biosphere Reserve Foundation, 2008; Barichivich & Dodd, 2002).

One important issue that was found with the project was that the wall that was installed did not prevent hylids (tree frogs) from jumping over the barrier and onto the highway. There were still large numbers of hylids killed on the highway (Barichivich & Dodd, 2002; U.S. Geological Survey, 1999). Most other animals used the culverts effectively and there was a large reduction in the total number of animals killed on the road. If an ecopassage is being installed in an area that has a large number of tree frogs then the lipped wall design would need to be enhanced (Barichivich & Dodd, 2002; Dodd, Barichivich, & Smith, 2004).
Lake Jackson

Lake Jackson is the deadliest road for turtles in the world. In 2000, Matthew Aresco noticed the amount of turtles on the US Highway 27 and started research into why so many turtles were attempting to cross (Current Science, 2005; Aresco M., 2004). Aresco determined that the large number of turtle crossings is largely due to the migrations that occur between Lake Jackson and Little Lake Jackson (Aresco, 2005; Lake Jackson Ecopassage Alliance, 2015). The migrations occur annually when females cross to Little Lake Jackson in order to breed in a more sheltered environment. During periods of drought when Lake Jackson dries up, there are even large migrations of herpetofauna to Little Lake Jackson (Aresco, 2005; Aresco, 2003). This mass movement of animals is something that is not seen at the other case study locations and so is not discussed as a central theme in their literature.

In the reference literature, migration is mentioned as one of the central reasons for which animals attempt to cross roads (Coffin, 2007; Patrick, Schalk, Gibbs, & W., 2010). Many ecopassages are placed in areas where it is known a large number of animals will attempt to cross. When placing an ecopassage, research will be done to determine where the highest wildlife mortality is occurring and these locations are considered the hotspots (Aresco M. J., 2003; Jongerden, 2008; Garrah, 2012). This means that the maximum number of animals will use the culvert and animals will not need to travel long distances to access a culvert. Reptiles and amphibians move slowly and so it is necessary to have culverts that are close by (Fahrig & Rytwinski, 2009).
Long Point

One of the most used words in the Long Point project is ‘improvements’. The long point ecopassage design plan is to not only put in ecopassages but also to expand the road in order to create new recreation opportunities. Since the road will already be under construction in order to put in the 12 planned culverts the planning committee wants to take that opportunity to improve the road (Jongerden, 2008; Ashley & Robinson, 1996). If the project goes through according to plan there will be multiple benefits. There will be improved hydrological connectivity, the habitats of many species will be restored and an enhanced recreational experience will be provided (Jongerden, 2008).

Another issue at Long Point, and many other sites, is that female turtles use the road as a nesting site. At many other sites, such as Paynes Prairie, once culverts and fences are installed the turtles can no longer access the road and must find new sandy areas to nest (Jongerden, 2008). At Long Point, they are planning to construct new nesting sites so that the turtles will have a new area nearby in which to nest (Jongerden, 2008; Long Point World Biosphere Reserve Foundation, 2008; Wilson & Craig, 2008). The ecopassage at Long Point will go above and beyond what is required to allow animals to pass under a road. The widening of the road will create recreation and learning opportunities and the new nesting sites will assist turtles in adjusting to the changed environment (Jongerden, 2008).

1000 Islands

The most used words for the 1000 Islands case were very similar to those for the other cases. Some of the words that stood out for this case were ‘study’, ‘effects’, and ‘using’. The
word ‘using’ was also among the top 10 most common words for the Long Point case study. In both of these cases there was an emphasis on how the use of the road could be improved. For the 1000 Islands Parkway this is a combination of changing both wildlife and driver behaviour (Garrah, 2012). Since there are so many driveways that enter onto the parkway it is not possible to install a fence along the length of the road. In order to resolve this issue, Garrah (2012), proposes to attempt to change driver behaviour along with installing culverts and fencing in the hot spot areas. Encouraging drivers to slow down and be aware of crossing wildlife while also installing ecopassages, could lead to significant reductions in the death of animals on the 1000 Islands Parkway.

**Contribution to Theory and Practice**

It is already well discussed in the literature that it is important to identify the species that need protecting, to build fencing to accompany the ecopassages, and to build the wildlife culverts in areas where there are ‘hot-spots’ for migration. The themes that were brought out in the Long Point Causeway and 1000 Islands Parkway cases however, bring new ideas. The idea to incorporate both changes in driver behaviour and animal behaviour could lead to much better results in ecopassage projects. Also, the creation of multi-use roads would provide many benefits to the community and would help to negate some of the drawbacks from ecopassage projects.

Ecopassages are important for the environment, they allow for wildlife to pass under roads and reduce habitat fragmentation. Implementation of ecopassages should be included as part of the construction plan for all new roads that are built through sensitive habitats and
ecosystems. Road improvements should similarly plan for ecopassages. This would reduce the cost and time associated with constructing ecopassages. Additionally constructing ecopassages and roads concurrently should result in less disruption of species as they will not need to adapt first, to a barrier, and then to a new culvert system.

It is nearly impossible to stop every animal from entering a roadway even if the best possible ecopassage is built. For this reason, it is important to focus on how to change driver behaviour along with animal behaviour. Putting up road crossing signs does help to slow drivers at first but over many years these signs become less effective (Garrah, 2012). This research suggests that creating education programs could be more effective in changing driver behaviour. These education programs could start in schools to make children in the community more aware of the benefits that herpetofauna bring to the ecosystem and the risk that these species face every time they enter a roadway. These education programs could serve not only to help the wildlife but also to involve the community with their natural environment and could provide social benefits.

In the future, it is likely that many ecopassage systems will be constructed on roads that pass through wetlands. These are often beautiful environments that can be enjoyed by tourists, hikers, or people driving by. At Long Point Causeway, the current plan is to widen the road when building the ecopassages in order to create bike paths and observation platforms. By creating a multi-use road the community benefits along with the wildlife (Jongerden, 2008). The observation decks will serve as a platform for education and the bike paths will provide recreation opportunities. The drawbacks from ecopassage construction are time, cost, and public perception (Garrah, 2012). By creating a multi-use road you are providing a benefit to
the community. This can help to offset the perceived negative aspects of cost and time for the project which may then help to improve public perception.

These two case studies show that there are some changes occurring in the practice of developing ecopassages. It is important to bring these ideas into the theory. During the planning stages there should be integration between land-use planning and conservation biology. This could be done using collaborative planning theory. Collaborative planning theory suggests that by bringing in multiple stakeholders with different opinions you can create better plans for both the environment and society (Healy, 2003). It is important that discussion and collaboration take place between town planners, environmental groups, and departments of transportation. When multiple uses are combined, more benefits to a single project may be realised.
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