Freshwater Turtle Population Characteristics and Habitat Use within Ontario's Dunnville Marsh Area

by

Bethanee Brown

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Author’s Declaration for Electronic Submission of a Thesis

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Habitat conservation and restoration can be effective solutions to habitat loss, fragmentation, and degradation that impacts freshwater turtle species. Although some studies have been conducted in Ontario regarding freshwater turtle habitat use, few studies have examined habitat use within and adjacent to an ecologically restored riparian area. The purpose of this study was to determine freshwater turtle population characteristics and areas of micro and macrohabitat use located within and adjacent to an ecologically restored marshland in Southern Ontario. Mark and recapture of freshwater turtles took place with the use of baited hoop nets and basking traps. Twelve turtles were radio-tracked throughout the active season, which included 11 painted turtles (*Chrysemys picta*) and one Blanding's turtle (*Emydoidea blandingii*). Microhabitat variables were measured and recorded at relocation points, and macrohabitats were mapped with location points in ArcMap 10.3.1. The most abundant species was painted turtles, followed by snapping turtles (*Chelydra serpentina*), and Blanding's turtles. The overall male to female ratio for adult painted turtles was 2.6:1, and the adult to juvenile size-class ratio was 3:1. The adult to juvenile size-class ratio for snapping turtles was 1:1. Only one female juvenile Blanding's was captured throughout the field season. The mean daily distance travelled by turtles was 25.9 meters for females and 13.3 meters for males. A repeated measures ANOVA test revealed that the sex, as well as month (season) significantly influenced daily distances travelled. Average home ranges were 5.9 hectares for females, and 2.7 hectares for males. A one-way ANOVA test indicated there was no significant influence of sex on home range size. Painted turtles spent the most time in Mixed Shallow Aquatic habitats, while the Blanding's turtle spent the most time in Organic Shallow Marsh habitats. Individuals did not appear to use the interior marsh or the ecologically restored areas due to a difference in microhabitat variables compared to areas of habitat use. Further restoration of the marsh to include macro and microhabitats variables that accommodate the needs of freshwater turtles could encourage individuals to occupy the interior areas of the restored marsh.

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Chapter 1 - Introduction

1.1 Problem Statement

Southern Ontario is the most densely populated region in Canada, with the majority of its land occupied by agriculture and urban landscapes (Bone, 2014). Due to urban sprawl, the encroaching boundaries of urban areas in the form of housing, roads, and retail outlets replace and fragment natural areas occupied by wildlife (Bone, 2014). This can have a devastating impact on biodiversity and wildlife populations within Southern Ontario (Freedman, 2010; Bone, 2014). As indicator species who are very sensitive to their environment, certain species of reptiles and amphibians are often the first to show signs of decline due to changes in their environment (Bishop & Gendron, 1998; Mifsud, 2014). Southern Ontario is home to eight species of freshwater turtles, seven of which are either listed as endangered, threatened, or a species of special concern under the Canadian Species at Risk Act (Ministry of Natural Resources and Forestry [MNRF], 2015). This demonstrates the need to understand turtle habitat use within Southern Ontario, in order to direct policy to preserve suitable habitats for the protection of these species.

Habitat loss, fragmentation, and degradation have the greatest impact on different turtle species (De Solla, Palonen, & Martin, 2014; Dorland et al., 2014; Mifsud, 2014). Over the past several decades, shoreline development, increased recreational use of waterways, and the conversion of riparian areas to farmland within Southern Ontario has reduced suitable habitat for freshwater turtles (Bennett & Litzgus, 2014; Mifsud, 2014; Roosenburg et al., 2014). In light of mitigating these impacts, ecological restoration is often acknowledged as a way to provide suitable habitat for turtle species, thereby contributing to their conservation (Erb & Jones, 2011; Hartwig & Kiviat, 2007; Mifsud, 2014; Roe & Georges, 2007; Roosenburg et al, 2014).

Freshwater turtles utilize habitats that encompass a variety of characteristics to support different behaviours such as open or cryptic basking, hiding to avoid predators, finding food, courting or mating, overwintering, or travelling on land to nest (Steen et al., 2012; Yagi & Litzgus, 2012).

This can make it difficult to determine or achieve all habitat requirements within riparian land restoration projects to accommodate freshwater turtle species (Steen et al., 2012). Through examination of current literature, it becomes apparent that researchers often study how certain threats impact turtle populations, and then they suggest ways to mitigate such impacts through efforts involving habitat management and ecological restoration (Erb & Jones, 2011; Hartwig & Kiviat, 2007; Mifsud, 2014; Roe & Georges, 2007; Roosenburg et al., 2014). One form of ecological restoration is removal of invasive species like *Phragmites australis*, which grow denser than native vegetation in wetlands, thereby reducing the ability for turtles to travel (Mifsud, 2014). The construction of nesting habitat on islands within wetlands to reduce nest predation rates caused by mammals is an alternative path (Roosenburg et al., 2014). The presence of suitable nesting sites is of particular importance when restoring a habitat for freshwater turtles because nests often become concentrated within small areas due to habitat loss, causing high nest predation rates and an overall decline in turtle population numbers (Roosenburg et al., 2014). The construction of nesting sites can also protect turtle population numbers by reducing the required travel distance to find a suitable nesting site. This could reduce mortality caused by vehicles, agricultural equipment, and predation by mammals as turtles travel across fragmented landscapes (Dowling, Hartwig, Kiviat, & Keesing, 2010; Steen et al., 2012).

Although some studies have been conducted in Ontario regarding freshwater turtle habitat use, few studies have examined freshwater turtle habitat use within and adjacent to an ecologically restored riparian area. There are no documented scientific studies regarding community structure or population characteristics of freshwater turtles within the Dunnville marshland, located in Southern Ontario. The Dunnville marshland is an interesting area to conduct the proposed study because a large portion of the marsh was ecologically restored from farmland to upland forest and marshland (GRCA, 2012). The main purpose of this study is to determine freshwater turtle population characteristics and areas of habitat use within and adjacent to the ecologically restored marsh located within Dunnville, Ontario. The answer to this question can determine whether or not the restored area is supporting freshwater turtle species, and what habitat characteristics are ideal for their survival in this area. The study will also aid future studies done in the area by providing updated information regarding the variety, abundance, and distribution of freshwater turtle species within the Dunnville marshland.

1.2 Research Objectives

The main research objective is to determine freshwater turtle population characteristics and areas of habitat use located within and adjacent to the ecologically restored area in Dunnville. Since Southern Ontario's freshwater turtle species are semi-aquatic, they use a variety of different landscapes and could nest within dry upland areas of the restored marsh if they do not primarily live in the area (Steen et al., 2012). The restored marsh is adjacent to other wet landscapes that are suitable for providing habitat for turtles, such as a canal, ponds, and streams that flow into the Grand River. Turtle population characteristics and areas of habitat use were examined in these adjacent areas in addition to areas within the restored marsh. This allows for multiple habitat types to be assessed so habitat use characteristics can be compared to those areas within the restored marsh that are not used by freshwater turtles. Understanding the habitat preferences and needs of freshwater turtle species is required to successfully restore land that meets their habitat needs. Information regarding the habitat use of freshwater turtles in the area will provide guidance to further restore the Dunnville marsh area, or land within other regions, to provide habitat for freshwater turtles. Overall, this information is beneficial to the conservation of freshwater turtle species within Southern Ontario.

The main research objective is addressed through answering a series of sub-questions. These include the following:

I. How many different species of freshwater turtles are present within and adjacent to the restored marsh?
II. Which turtle species are more abundant than others within and adjacent to the restored area?
III. What are the population characteristics of the species (male to female ratio; juvenile to adult ratio)?
IV. How are freshwater turtles dispersed or concentrated throughout the area?
V. In what type of macrohabitats are individuals located?
VI. What are the microhabitat characteristics of the area where each turtle is located (e.g. water and air temperature, water depth, canopy cover, submerged aquatic vegetation cover, and shoreline vegetation density)?
VII. How many nests are present in the areas of study, if any?
VIII. What are the macro and microhabitat characteristics in areas where nests are located (e.g. canopy cover, ground vegetation cover, soil temperature, and soil texture)?
IX. What are the differences in habitat characteristics between areas of habitat use and areas not utilized by turtles in the marsh?

1.3 Thesis Organization

This thesis is comprised of eight chapters, beginning with an introduction that describes the problem statement and research objectives in Chapter 1. Chapter 2 is the literature review which gives an overview of research within the area of study. Topics covered in the literature review include macro and microhabitat use, threats to freshwater turtle survival and their habitats, current habitat management techniques, and ecological restoration as a tool for freshwater turtle conservation. Chapter 3 gives background information on the three turtle species that were involved in this study. The background information includes a physical description of the species, the range of each species within Ontario, the active season and overwintering, diet, mating and nesting behaviour. Chapter 3 also describes the area of study and where trapping, tracking, and surveying took place. Chapter 4 is the methodology, which details the procedures involved in trapping, tagging, and tracking turtles, and how environmental variables were measured in areas of habitat use. Chapter 5 outlines the study's results and findings. Chapter 6 is a detailed discussion of the results and how they answer the research questions. Finally, Chapter 7 concludes the study and gives recommendations for conservation and future research.

Chapter 2 - Literature Review

2.1 An Overview of Freshwater Turtle Research Conducted in Ontario

There have been several studies on freshwater turtles conducted throughout Ontario. Most of the studies focus on population structures, home ranges, threats, and habitat use of Ontario's freshwater turtle species (Bennett & Litzgus, 2014; DeCatanzaro & Chow-Fraser, 2010; Gunson, Ireland, & Schueler, 2012; Hughes & Brooks, 2006; Millar & Blouin-Demers, 2011; Obbard & Brooks, 1980; Paterson, Steinberg, & Litzgus, 2012; Rollinson & Brooks, 2007; Yagi & Litzgus, 2012). These topics provide context on how to protect freshwater turtle species' survival, since seven of Ontario's eight freshwater turtle species are listed as species at risk by the Ministry of Natural Resources and Forestry (MNRF, 2015). Two key authors who have published several studies on freshwater turtles in Ontario are Dr. Ronald Brooks from the University of Guelph, and Dr. Jaqueline Litzgus from Laurentian University. Dr. Ronald Brooks has participated in several studies located in Algonquin Park, studying topics such as nesting migrations of snapping turtles, nest-site selection by painted turtles, and the frequency of painted turtle nest depredation (Hughes & Brooks, 2006; Obbard & Brooks, 1980; Rollinson & Brooks, 2007). Dr. Jaqueline Litzgus has participated in studies conducted in Algonquin Park, Sudbury, Southern Ontario, and along the Trent-Severn Waterway in Ontario. Some of Dr. Jaqueline Litzgus' published studies include information regarding injury rates of freshwater turtles on recreational waterways, nest-site selection by wood turtles, habitat selection by snapping turtles, and the effects of flooding on the spatial ecology of spotted turtles (Bennett & Litzgus, 2014; Hughes, Greaves & Litzgus, 2009; Paterson et al., 2012; Yagi & Litzgus, 2012). Other studies done in Ontario have taken place in the St. Lawrence Islands National Park, within coastal marshes along three Laurentian Great Lakes, in Point Pelee National Park, and at several turtle road crossing hotspots throughout Southern Ontario. Topics of study conducted in these areas include the spatial ecology and seasonal activity of Blanding's turtles, the relationship of road density and marsh condition to freshwater turtle assemblage characteristics, species loss and shifting population structures of freshwater turtles, and ways to identify high-risk road mortality locations (Browne & Hecnar, 2007; DeCatanzaro & Chow-Fraser, 2010; Gunson et al., 2012; Millar & Blouin-Demers, 2011). Each of these studies conducted in Ontario reveal important information that guides government policy regarding land-use planning and herpetofauna conservation, thereby contributing to the protection of Ontario's eight freshwater turtle species.

2.2 Threats to Turtle Populations

2.2.1 Habitat loss

Habitat loss through urbanization and land conversion to agriculture has significantly contributed to declining turtle population in Southern Ontario and other areas surrounding the Great Lakes (Mifsud, 2014; Wieten, Cooper, Parker, & Uzarski, 2012). Habitat loss can impact turtle populations for various reasons. For example, habitat loss can lead to a reduction in turtle populations from increased predation (Browne & Hecnar, 2007; Holcomb & Carr, 2014; Mifsud, 2014; Paterson, Steinberg, & Litzgus, 2012). Predators of turtles such as raccoons, possums, skunks, and coyotes are habitat generalists and can adjust more easily to landscapes converted into urban or agricultural areas (Holcomb & Carr, 2014; Mifsud, 2014). For example, raccoon populations can sometimes increase in areas converted into an urban landscape because of food availability from garbage waste (Mifsud, 2014). In contrast, most turtle species require very specific habitats to meet their survival needs and cannot survive in an urban or agricultural landscape (De Solla et al, 2012; Mifsud, 2014). As natural wetland areas shrink in size from encroaching anthropogenic development, turtle populations and their nests often become concentrated in these small areas. This makes adult turtles, juveniles, and turtle eggs more vulnerable to predators like raccoons (Browne & Hecnar, 2007; Holcomb & Carr, 2014; Mifsud, 2014; Paterson et al., 2012). Similarly, because turtles are slower and less mobile than many other species, they are less likely to be able to adapt to anthropogenic development that introduce habitat barriers like fences and curbs (Mifsud, 2014; Paterson et al., 2012). Although turtles can nest in lawns, along diked wetlands, and on sandy beaches, these areas introduce a series of other threats to nests and hatchlings, such as lawnmowers, embryo suffocation from alterations in water levels, and beach grooming (Mifsud, 2014).

2.2.2 Habitat fragmentation

Habitat fragmentation caused by roads, drainage ditches, agricultural lands, housing, and invasive species can reduce turtle populations (Beaudry, deMaynadier, & Hunter Jr., 2008; Dorland et al., 2014; Mifsud, 2014; Proulx, Fortin, & Bloudin-Demers, 2014). Several studies have been undertaken to discover the impacts that habitat fragmentation can have on turtle populations, and how these impacts can be mitigated.

Fragmentation caused by roads

Roads are a main cause of habitat fragmentation and direct mortality of turtles (Proulx et al., 2014). Proux et al. (2014) conducted a study to test the hypothesis that roads pose a barrier to the movements of Blanding's Turtles. The researchers calculated the number of inferred road crossings from movement data obtained by radio-telemetry on 52 individuals (Proux et al., 2014). The researchers found that 24 of the 52 radio-tracked Blanding's Turtles crossed roads. Blanding's turtles crossed roads on an average of two times during the active season, but if moving randomly in relation to roads, they would cross an average of six times (Proulx et al., 2014). Overall, the researchers concluded that Blanding's Turtles crossed roads significantly less than expected. The researchers also concluded that both male and female Blanding's Turtles purposefully avoid roads that are paved or unpaved, regardless of whether or not they have vehicular traffic (Proulx et al., 2014). This could indicate that the construction of roads through Blanding's turtle habitat can significantly reduce the amount of habitat available for their use. Blanding's turtle's could become isolated from important nesting, basking, or overwintering areas since they avoid crossing roads, which could eventually impact their population.

Another study examined how road collisions can impact aquatic, semi-aquatic, and terrestrial turtle populations (Steen et al., 2006). Aquatic, semi-aquatic, and terrestrial female turtles travel more frequently than male turtles at certain times of the year to nest, and may seek out roadsides during nesting season due to loose gravel along roadsides that is attractive as nesting material (Steen et al, 2006). This has lead researchers to hypothesize that female turtles are more likely to experience mortality by road collisions, causing male-biased sex ratios within turtle populations (DeCatanzaro & Chow-Fraser, 2010; Steen et al., 2006). Steen et al. (2006) tested this hypothesis by examining sex ratios from 157 studies that surveyed areas for turtles both on-road and off-road. The researchers discovered that of the 38,166 turtles recorded in surveys, a larger percentage of females were reported to be found on roads (61%), either dead or alive, than found off roads (41%) (Steen et al., 2006). A higher proportion of aquatic and semi-aquatic female turtles were found to be encountered on roads then aquatic and semi-aquatic male turtles. The researchers concluded that female turtles are likely to cross roads more than males, leading to biased sex ratios and eventual population declines caused by road mortality of nesting females (Steen et al., 2006). This study signifies the negative impacts land fragmentation can have on turtle populations, as well as the importance of maintaining connective corridors between terrestrial and aquatic habitats used by aquatic and semi-aquatic turtle species.

Fragmentation caused by invasive species

Mifsud (2014) examined the abundance of reptile and amphibian species throughout the Saginaw Bay area; turtle populations were significantly lower, if not completely absent, in areas that contained invasive *Phragmites australis* (Mifsud, 2014). Although there is a species of *Phragmites* native to North America, *Phragmites australis* is thought to be an invasive sub-species from Eurasia that grows more dense and crowds out native vegetation (MNRF, n.d.). Dense stands of *Phragmites australis* restrict the movement of turtles throughout wetland and upland areas, which reduces the potential for turtles to use these areas as travel corridors (Mifsud, 2014). This demonstrates that not only do athropogenic features fragment turtle habitats, but invasive species like *Phragmites australis* can also fragment turtle habitat and restrict their movement across a landscape (Mifsud, 2014).

2.2.3 Habitat degradation

Water quality and its impact on turtles

Habitat degradation from urban and agricultural pollutants is another issue that affects turtle populations (Burgin & Ryan, 2008; De Solla et al., 2014; Mifsud, 2014; Tryfonas et al., 2006). Continued degradation of waterways may be the most significant environmental threat to the survival of freshwater turtles (Burgin & Ryan, 2008). Freshwater turtles rely on permanent water sources to forage for food and hide from predators during times of drought; however, temporary wetlands also provide habitat for foraging and shelter from predators when flooded (Cosentino et al., 2010). The quality of these water sources can affect the structure and abundance of freshwater turtle populations (Burgin & Ryan, 2008; DeCatanzaro & Chow-Fraser, 2010). DeCatanzaro and Chow-Fraser (2010) examined freshwater turtle populations in areas with different water qualities throughout the Laurentian Great Lakes region. The Water Quality Index (WQI) and the Wetland Macrophyte Index (WMI) were used to determine the ecological condition of each marsh area (DeCatanzaro & Chow-Fraser, 2010). Wetland sites rated as having excellent water quality conditions were mainly located in Georgian Bay and the North Channel, while lower quality sites were in Lake Erie and Lake Ontario. Wetland sites rated as having the lowest water quality were located in the western end of Lake Ontario (DeCatanzaro & Chow-Fraser, 2010). Species richness was highest in wetland areas containing a 'good' water quality; painted turtles were the most abundant turtle species in degraded wetlands, and common snapping turtles were most abundant in wetlands containing intermediate water quality (DeCatanzaro & Chow-Fraser, 2010). The common musk turtle was most abundant in regions with low human disturbance and high water quality, such as Georgian Bay and the North Channel, and was absent from degraded wetlands near Lake Erie and Lake Ontario (DeCatanzaro & Chow-Fraser, 2010). The lower Great Lakes (Erie and Ontario) fall within the historic range of common musk turtles. Therefore, their absence from this area is likely related to a decrease in water quality caused by human disturbance (DeCatanzaro & Chow-Fraser, 2010). The study indicates that wetland water quality is related to freshwater turtle species richness, and wetlands containing water of a high quality is more likely to support a variety of turtle species.

Soil pollutants and their impact on turtles

Soil degradation from urban and agricultural pollutants is an issue that affects turtle populations (De Solla & Martin, 2007; De Solla & Martin, 2011; De Solla et al., 2014; Mifsud, 2014; Sparling et al., 2006; Tryfonas et al., 2006). Contaminants in soil from agricultural pesticides, fumigants, and fertilizers can threaten turtle populations by increasing the mortality rate of turtle eggs (De Solla et al., 2014). De Solla et al. (2014) evaluated the toxicity of a pesticide regime, which is used for potato production in Ontario, on the survival rate of snapping turtle eggs. A mixture of four different pesticides, as well as the soil fumigant metam sodium was applied to soil used to incubate snapping turtle eggs (De Solla et al., 2014). The researchers found that the pesticide mixture did not affect survival rates, deformities, or body size of hatchlings at applications up to 10 times the typical field application rates. However, eggs exposed to the lowest recommended application of metam sodium had 100% mortality (De Solla et al., 2014).

Sparling et al. (2006) examined the impact of soil contaminated with the pesticide known as glyphosate on embryos and early hatchlings of the red-eared slider. Turtle eggs are porous and can absorb moisture from surrounding soil, as well as exchange gases with the atmosphere (De Solla & Martin, 2011; Sparling et al., 2006). This leaves turtle embryos vulnerable to soil contaminants like glyphosate (Sparling et al., 2006). Sparling et al. (2006) discovered that red-eared slider eggs exposed to soil containing high levels of glyphosate (1,501-11,206 ppm) had a lower hatching success rate (73-93%) compared to the success rate of eggs that were not exposed to soil contaminated with glyphosate (100% success), or that were exposed to low levels of glyphosate (68-466 ppm). Furthermore, the researchers found that hatchlings exposed to soil containing high levels of glyphosate had significantly lower body mass, and lacked the ability to right themselves when turned on their backs in comparison to hatchlings that were not exposed to high levels of the contaminant. The researchers also found a relationship between genetic damage and the concentration of glyphosate in soil, where genetic damage increased as the concentration increased (Sparling et al., 2006). However, the researchers concluded that normal field application amounts of glyphosate would not harm red-eared slider turtle eggs, and only carelessness in handling glyphosate or failure to follow label directions could lead to high contamination of soil and damage to eggs (Sparling et al., 2006). The study is significant because it shows that high concentration of certain pesticides, which would otherwise be safe, can harm populations of young turtles.

A similar study conducted by Tryfonas et al. (2006) examined levels of metal contamination in water, river sediment, soil, and plants in the Lower Illinois River Basin, as well as metal accumulation in eggs of the red-eared slider. The researchers found that high concentrations of metals from municipal pollution sources were present in lake sediment and the surrounding soil (Tryfonas et al., 2006). Five detectable metals were found in the red-eared slider egg content that were also present in the contaminated soil. These metals included Zinc, Aluminum, Tin, Manganese, and Copper (Tryfonas et al., 2006). The study shows that metals accumulating in river beds and surrounding soil from industrial and municipal sources can be absorbed into turtle eggs during their development. This can negatively impact turtle populations, since certain forms of Tin (organotin) can have damaging effects on the immune system, physical development, and endocrine system of turtles (Tryfonas et al., 2006).

De Solla and Martin (2011) examined the extent that snapping turtle (*Chelydra serpentina*) eggs absorbed different pesticides from contaminated soil. The researchers incubated eggs in soil contaminated with 10 different pesticides of varying amounts, and eggs were removed from the mixture after one and eight days of exposure and analyzed for pesticides (De Solla & Martin, 2011). It was discovered that out of the 10 pesticides, atrazine and metolachlor had the greatest absorption rates into eggs, and azinphos-methyl had the lowest (De Solla & Martin, 2011). Furthermore, the researchers determined that pesticides which had the highest absorption into eggs also had high water solubility. This could indicate that the pesticides are absorbed into eggs as they take in moisture from the surrounding soil (De Solla & Martin, 2011).

This study is important for understanding how soil contaminants can impact turtle populations because it demonstrates that some pesticides are more easily absorbed into turtle eggs than others. The use of certain pesticides, like azinphos-methyl, might be preferential versus others that are more easily absorbed into turtle eggs from agricultural soil (De Solla & Martin, 2011).

An earlier study done by De Solla and Martin (2007) examined the effects of two nitrogenous fertilizers, known as urea and ammonium nitrate, on the survival rate of snapping turtle eggs. Eggs were incubated and exposed to realistic levels of fertilizers in an outdoor garden plot, as well as in soil enclosed in bins to minimize loss of nitrogenous compounds through soil leaching (De Solla & Martin, 2007). Neither urea nor ammonium nitrate had any impact on hatching success or development of snapping turtle eggs that were incubated in the garden plot; however, laboratory exposures in enclosed bins resulted in lower hatching success, lower body mass of hatchlings, and reduced rates of post-hatching survival compared to controls (De Solla & Martin, 2007). De Solla and Martin (2007) explain that the snapping turtle eggs exposed to fertilizers in outdoor soil plots were most likely unaffected by the fertilizers due to soil leaching and atmospheric loss. This finding is important because it suggests that fertilizers in soils which have a higher leaching capacity could be less damaging to turtle eggs (De Solla & Martin, 2007).

2.3 Habitat Use and Requirements

2.3.1 Habitat used by different species

Many different factors, such as wetland type, vegetation, and abiotic conditions, influence turtle community structure throughout landscapes (Lescher, Tang-Martinez, & Briggler, 2013; Wieten et al., 2012). Different turtle species prefer different habitats for hibernating, feeding, or nesting, which means that habitat requirements depend on the turtle species (Lescher et al., 2013; Pittman & Dorcas, 2009; Wieten et al., 2012). Wieten et al. (2012)

examined the effects of different habitat conditions on turtle communities in 56 wetlands throughout the Great Lakes region. Overall, 1,366 turtles representing seven species were used in the study. Turtle species abundance was identified in three different wetland types (drowned river mouth, protected embayment, and fringing exposed wetlands) and six vegetation types (water lily, arrow arum, submerged aquatic vegetation, bulrush, bur-reed, and cattail; Wieten et al., 2012). The study found that most of the different turtle species prefer to live in drowned river mouth wetlands as opposed to protected embayment or fringing exposed wetlands. Red-eared sliders, spiny softshells, map turtles, Blanding's turtles, musk turtles, common snapping turtles, and painted turtles were all found in drowned river mouth wetlands. However, only painted turtles and common snapping turtles were found in protected embayment and fringing exposed wetlands (Wieten et al., 2012). The study also found that the different turtle species preferred certain vegetation types. For example, painted turtles were most abundant in cattail and submerged aquatic vegetation, while map turtles were found in water lilies, submerged aquatic vegetation, bulrush, and cattail (Wieten et al., 2012). The study demonstrates that different turtle species prefer different habitat types, which is useful information when conducting ecological restoration for certain turtle species (Mifsud, 2014; Paterson et al., 2012; Wieten et al., 2012). Pittman and Dorcas (2009) found that habitat specialists, like the bog turtle, require specialised wetland habitats. The researchers radio-tracked and monitored 11 adult bog turtles at an isolated meadow bog in North Carolina. It was discovered that the bog turtles used soft, shallow mud habitat in the bog, but moved to a streambed when the bog became dry (Pittman & Dorcas, 2009). While in the bog, turtles were often found within or underneath woody debris, and all but one turtle overwintered in a streambed adjacent to the bog. The findings suggest that high-quality bog habitat and microhabitat heterogeneity are important for populations of isolated bog turtles

(Pittman & Dorcas, 2009). Each of the studies analyzed suggest that different species of turtles require and prefer certain habitat types.

2.3.2 Snapping turtle habitat use

Other researchers have studied habitat requirements of habitat generalist species, like the snapping turtle (Lescher et al., 2013; Paterson, Steinberg, and Litzgus, 2012; Ryan, Peterman, Stephens, & Sterrett, 2014). Ryan et al. (2014) conducted a study on the common snapping turtle that examined the manner in which an urban landscape's varied environment shapes movements and habitat associations of the snapping turtle. The study found that waterways surrounded by residential areas were rarely used by snapping turtles (Ryan et al., 2014). Snapping turtles were more likely to hibernate in waterways surrounded by woodlots than other landscapes within the urban setting, and were most commonly found using waterways surrounded by woodlots, followed by residential areas, roads, commercial areas, and rivers (Ryan et al., 2014). Snapping turtles were least likely to be found in waterways surrounded by open areas (Ryan et al., 2014). The study is significant because it suggests that waterways surrounded by woodlots in urban settings serve as important habitat for snapping turtles to live and hibernate within. A similar study by Paterson et al. (2012) examined habitat selection of the snapping turtle throughout Algonquin Provincial Park, located in Ontario. The study found that snapping turtles were most abundant in marsh, nesting habitats, and swamp habitats, followed by ponds, lakes, and fens (Paterson et al., 2012). Moreover, snapping turtles were least abundant in rivers, creeks, and forest (Paterson et al., 2012). Overall, the snapping turtles were found to prefer home ranges close to wetland and nesting habitats, and were farthest from upland forest habitat. This study is significant to conservation and restoration initiatives, because it suggests that snapping turtles prefer damp and lentic habitats, over flowing water or forested areas.

Lescher et al. (2013) compared habitat use by the alligator snapping turtle and eastern snapping turtle. Alligator snapping turtles preferred waterways that contained a high abundance of submerged physical structures, deeper water, relatively high levels of detritus, and warmer water temperatures (Lescher et al., 2013). Furthermore, eastern snapping turtles preferred waterways that contained greater amounts of aquatic vegetation. The findings suggest that future conservation plans should consider microhabitat characteristics of sites used by the alligator snapping turtle and the eastern snapping turtle (Lescher et al., 2013). Although certain turtle species select overwintering sites based on water depth, research regarding snapping turtle selection of overwintering sites indicates that water depth does not play a large role in site selection (Paterson et al., 2012). However, temperature is an important factor in site selection. Snapping turtles have been found to select overwintering sites with low temperatures to reduce metabolic costs and metabolic acidosis (when the body produces excessive amounts of acid; Paterson et al., 2012). This information regarding snapping turtle habitat selection is important for understanding what habitat types should be preserved or restored in order to protect the at risk species.

2.3.3 Blanding's turtle habitat use

Blanding's turtles normally live in shallow water within marshes and lakes (MacCulloch, 2002). They are known to wander onto land, but do not normally travel far distances unless they are in search of suitable nesting habitat (MacCulloch, 2002). A study done in Ontario, at St. Lawrence National Park, tracked 38 Blanding's turtles via radio-telemetry to examine microhabitat selection, home ranges, and movement patterns in relation to reproduction (Millar & Blouin-Demers, 2011). The researchers tracked 20 males, 13 gravid (carrying eggs) females, and 5 non-gravid females. Microhabitat features examined include percentages of emergent, submerged, and floating vegetation, as well as water depth, water temperature, and air temperature (Millar & Blouin-Demers, 2011). Blanding's turtles selected colder waters, at a depth of 1-220 cm, with muck substrate, and an abundance of floating and submerged aquatic vegetation (Millar & Blouin-Demers, 2011). The probability of a Blanding's turtle selecting a habitat area increased by 70% if there was a 25% increase in submerged aquatic vegetation cover. However, if the amount of open water increased by 25%, there was a 31% decrease in the probability of that habitat being selected by a Blanding's turtle. It is thought that Blanding's turtles select these microhabitat features because they provide a sufficient amount of food and shelter from predators (Millar & Blouin-Demers, 2011). This demonstrates that environments being restored to support Blanding's turtles should have an abundant amount of floating and submerged aquatic vegetation. Gravid females had a significantly larger home range than males and non-gravid females, which is likely due to travel distances to find suitable nesting areas; and nesting females occupied wetlands adjacent to their nesting sites (Millar & Blouin-Demers, 2011). This is important information for land use planning to conserve the species, and may also indicate the importance of connective corridors between different habitat types (Hartwig & Kiviat, 2007; Millar & Blouin-Demers, 2011).

Hartwig and Kiviat (2007) conducted a similar study that examined microhabitat preferences of Blanding's turtles. Similar to Millar and Blouin-Demer's (2011) study, the researchers discovered that Blanding's turtles preferred habitats with muck substrates, dense submerged aquatic vegetation, and an abundance of nearby vegetation cover (Hartwig & Kiviat, 2007). Contrary to Millar and Blouin-Demer's (2011) study, Hartwig and Kiviat (2007) determined that Blanding's turtles favoured warm shallow water, at depths of 1-110 cm, rather than water with cooler temperatures and greater depths. Regarding preferred nesting habitat for

Blanding's turtles, they tend to select well-drained sparsely vegetated soil for nesting (Dowling, Hartwig, Kiviat, & Keesing, 2010). Blanding's turtles have been found to travel farther distances to find suitable nesting areas if traditionally used nesting areas become overgrown with vegetation (Dowling et al., 2010). This further demonstrates the importance of connectivity between different habitat types, as well as preserving suitable nesting areas close to living areas, since longer travel distances can subject turtles to increased chances of predation, collection, or road mortality from vehicles (Dowling et al., 2010).

2.3.4 Painted turtle habitat use

Painted turtles are known to prefer smaller bodies of water, like ponds and slow moving lentic systems, but are also found in sheltered bay areas of rivers and lakes (Costentino, Schooley, and Phillips, 2010; MacCulloch, 2002). Painted turtles are also known to inhabit shallow wetlands with aquatic vegetation, and prefer areas that contain a lot of basking sites, such as logs, rocks, sloped shoreline, and floating or submerged aquatic vegetation (Costentino et al., 2010; MacCulloch, 2002). Costentino et al. (2010) examined painted turtle habitat use in relation to wetland hydrology, habitat area, and isolation. Measured variables included emergent vegetation cover, canopy cover, water pH, and whether wetland areas had a permanent source of water or were temporarily inundated (flooded). Most painted turtles spent the majority of the season in permanently flooded or long-hydroperiod wetlands, and were more likely to occupy highly connective wetlands rather than isolated patches (Costentino et al., 2010). Furthermore, painted turtles actively selected sites containing high water levels, abundant emergent vegetation, and minimal canopy cover. Individuals were thought to select these areas due to the abundance of biomass production (food sources) found in open marshes with high amounts of emergent vegetation, rather than closed canopy wetlands that have a lower ground vegetation biomass (Cosentino et al., 2010). This study reveals certain habitat characteristics that are preferred by painted turtles, which is useful information when making decisions regarding the best way to restore a landscape to support painted turtles, or what types of landscapes should be preserved in order to protect painted turtle populations.

2.3.5 Turtle nesting habitat

Microhabitat characteristics of nest sites

In general, most semi-aquatic freshwater turtles prefer to nest in areas containing sandy soil, low to moderate ground vegetation cover (less than 20%), and low canopy cover that allows an abundance of sunlight to reach the nest site (since nest temperature is related to embryo development; MacCulloch, 2002; MNRF, 2010). Freshwater turtles have been found to nest in a variety of modified habitats which include road shoulders, railway embankments, clear-cut forests, agricultural fields, pastures, and gravel pits (MNRF, 2010). Hughes and Brooks (2006), examined the relationship between painted turtle hatching success rates, and the microhabitat characteristics of nest sites. Painted turtles selected nest sites containing little canopy cover, sparse understory (ground) vegetation, and a south-western slope aspect (Hughes & Brooks, 2006). Turtles are thought to choose nest sites based on slope direction and angle because nest temperature is related to embryo development, and the operative temperature of a turtle's nest depends on exposure to solar radiation (Hughes & Brooks, 2006). Moreover, nests containing less soil organic content showed a greater survival to hatch than nests with higher amounts of soil organic content. This could be because soil containing larger amounts of organic content tends to hold in water, which could prevent gas exchange through eggshells and cause suffocation of embryos (Anderson & Horne, 2009). Overall, the study found that nests in sites selected by turtles had higher survival to hatch rates than nests chosen randomly by the researchers. This indicates that turtles might consciously choose nest sites that increase offspring survival. The study is significant because it identifies microhabitat characteristics that are important for turtle nest survival and offspring fitness.

Soil types and their impacts on nests

Freshwater turtles require both aquatic and terrestrial habitat in order to survive. They use aquatic habitat to forage and regulate their body temperature, and upland terrestrial habitat for nesting (Costanzo et al., 2001; Hughes & Brooks, 2006; Steen et al., 2012). While some freshwater turtle species will travel only 8 meters away from a freshwater source, such as a swamp, in search of suitable nesting habitat, others will travel as far as 1400 meters (Steen et al., 2012). Soil plays an important role in providing suitable nesting habitat for freshwater turtles (Anderson & Horne, 2009; Costanzo et al., 2001). Turtle species from different areas will adapt to nesting in different types of soil. For example, the eastern mud turtle, located in the south-eastern area of the United States, is known to lay eggs within sandy soil or lightly vegetated loose soil. However, Anderson and Horne (2009) found that the eastern mud turtle will lay eggs on the surface of clay soils under leaf litter to compensate when sandy soil is not available for nesting. The eastern mud turtle prefers sandy soil for nesting because this type of soil maintains high water potential with low water content, and the spaces between sand grains provides oxygen for developing embryos. In contrast, clay soils have a much smaller particle size that maintain a high water content and decrease the availability of gas exchange between particles (Anderson & Horne, 2009). The small particles of clay can clog eggshell pores that are required for gas exchange. This can cause embryos to suffocate if eggs are buried in clay soil. Sandy soils are important to allow eggs to be buried and concealed from predators, rather than being laid on the surface of clay soils under leaf litter (Anderson & Horne, 2009).

Costanzo et al. (2001) found that clay soils are important for the survival of overwintering painted turtle hatchlings. Unlike many other turtle species, painted turtle hatchlings overwinter in their nest and emerge from underground the following spring. The researchers discovered that overwintering painted turtle hatchlings had a higher incidence of mortality by freezing in sandy loam soils than in soil containing high amounts of clay and organic matter (Costanzo et al., 2001). The susceptibility for hatchlings to freeze was influenced by moisture content in frozen soil. The clay soils bound to more moisture and kept hatchlings from freezing because there were less ice nuclei coming into contact with them (Costanzo et al., 2001). These two studies indicate that sandy soil is important for turtle embryos developing within their nest during the summer months due to ample gas exchange; however, clay soils are more useful for preventing freezing of overwintering painted turtle hatchlings (Anderson & Horne, 2009; Costanzo et al., 2001).

Soil salinity, soil moisture content, and their impact on nests

Soil moisture content, as well as the salinity of soil can impact the development and survival rate of hatchlings in turtle nests (Bower & Hodges, 2013; Delmas, Bonnet, Girondot, and Prevot-Julliard, 2008; Finkler, 2006). Finkler (2006) used soil from snapping turtle nesting areas as an incubation medium to study the effects of soil moisture content on the size of snapping turtle hatchlings. Snapping turtle eggs were buried in sterilized soil that had previously been dried and wet with six different levels of hydration (3, 5, 7, 9, 11, and 13% gravimetric water content). Finkler (2006) discovered that eggs which were in the driest soil (3%) had a loss of mass during incubation. Moreover, eggs buried in soil containing higher water content had gained mass to varying degrees that correlated positively with soil water content. Hatchling mass was significantly lower in the two driest soils (3 and 5%) than in the two wetter soils (11 and

13%), and hatchling shell length was significantly shorter on hatchlings from the driest soils than from the wetter soils (Finkler, 2006). The findings indicate that soil hydration within turtle nesting sites can influence the size and fitness of hatchlings (Finkler, 2006). This finding is significant because it outlines the importance of maintaining sufficient soil moisture content for turtle nesting sites, which is useful information when conducting ecological restoration for freshwater turtles (Delmas et al., 2008; Finkler, 2006).

Delmas et al. (2008) examined the effects of different soil moisture levels on red-eared slider turtle eggs. The researchers buried different eggs in a wet substrate (2 grams of water per gram of vermiculite), an intermediate substrate (0.44 g of water per gram of vermiculite), and a dry substrate (0.09 g of water per gram of vermiculite; Delmas et al., 2008). The researchers found that there was a greater increase in mass from eggs in the wet substrate than in the intermediate or dry substrate. This difference in mass became more prominent towards the end of the incubation period (Delmas et al., 2008). At the end of the incubation period, both eggshell size and hatchlings from wet substrate had a significantly higher mass than hatchlings from the dry substrate. The findings provide further evidence which indicates that soil moisture content at nesting sites influences the mass, and therefore, the fitness of freshwater turtle hatchlings like the red-eared slider (Delmas et al., 2008; Finkler, 2006).

A related study done by Bower and Hodges (2013) examined salinity of soil in relation to soil moisture, and their affect on embryonic development of freshwater turtles. The researchers predicted that since soil moisture content affects embryological development of turtles, it is likely that the salinity of soil would also affect their development (Bower & Hodges, 2013). They examined the influence of soil salinity on eggs of the broad-shelled turtle contained in four substrate treatments that varied in salinity (0, 15, 35, & 70% NaCl). Embryos incubated in higher levels of salinity had 39% less survival than those incubated in substrates with fresh water. Eggs buried in substrate containing 70% saline water had a 54.5% survival rate, whereas eggs buried in freshwater had a 94.4% survival rate (Bower & Hodges, 2013). The study demonstrates that soil salinity decreases the rate of freshwater turtle hatchling survival. This information is important when conducting soil remediation and ecological restoration initiatives for areas containing freshwater turtle species (Bower & Hodges, 2013). Road salt used in Ontario during winter months could accumulate in soil and gravel embankments at the edge of roads, where freshwater turtles commonly nest if more sufficient nesting habitat is not available. Since high salinity content in soil can reduce hatching success rates, this could indicate that turtle nests within gravel at the edge of roads that accumulate road salt during the winter may have low hatching success rates. The construction of nesting sites for freshwater turtles in more suitable areas could reduce this impact. Studies regarding turtle nest site construction have had positive results when the goal was to direct nesting away from roads and into enhanced habitats (MNRF, 2010).

2.4 Provision of Turtle Habitat via Habitat Management and Restoration

2.4.1 Habitat management

Nesting habitat management

Habitat management can increase the size of suitable habitat for turtles, and make their living space safer from anthropogenic harm (Dowling et al. 2010; Erb & Jones, 2011; Roe & Georges, 2007). Due to habitat loss, fragmentation, and degradation of natural wetlands, habitat management is becoming increasingly important for the conservation of many turtle species (Dowling et al., 2010; Erb & Jones, 2011; Roe & Georges, 2007). Sufficient nesting habitat is crucial for the survival of different turtle species, but it is continuously threatened by anthropogenic land-use (Dowling et al., 2010; Roosenburg et al., 2014). The Blanding's turtle lives primarily in wetlands and requires sparsely vegetated soil for nesting (Dowling et al., 2010). Dowling et al. (2010) examined the success and cost-effectiveness of three methods of nesting habitat management (tilling, mowing, and weeding) on replicated land plots. The researchers discovered that female Blanding's turtles preferred nesting in tilled plots as opposed to weeded or mowed plots (Dowling et al., 2010). Dowling et al. (2010) concluded that tilling plots can be a successful and cost-effective means for managing nesting habitat. A similar study done by Erb and Jones (2011) evaluated the risk of wood turtle mortality in agricultural fields caused by the style of plot mower, mower blade height, and tractor tires. Mower blade height did not affect wood turtle mortality rates when set to 15 cm or higher, and different types of mowers caused different mortality rates (Erb & Jones, 2011). Sickle bar mowers resulted in 50% lower mortality rates than rotary mowers and other models. Since agricultural plots are often used as nesting habitat by some turtle species, this study suggests that agricultural plot management techniques can reduce turtle mortality (Erb & Jones, 2011).

Habitat management through land preservation and connectivity

A study done by Roe and Georges (2007) found that, not only are terrestrial habitats near wetlands important for turtle survival through nesting, but the proximity of different nearby wetlands with diverse functions is also important for survival. The researchers found that different turtle species will travel 499-1518 meters between wetlands during migration or drought periods (Roe & Georges, 2007). The different wetlands offered turtles different microhabitats that meet certain survival needs. The study suggests that turtle habitats should be managed to conserve heterogenous groups of wetlands together with terrestrial buffer zones and travel corridors between wetlands, rather than managing wetlands as isolated units (Roe &

Georges, 2007). Several other researchers have noted the importance of maintaining connective corridors between habitat types, since freshwater turtle species utilise a variety of habitats throughout different seasons and life stages (eg. for breeding, nesting, or overwintering; Browne, Bowers, & Hines, 2006; Hartwig & Kiviat, 2007; Millar & Blouin-Demers, 2011). Browne et al. (2006) conducted a study on Painted turtle habitat use in a pond complex located within an agricultural landscape. The researchers discovered that connectivity between the pond complexes was important, especially during drought. For example, the population density of painted turtles was low for one pond during a wet year, but increased significantly as the surrounding ponds dried up during a dry year (Browne et al., 2006). This study demonstrates the importance of managing landscapes to preserve connectivity between different heterogeneous habitats used by freshwater turtles.

Habitat management through laws and education

There are several studies, conducted both academically and through government organizations, which reveal methods of habitat management through laws and public education (Gunson, Ireland, & Schueler, 2012; MNRF, 2010; Ministry of Transportation [MOT], 2012; City of Kingston [COK], 2013). Gunson et al. (2012) stresses the importance of promoting proactive mitigation planning with government transportation agencies at the municipal and provincial level to reduce road mortalities of turtle species across Ontario. The researchers designed a GIS modeling tool that predicts high-risk road mortality locations for herpetofaunal species, such as freshwater turtles. The resulting models are then used to prioritize locations where mitigation solutions to road mortality are needed. Such mitigation solutions include turtle crossing signs and wildlife crossing structures (Gunson et al., 2012). The Wood Turtle Recovery Program in Ontario also lists road mortality mitigation as a habitat management strategy for protecting semi-aquatic turtles (MNRF, 2010). Such road mortality mitigation measures include signage that alerts drivers to slow down where turtles frequently cross roads, fences to prevent turtles from crossing areas of high traffic, and seasonal road closures where turtles commonly travel to nest (MNRF, 2010).

A report by the Ministry of Transportation (2012), as prepared by Gunson, Schueler, and Middleton, outlines the importance of proper signage placement to enhance the effectiveness of wildlife awareness signage. The study analysed placement of municipal turtle crossing signs across Ontario and found that 27% of placed signs were stolen and 13% of signs were not located at validated turtle crossing hotspots (MOT, 2012). The researchers suggest that the locations of wildlife awareness sign placement should be supported by turtle on-road location data, geospatial technologies, expert opinion, and habitat-based models to ensure effective placement of signs (MOT, 2012). Similarly, a report by the City of Kingston (2013) suggests the addition of amber flashing beacons to existing turtle warnings signs, to enhance their effectiveness at preventing road mortality during the day or at night. Other studies have shown that off-road vehicles, such as all-terrain vehicles (ATVs), not only cause mortality of turtles, but can also destroy their nests in natural habitat areas (MNRF, 2010). For this reason, laws that prohibit the use of off-road motorized vehicles in habitats used by freshwater turtles would be beneficial to their conservation (DMMP, 1997). Other forms of public education, other than wildlife awareness signs, can be used to manage freshwater turtle habitats. For example, land owners can be educated on the habitat needs of semi-aquatic turtles through outreach programs and land stewardship documents to encourage land owners to adopt 'turtle-friendly' landscapes or land management techniques on their property (MNRF, 2010). Landowners can also be encouraged to report poachers, since poaching is an issue with certain species of semi-aquatic turtles like the wood turtle (MNRF, 2010). Each of these habitat management strategies can be useful tools for protecting freshwater turtle habitat across Ontario.

2.4.2 Ecological restoration as a tool for freshwater turtle conservation

A common theme is apparent in literature regarding turtle conservation. Researchers tend to study the impact that certain threats have on turtle diversity, abundance, or health, and then suggest ways that these impacts can be mitigated (Darst et al., 2013; De Solla et al., 2014; Erb & Jones, 2011; Hartwig & Kiviat, 2007; Mifsud, 2014; Roe & Georges, 2007; Sterrett et al., 2011). As turtle habitats are reduced in size and quality by anthropogenic development and invasive species, a popular mitigation strategy is ecological restoration (Darst et al., 2013; Gibbs, Marquez, & Sterling, 2007; Hartwig & Kiviat, 2007; Mifsud, 2014; Roosenburg et al., 2014; Sterrett et al., 2011). Before conducting ecological restoration in an area, specific threats to turtle populations must be identified (Darst et al., 2013; Roosenburg et al., 2014). There are many different types of ecological restoration efforts that can take place such as creating nesting habitat, removing invasive species, planting or seeding native vegetation, creating buffer zones between landscapes, and removing shoreline hardeners like stones or metal bulkheads (Darst et al., 2013; Gibbs et al., 2007; Hartwig & Kiviat, 2007; Mifsud, 2014; Roosenburg et al., 2014; Sterrett et al., 2011). However, among the literature that examines ways to conduct ecological restoration, there is very little research that examines if turtle species use ecologically restored areas after restoration efforts are completed. Without this information, it is difficult to determine if suggested restoration actions to conserve turtle species would be successful.

Ecological restoration through the removal of invasive species

Darst et al. (2013) identified threats to the Mojave Desert tortoise to prioritize recovery actions based on their potential to mitigate threats. Urbanization, habitat loss, human access, disease, and illegal use of off-road vehicles were the most serious threats to the desert tortoise (Darst et al., 2013). Based on these findings, it was determined that recovery actions which decreased habitat loss, predation, and crushing would be effective. The researchers concluded that ecological restoration through weed suppression and native plant seeding would be the most effective recovery action because it would reduce the stresses of nutritional compromise and dehydration caused by establishment of non-native plants (Darst et al., 2013). Mifsud (2014) also stressed the importance of removing invasive species as a form of ecological restoration to provide habitat for turtles. As mentioned previously, Mifsud (2014) compared the distribution of different reptile species throughout the Saginaw Bay area, and discovered that turtle species abundance was significantly lower in areas that contained the invasive species known as *Phragmites australis*. Since the invasive species grows denser and chokes out native species, Mifsud (2014) concluded that the removal of *Phragmites australis*, along with seeding native vegetation, would provide habitat for different turtle species and aid in their conservation. These studies indicate that invasive species removal is an important form of ecological restoration, since invasive species can overtake native species that freshwater turtles rely on to survive.

Ecological restoration through habitat construction

Ecological restoration through habitat construction is another method for freshwater turtle conservation. Hartwig and Kiviat (2007) studied Blanding's turtle use of microhabitats in natural wetlands and wetlands constructed for the turtles. Their goal was to investigate ways to increase the extent of Blanding's turtle habitat and improve its quality. The constructed wetlands had less vegetation cover and warmer water in comparison to natural wetlands. This caused the constructed wetlands to be used differently by Blanding's turtles than the natural wetlands. Although the turtles used areas of similar water depth in both wetlands (26-27 cm), they used constructed wetlands mainly to bask and forage for food in the spring and early summer. Constructed wetlands were also used as areas to rest in or rehydrate during nesting season when the Blanding's turtles travelled more (Hartwig & Kiviat, 2007). Later in the summer when water in constructed wetlands dried up or became too warm, the turtles moved to wetlands containing deeper water (Hartwig & Kiviat, 2007). Based on microhabitat usage by Blanding's turtles, the researchers discovered that ecological restoration could improve turtle habitat. Hartwig and Kiviat (2007) concluded that ecological restoration for the purpose of providing new habitat for the Blanding's turtle should include abundant land vegetation, basking areas (logs or rocks), muck, floating aquatic vegetation, and submerged aquatic vegetation. This study is important because it indicates that ecologically restored areas are used by freshwater turtles, depending on microhabitat features, and can be used as a tool to provide habitat.

Sterrett et al. (2011) assessed turtle diversity and abundance in agriculturally disturbed and undisturbed or restored streams in a riparian habitat. Disturbed areas were distinguished from undisturbed or restored areas by having limited riparian forest cover adjacent to streams due to agricultural land conversion. Furthermore, disturbed areas experienced water withdrawals for irrigation during growing season (Sterrett et al., 2011). Undisturbed or restored areas had a large riparian forest buffer zone along streams. The researchers found that turtle species were less diverse and less abundant in areas of disturbed land cover than they were in undisturbed or restored areas. Sterrett et al. (2011) concluded that loss of riparian forest is associated with decline in freshwater turtle diversity and abundance, and ecological restoration through seeding and regenerating riparian forests is critical to freshwater turtle conservation.

Roosenburg et al. (2014) point out that nesting habitat loss can concentrate turtle nesting sites, leading to increased nest predation efficiency. In order to mitigate this issue, the researchers suggest creating nesting sites for turtles in areas where they are less vulnerable to primary predators like raccoons and foxes. For example, nesting areas could be constructed on small lake or pond islands where land predators cannot access nests (Roosenburg et al., 2014). Roosenburg et al. (2014) examined turtle use of constructed nesting sites on an isolated island habitat. The goal of the study was to determine how easily female turtles could locate and use the nesting site, and if hatching rates would be positive in the absence of predators. Female diamondback terrapins found the constructed nesting site and began nesting within one year of the site's construction (Roosenburg et al., 2014). Furthermore, because the nesting site was located on an island, isolated from the mainland, there was no disturbance of the nests by primary predators like raccoons or foxes. This caused nest survivorship to be significantly higher on islands with constructed nesting sites, than on the mainland (Roosenburg et al., 2014). The study demonstrates that certain turtle species will use constructed nesting habitats, which is useful information when planning ecological restoration for the purpose of expanding nesting habitat. Similarly, the study reveals that nesting habitat constructed on islands can be useful for increasing nest survivorship in areas dominated by common nest predators like raccoons and foxes (Roosenburg et al., 2014). Research in Ontario has documented the construction and restoration of nesting habitat for wood turtles in areas degraded by invasive vegetation overgrowth (MNRF, 2010). The loss of sufficient nesting habitat caused wood turtles to nest along busy logging access roads. After restoration and construction of nesting sites took place, wood turtles used the restored nesting habitat rather than the shoulder of roads (MNRF, 2010). Based on the research mentioned, ecological restoration through actions such as invasive species removal, seeding native vegetation, and constructing nesting sites can provide habitat for turtles and aid in their conservation.

Chapter 3 - Species and Area of Study

3.1 About the Species of Study

One of the goals of this field study was to discover what turtle species are present within the Dunnville marsh area. Three of Ontario's eight freshwater turtle species were encountered at the marsh and became a part of this field study. These species include the snapping turtle (*Chelydra serpentina*), Blanding's turtle (*Emydoidea blandingii*), and midland painted turtle (*Chrysemys picta marginata*). No other turtle species were observed or captured in the Dunnville marsh area.

3.1.1 The snapping turtle

The snapping turtle is the largest turtle species in Ontario, reaching up to 45 cm in length, with an average length of 20-36 cm, and can weigh 4.5-16 kg (*Figure 3.1*; MacCulloch, 2002; MNRF, 2016). Their range in Ontario extends throughout the South-western, central, and eastern regions, as well as some southern areas of Ontario's northern region (MacCulloch, 2002; MNRF, 2016). They are listed as a species of special concern, meaning they are not endangered or threatened, but could be in the future due to threats like habitat loss and habitat degradation (MNRF, 2016). Snapping turtles can be distinguished from other turtle species by their large size, long neck and tail, and small shell in comparison to their overall body size (MacCulloch, 2002). Their carapace is dark green or black in color with three longitudinal ridges and a serrated rear edge, while the plastron is cross-shaped and much smaller than most other turtle species' (MacCulloch, 2002). The tail is long with bony plates on top, giving it a saw-toothed look. Snapping turtles can extend their neck up to half the length of their carapace to defend themselves or catch prey with their powerful jaws (MacCulloch, 2002; MNRF, 2016). They rarely leave the water, and bask less frequently than other turtle species (MNRF, 2016). Furthermore, they are poor swimmers and prefer to walk on the bottom of water bodies in search for food (MacCulloch, 2002). Snapping turtles are mainly scavengers that feed on carrion, although they can also catch live prey and feed on aquatic vegetation (MacCulloch, 2002). It is estimated that snapping turtles can live to be over 100 years old (MNRF, 2016). Their eggs are small spheres, a little larger than a quarter, making them distinguishable from the oval eggs of all other Ontario turtle species (MacCulloch, 2002). Females can produce up to 40 eggs in one clutch, which are deposited in June and hatch in late August or September (MacCulloch, 2002; MNRF, 2016). The sex of hatchlings depends on the temperature in which eggs are incubated. Eggs incubated at a temperature of 23-28 °C hatch male turtles; however, eggs incubated above or below this range will hatch females (MNRF, 2016).

Figure 3.1: A snapping turtle that was captured by hoop net. It is common for snapping turtles to have algae on their carapace because they rarely leave water. Notice the three longitudinal ridges on the carapace, and the triangular bony plates above the front claws (photo: B. Brown).

3.1.2 The Blanding's turtle

Blanding's turtles are one of Ontario's medium-sized turtles and can reach 27 cm in length (*Figure 3.2*; MNRF, 2016). Their range in Ontario encompasses parts of the south-western, central, and eastern regions, as well as the southernmost area of Ontario's northern region (MacCulloch, 2002; MNRF, 2016). Blanding's turtles are listed as threatened by the MNRF, meaning they are not endangered but are likely to become endangered if steps are not taken to address threats (MNRF, 2016). They can be distinguished from other turtle species in Ontario by their high-domed shell that is more long and narrow than most other species (MacCulloch, 2002; MNRF, 2016). The head and limbs of Blanding's turtles are dark in color, but the underside of the head and neck are bright yellow. The carapace is black with small flecks and streaks of yellow (MacCulloch, 2002; MNRF, 2016). Moreover, Blanding's turtles have a longer neck than most other turtle species, as well as a flexible hinged plastron which allows their shell to close partially if threatened by a predator (MacCulloch, 2002). Like snapping turtles, Blanding's turtles are poor swimmers and often move throughout shallow water bodies by walking on the bottom. Their diet consists of aquatic insects, molluscs, crustaceans, and vegetation (MacCulloch, 2002). A female Blanding's turtle can take up to 25 years to mature, and adults can survive in the wild for more than 75 years (MNRF, 2016). Females lay eggs in early summer and produce 6 to 11 eggs in one clutch, which hatch in late summer or early fall (MacCulloch, 2002).

Figure 3.2: A female Blanding's turtle. Blanding's turtles have been nick-named the 'sunshine turtle' due to their bright yellow 'smile'. Notice the yellow and black coloring on the limbs and the bright yellow chin (photo: B. Brown).

3.1.3 Midland painted turtle

There are two sub-species of painted turtle in Ontario, known as the midland painted turtle and the western painted turtle which is larger in size and has different coloring (MacCulloch, 2002). The western painted turtle was not a part of this field study, so when the name 'painted turtle' is used, it is in reference only to the midland painted turtle. The midland painted turtle is one of Ontario's medium-sized turtles and can reach 17 cm in length and weigh 300 to 500 grams (*Figure 3.3*; Friends of Algonquin Park [FAP], 2005; MacCulloch, 2002). Their range extends throughout the south-western, central, and eastern regions of Ontario, as well as the southernmost areas of Ontario's northern region (MacCulloch, 2002). Unlike the other 7 species of turtles in Ontario, painted turtles are not listed as a species at risk by the MNRF. They are the most common and widespread freshwater turtle population in Ontario (FAP, 2005; MacCulloch, 2002). The midland painted turtle's carapace and limbs are dark green or black, with bright orange, yellow, or red marking on the head, limbs, and underside of the carapace (FAP, 2005; MacCulloch, 2002). Moreover, the plastron is yellow with a dark central marking. Painted turtles can often be seen basking in full-sun on logs or fallen vegetation in small, shallow water bodies (MacCulloch, 2002). They are omnivores and eat carrion, aquatic plants, aquatic and terrestrial insects, snails, amphibians, crayfish, leeches, fish eggs, and small fish (FAP, 2005). It is theorized that painted turtles can live up to 300 years, and some encountered during field studies have been estimated to be 100 years old (FAP, 2005). Females lay eggs in early summer and produce clutches from 4 to 23 eggs, which hatch later in the summer or early fall (MacCulloch, 2002). Although the eggs typically hatch around September, hatchlings do not emerge from the nest until the following spring (FAP, 2005). Unlike other hatchling species, painted turtle hatchlings remain in the nest over winter and withstand temperatures as cold as -10

°C. Their bodies produce natural antifreeze that prevents cells from freezing and becoming damaged (FAP, 2015). Similar to other turtle species, the sex of hatchlings depends on the incubation temperature of their nest. Male hatchlings will be produced at an incubation temperature between 23-27 °C, and females will be produced at incubation temperatures above or below that range (FAP, 2005).

Figure 3.3: A midland painted turtle. This photo depicts a juvenile male midland painted turtle. Notice the yellow and orange markings on the face, limbs, and underside of the carapace (photo: B. Brown).

3.2 Area of study

The study took place in the Dunnville Marsh, located in southern Ontario. To address the research gap found in the literature, the ecologically restored marsh within Dunnville and areas adjacent to the restored marsh were chosen as the field study site. The area of study was restored from farm land back to marshland between 2005 and 2008 (Neumann, 2012). Moreover, areas within and adjacent to this restored area had not been studied before in regard to freshwater turtle population characteristics and habitat use. Therefore, choosing this area was logical in order to fill the research gap regarding freshwater turtle population characteristics and habitat use for the region. The restored marsh is also a significant area to conduct the field study in order to fill the research gap regarding if ecologically restored wetland areas are utilized by freshwater turtles. The Ministry of Natural Resources and Forestry (MNRF), and the Grand River Conservation Authority (GRCA) are aware that freshwater turtles are present in the general area of the Dunnville region; however, no scientific data had been gathered regarding population characteristics or specific areas of habitat use within the region prior to this study. Therefore, the chosen area of study is important for providing this missing information. *Figure 3.4* shows where the study site is located in southern Ontario.

Figure 3.4: The location of the Dunnville marsh within southern Ontario. The yellow star indicates the study site. The marsh is located adjacent to the Grand River, which empties into the north-eastern part of Lake Erie (Google Maps, 2016).

3.2.1 The Dunnville marsh

In 1993, the Nature Conservancy of Canada, combined with funding from Eastern Habitat Joint Venture and other stakeholders, purchased most of the land within the Dunnvile Marsh (Neumann, 2012). Later, ownership was transferred to the Grand River Conservation Authority, and the initial 343 ha property was expanded to 386 ha in 2007 with funding from Ducks Unlimited Canada (Neumann, 2012). The main goal of the Dunnville Marsh Management Plan is "to preserve the lands as a natural area for the conservation and management of waterfowl, other wildlife, and natural communities" (Neumann, 2012, p. 22). Between 2005 and 2008, 44 hectares of agricultural land within the Dunnville marsh was restored to swamp, upland forest, and grassland (*Figure 3.5*; Neumann, 2012). More specifically, some of the objectives of the Dunnville Marsh Management plan include:

- "To conserve and protect rare and endangered species;
- Enhance the productivity, biodiversity, and ecological integrity of the wetlands;
- Increase populations of waterfowl by improving wetland habitat;
- provide fish with access to existing spawning and nursery habitats;
- Intensify efforts to control and eliminate invasive, non-native species; and
- Improve habitat for wildlife utilizing the wetlands" (Dunnville Marsh Management Plan [DMMP], 1997, p. 13).

Figure 3.5: The Dunnville marsh as pictured from satellite. This figure illustrates the general area and natural land features that make up the Dunnville marsh. The area that was restored from farmland back to marshland is outlined in red (Google Maps, 2016).

Techniques and features used to restore the marsh include pit and mound micro-topography recreation, vernal pool creation, direct seeding of native plants, planting of nursery vegetation, and control of invasive species (Neumann, 2012). There are several significant species that have made the Dunnville marsh their home. The area is used by waterfowl like the mallard duck, wood duck, least bittern, goldeneye, and snow goose, among many others (DMMP, 1997; Grand River Conservation Authority [GRCA], 2012). Areas throughout the marsh dominated by cattails are occupied by species such as the common yellowthroat, green-backed heron, great blue heron, Virginia rail, cedar waxwing, and spotted sandpiper (DMMP, 1997). Among other species at risk that occupy the area, Bald Eagles have been spotted nesting within the marsh (DMMP, 1997; GRCA, 2012; Neumann, 2012). Moreover, the marsh is home to mammal species like beaver, muskrat, raccoon, mink, red squirrel and deer (DMMP, 1997).

Since the Dunnville marsh contains streams that extend to the Grand River, fish species from the Grand River enter more shallow streams among cattail areas within the marsh to spawn (DMMP, 1997). The water quality of the streams reveals that the area contains a warm water fishery, providing habitat for 44 different fish species that have been located throughout the property (DMMP, 1997). The marsh provides nursery habitat for young fish, and some fish species spend their entire life in the marsh, while others migrate to the Grand River and Lake Erie (DMMP, 1997). Pits and vernal pool creation throughout the marsh has been successful at providing breeding habitats for herpetofaunal species that inhabit the area, which include the leopard frog, green frog, bull frog, and spring peeper (DMMP, 1997). The more open and deep waters throughout the marsh provide habitat for reptile species like the northern water snake (DMMP, 1997).

The Dunnville marsh area is an ideal place to conduct research related to freshwater turtles and ecological restoration, since it is thought to be home to turtle species like the Blanding's turtle and the common snapping turtle (DMMP, 1997; Neumann, 2012). There is also a chance that the northern map turtle is present within the deeper open waters near the marsh (A. Yagi, personal communication, March 25, 2015). Finally, the Dunnville marsh area was an ideal place to conduct this field study because the total land area was a feasible size for one researcher to manoeuvre.

3.2.2 Areas of capture

There were four main areas where trapping took place throughout the duration of this study (*Figure 3.6*). One of the trapping areas was situated inside the restored marsh property that is owned by the Grand River Conservation Authority (GRCA), while the other three were situated in wet areas adjacent to the marsh. This is because surveys of the land and conversations with locals that took place prior to the start of the field study revealed where freshwater turtle populations were concentrated. Areas where freshwater turtle populations were concentrated are considered ideal locations for setting up traps. However, one trap was still situated inside the restored marsh property, although no turtles had yet been observed in that area. The reason for this was to determine if turtles were still in that general area, or passed through that area, even though they had not yet been observed at that time in the early season (April). Permission was given by landowners in areas where traps were situated.

Figure 3.6: A satellite image indicating trap locations within the area of study. As shown by the legend, four main trap sites (A, B, C, and D) were used throughout the study's duration. (Source: modified from Google Maps, 2016)

Trap site A

Trap site A was located just outside the west boundary of the restored marsh within a pond (*Figure 3.7*). The pond is located a few meters from a marina dock and the Grand River. The landowners revealed that different species of freshwater turtles are often seen basking or swimming within the pond, and nesting in areas around the pond. The pond's water depth near the shoreline ranges from two to four feet. Very little canopy cover (4%) is present around the pond, which is beneficial for openly basking turtles (Cosentino et al., 2010; Ernst et al., 1994; Millar & Blouin-Demers, 2011). Cattails, bulrushes, and submerged aquatic vegetation (SAV), such as coontail, are present within the pond and around its shores. Although a few logs, wooden panels, and a floating fish bait trap are within the pond, there are not many objects present within the pond for turtles to openly bask on. However, turtles have been seen openly basking on what is available to bask on in the pond, as well as cryptic basking among fallen reeds and mats of SAV. Although some of the land surrounding the pond remained wild, portions of land near the east and south shoreline of the pond was mowed frequently by the property owner.

Figure 3.7: Trap site A, located within a pond on private land beside the Dunnville marsh. The left side of this image depicts a baited hoop net set up to catch turtles that often bask on wooden boards attached to the fishing bait trap on the right. Turtles that bask on the shoreline and logs throughout other areas of the pond were also drawn to the baited hoop net (photo: B. Brown).

Trap site B

Trap site B took place within the canal, located outside the northern boundary of the Dunnville marsh (*Figure 3.8*). This study classifies the canal into three parts, since each of these parts have different environmental characteristics. These three parts includes the west, middle, and east canal. Trap site B describes the middle canal (Mid-canal). This canal is a significant area that provides habitat for dozens of painted turtles, several snapping turtles, and a few Blanding's turtles that were observed in the canal throughout the season. Soil along the canal's shoreline consists of sand, gravel, and loam, making it a popular nesting site for turtles that inhabit the canal waters. The canal's shoreline water depth fluctuated between 34 and 78 cm throughout the season. Water towards the centre of the canal can reach a depth between five and six feet. The canal has an open tree canopy, at 14% cover, allowing plenty of sunlight to reach basking turtles. Shoreline vegetation along the canal is high with an average density of 33.6 stocks per square meter. This provides a narrow buffer zone between the canal waters and roads on either side of the canal. There are several fallen logs and protruding rocks throughout the canal that are available for turtles to openly bask on. Turtles also bask on the canal's shoreline, and cryptic bask among SAV. Emergent aquatic vegetation (EAV) such as cattails and bulrushes are present throughout the canal, as well as SAV in the form of coontail and Eurasian watermilfoil. Water lilies become abundant throughout the canal in mid to late summer. The baited hoop net used to capture turtles within Trap Site B (the canal) was not left in the same spot throughout the entire season, but was moved to different areas of the canal to prevent turtles from becoming trap shy (Robertson et al., 2013).

Figure 3.8: Trap site B, located within a canal outside the northern boundary of the Dunnville marsh. This area depicts the location where a baited hoopnet was often set up to lour turtles. The logs in the background are a popular basking area for turtles (photo: B. Brown).

Trap site C

Trap site C was located in a small bay area within Maple Creek. This trap site is just outside the northern boundary of the Dunnville marsh (*Figure 3.9*). Maple Creek runs throughout the Dunnville marsh before emptying into the Grand River (DMMP, 1997). Water levels at trap site C fluctuated between 43.5 and 92 cm throughout the season. Shoreline vegetation density is high in this trap location (34 stocks per square meter), and there is little canopy cover from trees (5%). Aquatic vegetation in the area includes cattails, bulrushes, coontail, Eurasian watermilfoil, water lily, yellow spatterdock, and duckweed. There are several logs in this area for turtles to bask on, as well as shoreline, fallen cattails, floating aquatic vegetation (FAV) such as water lilies, and mats of SAV. A nesting area near trap site C is located along a train track where bare soil consisting of sand and gravel is present.

Figure 3.9: Trap site C, located within a bay area along Maple Creek. Although not present in this photo, a baited basking trap was set up at this trap site. Dozens of painted turtles and several snapping turtles were frequently seen within this area (photo: B. Brown).

Trap site D

Trap site D was located further down Maple Creek, within the boundaries of the Dunnville marsh area that is owned by the GRCA (*Figure 3.10*). The water depth within this trap site fluctuated between 68.5 and 133 cm throughout the season. The shoreline vegetation density had an average of 38 EAV stocks per square meter, and canopy cover was classified as open, at 36.7% canopy cover. Some SAV was present at trap site D (22% cover), although cover is lower than at the other trap sites. Aquatic vegetation such as coontail, Eurasian watermilfoil, cattails, bulrushes, and duckweed was present at trap site D. Several fallen logs and shoreline was available for turtles to openly bask on. Although there were not large mats of SAV for turtles to bask on, some fallen reeds were present.

Figure 3.10: Trap site D, located within Maple Creek inside the GRCA property boundary at the Dunnville marsh. Depicted in this photo is a baited basking trap. The basking trap was later situated closer to the shoreline among SAV (photo: B. Brown).

3.2.3 Survey areas

Four areas were routinely surveyed for freshwater turtles and nests throughout the duration of this study (*Figure 3.11*). Three of these areas were located within the restored marsh area that is owned by the GRCA, while one of the areas was located just outside the northern boundary of the Dunnville marsh. Each area was chosen based on certain environmental characteristics such as the presence of water, surrounding vegetation density, and objects available to bask on (Ernst et al., 1994; MacCulloch, 2002). One of the three areas, located outside the restored marsh's northern boundary, was chosen to determine if turtles travelled from the canal to areas inside the marsh.

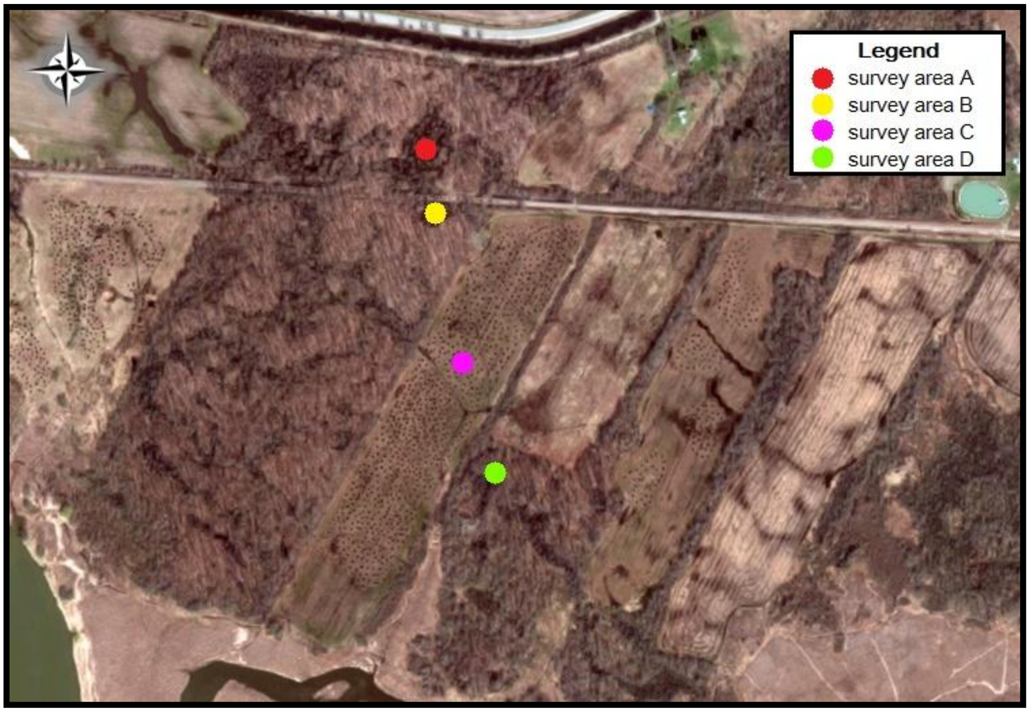

Figure 3.11: A satellite image indicating survey areas within the place of study. This image depicts four different areas that were routinely surveyed for freshwater turtles and nests within the marsh throughout the field study's duration (Google Maps, 2016).

Survey area A

Survey area A was located just outside the restored marsh's northern boundary (*Figure 3.12*). The reason for this was to determine if freshwater turtles were travelling through this particular area from the canal to areas inside the restored marsh. There was a chance freshwater turtles would be present in this area, even temporarily, due to the presence of water (Cosentino et al., 2010; Ernst et al., 1994; MacCulloch, 2002). Due to the size of this survey area, it was divided into a north and south end when environmental measurements were taken. Early in the season (April-June) survey area A was flooded with water that reached depths up to 24 cm. There was no SAV in the water, but there was a high amount of leaf litter. Although this is a forested area, light was able to penetrate to the ground early in the season before the trees produced leaves. However, later in the season (July-September) the water dried up, and tree canopy shaded the ground. This survey area was measured to have a closed canopy cover, at 75% cover, and a low to moderate ground vegetation density. Fallen logs and small islands within the flooded area provided potential basking sites.

Figure 3.12: Survey area A, located just outside the northern boundary of the restored marsh. As seen in this image, survey area A was flooded with water early in the season (photo: B.Brown).

Survey area B

Survey area B was located within the boundaries of the restored marsh, near the northern boundary beside a train track (*Figure 3.13*). This survey area is similar to survey area A. Early in the season the area was flooded with water that reached a depth up to 21.4 cm, but dried up later in the season. The water did not contain SAV; however, it did contain a large amount of leaf litter. Survey area B is also a forested area that allowed light to penetrate early in the season, but shaded the area once canopy grew. This area's canopy was measured to be closed, at 73% cover, and had a moderate ground vegetation density. Many fallen logs provided potential basking sites.

Figure 3.13: Survey area B, located within the restored marsh boundary. As seen in this image, survey area B was flooded with water early in the season (photo: B. Brown).

Survey area C

Survey area C was located inside the restored marsh within an open field where pit and mound restoration and sparse tree planting took place (*Figure 3.14*; GRCA, 2012). This area has very little to no canopy cover, allowing light to reach ground vegetation and water within pits. Water within pits was present early in the season (April-June) but had dried up later in the season (July-September). Pits throughout survey area C were measured to have an average diameter of 10.5 feet, and an average water depth of 39.8 cm. Water within pits contained some leaf and plant litter, and no SAV. Aside from mossy ground surrounding some pits, there are not many potential basking sites in this area. Moreover, survey area C has a high ground vegetation density, making it a less than ideal area for turtles to nest in (Hughes & Brooks, 2006).

Figure 3.14: Survey area C, located within an open field in the restored marsh. As seen in this image, survey area C contains pits that are full of water early in the season. A pit can be seen on the lower right corner of the image (photo: B. Brown).

Survey area D

Survey area D was located in a flooded area within the restored marsh, east of survey area C (*Figure 3.15*). Survey area D was flooded with water early in the season (April-June), which began to dry up later in the season (July-September). Unlike survey areas A and B, the water in this area did not dry up completely until mid-September. The water in this area reached a depth of 38.1 cm, and contained a lot of leaf litter. This area is forested, allowing light to penetrate to the ground and water early in the season, but is shaded by canopy later in the season. The canopy cover in survey area D was measured to be closed at 70% cover. Survey area D has a high ground vegetation density surrounding the flooded area (28 stocks per square meter). Fallen logs and raised ground provided potential basking sites.

Figure 3.15: Survey area D, located in a flooded area within the restored marsh. This photo was taken in August when water in this area began to dry up (photo: B. Brown).

Chapter 4 - Methodology

4.1 Methodology Overview

Several steps were required to successfully plan and complete this study. *Figure 4.1* outlines a summarized overview of the methodology.

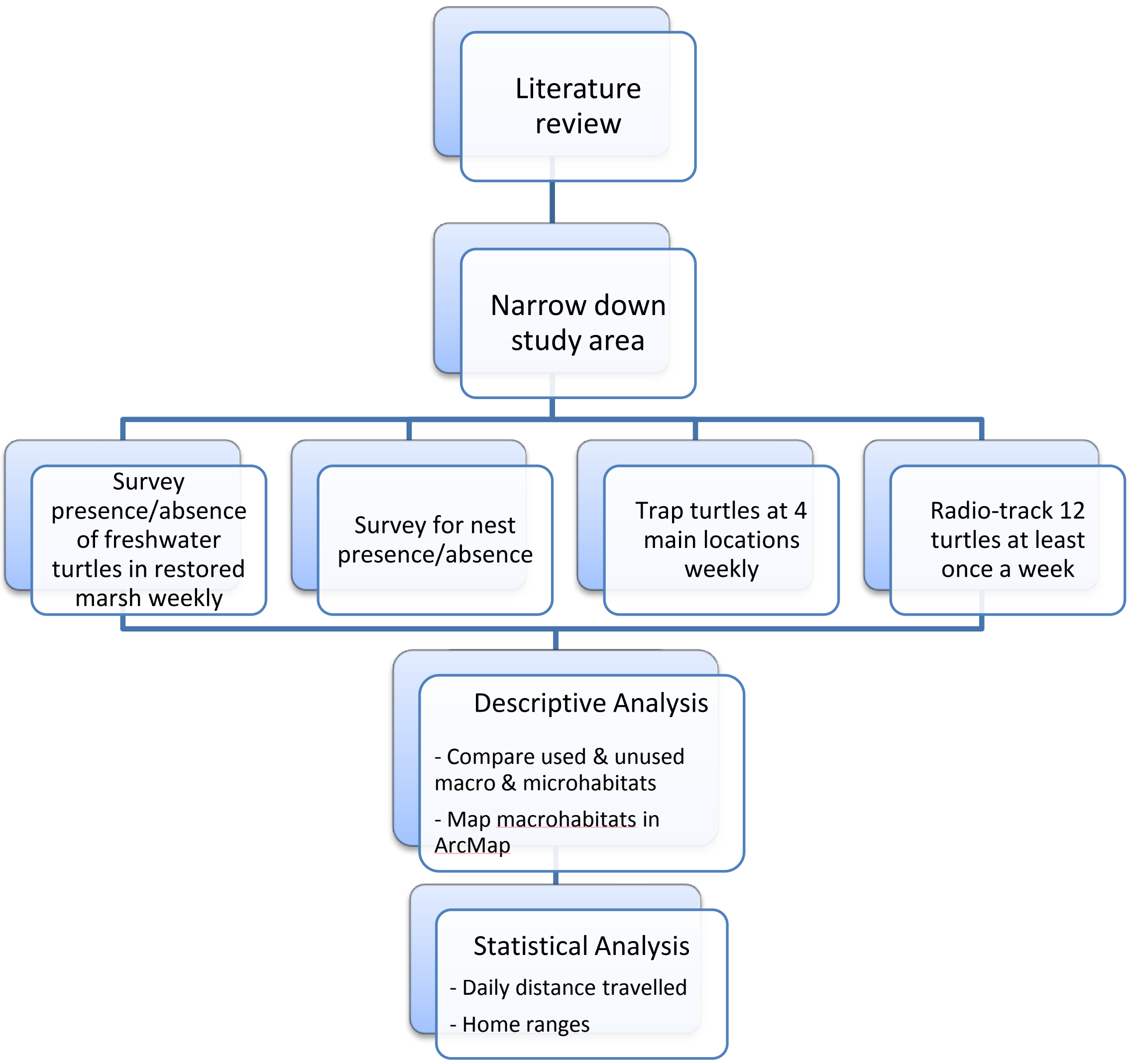

Figure 4.1: An overview of the methodology. This figure shows the steps required to complete this study. A literature review was conducted first to examine existing research on the topic and identify any research gaps. The study area was then narrowed down, followed by hands-on field research, and analysis of findings.

4.2 Survey Methods

Before surveying and data collection took place within the Dunnville marshland, a scientific studies permit was obtained from the Grand River Conservation Authority (GRCA). The permit is required to conduct scientific studies on GRCA property, and was obtained on January 25th, 2015. Survey of areas A, B, C, and D took place once a week from April 21st, 2015 to October 14th, 2015. The purpose of surveying these areas was to determine if they were inhabited or used either short-term or long-term by freshwater turtles. Determining the presence or absence of the studied species in a habitat use study is important because it is thought that species are present in suitable habitats, and absent from unsuitable ones (Murphy, 2010). During surveying, the researcher and research assistant would walk throughout survey areas to determine the presence or absence of freshwater turtles at any life stage (juvenile or adult), as well as the presence or absence of nesting sites (Anderson & Horne, 2009; Mifsud, 2014; Murphy, 2010). Both terrestrial and aquatic areas within survey sites were examined (Mifsud, 2014). Due to the possibility of recording false absences during surveying, multiple survey techniques were incorporated to optimize freshwater turtle observation (Mifsud, 2014). This included aural detection, visual observation, and the use of dip nets to separate vegetative debris in water (known as muddling; Mifsud, 2014; Robertson, Richards, & Karch, 2013). Nests were located by looking for signs of soil disturbance, an oval concave area within bare soil, and signs of nest predation such as a dug out hole in the ground with scattered eggshells in or surrounding it (*Figure 4.2*; Beehler, 2007; Lamb, Ennen, & Qualls, 2013).

Figure 4.2: A snapping turtle nest, eaten by a predator. This image shows a snapping turtle nest that was dug up and eaten by a predator soon after the eggs were deposited. Broken eggshells are visible in and around the nest (photo: B. Brown).

4.2.1 Survey data collection

Data was collected at each survey site throughout the season and photos were taken of each survey area. Environmental data was recorded for each survey area after determining water depth, water temperature, soil temperature, air temperature, weather conditions (precipitation and cloud cover), ground vegetation density (stocks per square meter), canopy cover, and GPS coordinates (Robertson et al., 2013). SAV cover was originally intended to be measured within wet areas of the survey sites as the season progressed, but no SAV was ever present to measure. Later in the season, soil samples were taken from survey areas to determine soil texture (Hughes & Brooks, 2006; Robertson et al., 2013). The methods used for soil sampling and analysis are described in section 4.5 of this chapter. Water depth was recorded in centimetres using a meter stick. Water temperature was determined using the Thermistor 400 series Digi-sense Thermometer and flexible probe. Depending on the location's water depth, water temperature was normally taken at 15 cm below the water's surface (Millar & Blouin-Demers, 2011). Soil and air temperature was also taken with the Thermistor 400 series Digi-sense Thermometer, but with an inflexible probe. Air temperature was taken in the shade to avoid getting a false temperature from sunlight. Ground vegetation density was determined using a one square meter quadrat and counting the main stocks of individual plants per square meter (Fidelibus & MacAller, 1993). Ground vegetation density sampling sites were selected within shoreline areas nearest to where turtles were tracked. In unused habitats, ground vegetation sites were selected randomly within survey areas. The average density of plants per square meter was taken from 10 to 15 quadrats within each survey site. Canopy cover was measured using a vertical densitometer while walking along linear transects within survey sites (Stumpf, 1993). The number and length of linear transects varied depending on the size of the study site. The average canopy cover amount (%) was later taken from densitometer measurements (Stumpf, 1993). The location of each survey site was recorded using a Garmin Oregon 550 GPS. GPS coordinates, environmental variables, and a photo of nest sites were taken when observed. Photos, GPS coordinates, and measurements were to be taken of each freshwater turtles observed within each survey area. The methods regarding handling freshwater turtles are described in section 4.3.2 of this chapter.

Surveys for the purpose of locating nests were conducted during the last week of July, after nesting season (May to mid-July). These surveys took place outside of the four main survey sites, in areas within and adjacent to the restored marsh. Survey areas were chosen based on information from locals who observed turtles nesting, and areas where turtles are likely to nest based on environmental characteristics such as soil texture, canopy cover, ground vegetation density or cover, and proximity to water (Hughes & Brooks, 2006; Micheli-Campbell et al., 2013; Hughes, Greaves, & Litzgus, 2009). Once a nest was located, environmental variables were recorded for soil temperature, canopy cover, and ground vegetation cover (Beehler, 2007; Hughes & Brooks, 2006). Methods and materials used to determine these variables are the same as those described previously for survey areas A, B, C, and D (Hughes & Brooks, 2006; Robertson et al., 2013). Ground vegetation cover was determined by placing a one square meter quadrat centered over the nest, and estimating the percentage of ground within the quadrat that was covered by vegetation (Hughes & Brooks, 2006; Wilson, 2007). GPS coordinates for each nest site were also recorded. Nest locations were not physically marked on-site because this has been found to increase predation of nests (Rollinson & Brooks, 2007). Later in the season, soil samples were taken from nest sites to determine soil texture (Hughes & Brooks, 2006; Hughes et al., 2009; Robertson et al., 2013). The methods used for soil sampling and analysis are described in section 4.5 of this chapter.

4.3 Trapping, Handling, and Tagging

4.3.1 Trapping

Before trapping and handling of turtles took place, the Animal Utilization Project Proposal (AUPP) for this study was reviewed and approved by the University of Waterloo's Animal Care Committee. A certificate of full ethics approval was obtained and is registered as AUPP # 15-01. Moreover, a Wildlife Scientific Collector's Authorization was obtained from the MNRF before trapping and handling of turtles took place (authorization #1079755), and activity related to Blanding's turtles was registered under Section 23.17 of Regulation 242/08 of the Endangered Species Act. Trapping took place from May 2015 to October 2015 at trap sites A, B, C, and D, as described in section 3.2.2. To avoid trapping bias, a variety of capture methods were used in this study. Baited hoop nets have been found to predominantly lure male turtles and very few juveniles, whereas basking traps tend to lure a high percentage of females (Ream & Ream, 1966). For this reason, both baited hoop nets and basking traps were used as the main methods for capture (Robertson et al., 2013). Two hoop nets and two basking traps were used in this study. The use of a dip net as well as hand catching turtles was employed as a method of capture when necessary (Robertson et al., 2013). One hoop net was used at trap site A, and the other was used at trap site B. Likewise, one basking trap was used at trap site C, and the other at trap site D. Basking traps were chosen to be used within Maple Creek to avoid the large amounts of fish by-catch that could occur if hoop nets were used in this area (DMMP, 1997; Robertson et al., 2013). Hoop nets were sufficient to use at trap sites A and B because these water bodies did not contain the large fish species that are present in Maple Creek and the Grand River (DMMP, 1997). Most fish species present within trap sites A and B were small enough to fit through the hoop net holes; however, catfish were caught as by-catch at trap site B on two different occasions. Upon inspection, they were released from the hoop net immediately, unharmed. Hoop nets and basking traps were set up and checked according to guidelines outlined in the *Standard Turtle Handling and Research Practices and Protocols* guidebook (Robertson et al., 2013).

Baited Hoop nets and basking traps were set up at trap sites at least once a week. Traps were usually set up in the morning, and checked several hours later on the same day (Robertson et al., 2013). For example, if a hoop net was set up at 09:00, it was checked later that same day at 16:00. On some occasions, if a hoop net or basking trap that had been set up for several hours did not catch any turtles, it would be left set-up overnight and checked the following morning (Robertson et al., 2013). Hoop nets were secured in place using three bamboo poles. Two bamboo poles were secured through the front of the net, and one was secured at the back of the net before being hammered into the ground with a rubber mallet to ensure the poles did not become unsecured over time. Hoop nets were set up to protrude at least 20 cm (between 20- 30 cm) from the water's surface to provide a breathing space for captured turtles (Robertson et al., 2013; S. Fraser, personal communication, May 21, 2015). An 18 inch inflatable boat bumper was placed inside the hoop nets to ensure that the nets would not sink into the water if they became unsecured (Robertson et al., 2013). When not in use, the hoop nets, bamboo poles, and boat bumper were removed from the water and stored off-site. Basking traps were set up in full sun, along the shoreline among SAV in trap sites C and D. Basking traps were secured in place using a rope with one section tied to the basking trap, and another section tied to a nearby fallen log. Turtles were removed from basking traps by hand and by dip net (Robertson et al., 2013). When not in use, the wooden ramps that allowed turtles to enter basking traps were folded up out of the water, onto the top of basking traps. The folded up wooden ramps acted as a lid that covered the top of the basking traps, and prevented any turtles or other animals from entering it. The basking trap was lifted out of the water to ensure it was empty before leaving the trap site. Hoop nets and basking traps were baited with raw white fish or sardines (Cosentino et al., 2010; Millar & Blouin-Demers, 2011; Robertson et al., 2013). All traps were labelled with the researcher's name and the research institution's name (Robertson et al., 2013).

4.3.2 Handling and tagging

Upon removal from traps, turtles were placed together in a large bin with one inch of water, and kept in the shade to ensure they did not overheat while measurements were taken (Robertson et al., 2013). Each captured turtle species was identified and sexed, weighed by being placed inside a cloth sack attached to a hook weight, and measured to determine approximate age (juvenile or adult). Straight-line carapace and plastron length, width, and depth were measured using large vernier calipers (Beehler, 2007; Bennett & Litzgus, 2014; DeCatenzaro & Chow-Fraser, 2010; Dorland et al., 2014). Individuals were identified as a juvenile or adult, and male or female based on the size of their plastron and the presence of secondary sex characteristics (Ernst et al., 1994; Moldowan, 2014). Secondary sex characteristics for freshwater turtles include the length of foreclaws, plastron shape, and pre-cloacal tail length (Ernst et al., 1994; Millar & Blouin-Demers, 2011; Moldowan, 2014). Female freshwater turtles are known to have short foreclaws, a straight or slightly domed plastron shape, and a cloaca that is positioned closer to the base of the tail near the plastron. Some male freshwater turtle species have long foreclaws, a slightly concave plastron, and a cloaca that is positioned further down the tail (Ernst et al., 1994; Moldowan, 2014). Although male Blanding's turtles are known to have a concave plastron, male painted turtles do not (P. Moldowan, personal communication, January 31, 2016). For the Dunnville marsh population of painted turtles, the plastron length of the smallest gravid female was used as the baseline plastron length for classifying adult females (≥ 11.3 cm). The smallest plastron length of a male painted turtle showing secondary sex characteristics was used as the baseline plastron length for classifying adult males (≥ 8.6 cm). Therefore, any painted turtle with a plastron length ≥ 8.6 cm that did not show male secondary sex characteristics could be classified as a juvenile female. However, painted turtles with a plastron length < 8.6 cm that did not show secondary sex characteristics could not be confidently identified as a male or female, and were classified as unknown sex juveniles (P. Moldowan, personal communication, January 31, 2016). The same method was used to identify the sex and size class of Blanding's and snapping turtles.

Seven 6.7 g and five 3.6 g Advanced Telemetry System (ATS) glue-on radio transmitters were used on 12 turtles (Yagi & Litzgus, 2012). One transmitter was used on a Blanding's turtle, and the remaining 11 transmitters were used on Painted turtles. Transmitters were attached to either the posterior marginal scutes or a costal scute on the lower right side of the carapace using a five-minute curing epoxy, smoothed over with a waterproof epoxy to prevent snagging on vegetation (*Figure 4.3*; Boarman et al., 1998; Yagi & Litzgus, 2012). Transmitters and epoxy combined did not weigh more than 7% of the turtle's body mass (Yagi & Litzgus, 2012).

Figure 4.3: A painted turtle with a 3.6 g glue-on radio transmitter attached to the carapace. As seen in this photo, the transmitter is attached to a lower right costal carapacial scute, and smoothed over with a waterproof epoxy to prevent snagging (photo: B. Brown).

Before being released, each adult turtle was marked with a number on their carapace, using paint, which allowed individuals to be distinguished between recaptures and newly captured turtles (*Figure 4.4*; Jones & Hartfield, 1995; Hughes & Brooks, 2006; Beehler, 2007; Selman & Qualls, 2007; Lescher, Tang-Martinez, & Briggler, 2013). Juveniles were marked with paint on the plastron to prevent the possibility of increased predation (Beehler, 2007). This marking allows identification of the turtles with minimal disturbance, and is a suitable form of non-invasive, non-permanent marking for the duration of the 5 month field study (Gordon & MacCulloch, 1980; Hughes & Brooks, 2006). A vehicle touch-up paint pen was used to mark turtles (Beehler, 2007). Paint colors used to mark individuals included tan, dark green and dark blue (Simon & Bissinger, 1983).

Figure 4.4: A female painted turtle tagged with tan paint. This photo shows a female painted turtle that has been tagged with the number 62 using paint for identification in case of recapture (photo: B. Brown).

Although concern over the risk of increased predation exists regarding paint marking, studies have found that the use of tagging paint on reptiles does not increase predation, and there are no documented studies on reptiles which suggest otherwise (Jones & Ferguson, 1980; Simon & Bissinger, 1983; Boitani & Fuller, 2000). Marking individuals with paint, for the purpose of tagging, was done as opposed to carapace notching because the latter is known to be a more invasive form of tagging which can occasionally cause a notched carapace wound to bleed (Cagle, 1939). If a juvenile turtle's carapace is not ossified or is partially ossified, it can be damaged by carapace notching through a serious fracture of carapacial plates, resulting in the death of the turtle or loss of a large portion of the carapace (Cagle, 1939). Furthermore, the notching of carapace marginals in certain turtle species can weaken the bridge between the carapace and plastron (Jones & Hartfield, 1995). Each individual was released in the same area of capture after being measured, tagged, and photographed.

4.4 Tracking

After attaching ATS glue-on radio transmitters, as described in section 4.3.2, individuals were tracked at least once a week throughout the duration of the study. Individuals were tracked using a R410 Scanning Receiver and a 3 Element Folding Yagi antenna from ATS Telemetry. Furthermore, individuals were tracked within four days after being fitted with a transmitter, to ensure they stayed in the general area of capture (A. Yagi, personal communication, May 15, 2015). The researcher normally tracked individuals within 2 km of the trapping site, and individuals were located within 20 feet of the researcher before GPS coordinates were recorded to mark their location. If an individual travelled out of tracking range, several hours were dedicated to tracking them until found. Data recorded once an individual was tracked to a specific area includes water depth, water temperature, air temperature, weather conditions (precipitation and cloud cover), ground vegetation density (stocks per square meter), canopy cover, SAV cover, and the individual's behaviour (Robertson et al., 2013). Materials and methods used for determining these environmental variables are the same as described in section 4.2.1. Moreover, a photo was taken of the individual and the area in which it was tracked. Upon observation, an individual's behaviour was recorded as open basking, cryptic basking, hiding, aestivating, swimming, nesting, mating, or courting (A. Yagi, personal communication, May 15, 2015). SAV cover was determined by placing a one square meter quadrat over the water and estimating what percentage of the water was covered by SAV within the quadrat. For measuring SAV cover where the turtle was located, the quadrat was placed within 3 feet of the turtle's location, or directly where the turtle was, and SAV cover was recorded for that area (Hughes & Brooks, 2006; Millar et al., 2011). For determing the average SAV cover for the body of water the turtle inhabited, this step was repeated along a linear transect within the water while the quadrat was placed randomly on either side of the transect line (Science & Plants for School [SPS], 2016). The number of quadrats used along the linear transect depended on the size of the water body. Average SAV cover was then calculated for the area measured (SPS, 2016). Attached transmitters that do not fall off on their own will be removed from turtles by the MNRF during the summer of 2016.

4.5 Soil Sampling and Texture Analysis

To determine soil texture in areas where nests were present, 10 composite soil samples were taken in December 2015 to represent soil from the different nesting areas (I. McKenzie, personal communication, December 15, 2015). The location of nesting areas can be seen in *Figure 5.9.* To determine soil texture in survey areas where no nests were found, 4 composite soil samples were taken to represent these areas (Micheli-Campbell, Baumgartl, Booth, Campbell, Connell, & Franklin, 2013). From the 10 sample sites where nests were present, a nest was located within the nesting area and 5 cores were taken from around the nest at a depth of 15 cm (Hughes & Brooks, 2006; I. McKenzie, personal communication, December 15, 2015). A sample depth of 15 cm was chosen because this is the maximum depth at which many species of freshwater turtles typically nest (Hughes et al., 2009). The 5 core samples were then combined into a bucket and mixed together to form a composite sample. Enough soil was taken from the composite sample to fill a zip-lock sandwich bag (I. McKenzie, personal communication, December 15, 2015; Micheli-Campbell et al., 2013). Each bag was labelled with the sample number, name of the area, and the GPS coordinates of the sample site. Soil was sampled similarly in the 4 sample sites representative of the 4 areas where no nests were found, except the 5 core samples were taken from an area with bare soil within the sample site since there were no nests to sample from. All 14 soil samples were then air dried for 3 weeks before soil texture analysis began (I. McKenzie, personal communication, December 17, 2015).

To determine each soil sample's composition, particle size analysis was employed using mesh screen sieves (Hughes et al., 2009). Firstly, organic material was removed from each soil sample before weighing out 75 - 100 g of the sample to be put through screen sieves (I. McKenzie, personal communication, December 17, 2015). To gently break apart clay and sand particles that may have been stuck together, without grinding down sand particles, the sample was gently grinded with a rubber ended pestle in a ceramic mortar (I. McKenzie, personal communication, Dec 17, 2015). The sample was then put through a series of screen sieves which included diameters of 2 mm, 1.18 mm, 600 µm, 300 µm, 250 µm, 150 µm, and 63 µm (Hughes et al., 2009; I. McKenzie, personal communication, Dec 17, 2015). The stack of sieves was placed in a sieve shaker for 10 minutes before contents left in the screens and base pan were weighed out and recorded (Hughes et al., 2009; I. McKenzie, personal communication, Dec 17, 2015). The percentage of each screen fraction sample was then calculated to determine the percentage of gravel, sand, and base pan material (silt and clay combined).

Since the percentages of silt and clay cannot be determined by sieving, a mason-jar test was conducted to measure percentages of sand, silt, and clay (Colorado State University [CSU], 2015). Soil samples were placed in separate one quart mason jars that were filled 1/4 full of soil and 3/4 full of water. A teaspoon of non-foaming detergent was added as a surfactant, and the sample was shaken for 10 minutes to break apart aggregates and separate soil into individual particles (CSU, 2015). Soil samples were left to settle in the jars for 6 days before each layer of sand, silt, and clay was measured in centimetres. The total thickness of the sample was measured, along with the thickness of each layer. The thickness of each layer was divided by the total thickness to obtain percentages of sand, silt, and clay (CSU, 2015). These percentages were then compared to the sieving percentages to estimate the most accurate results. Soil texture was determined by plotting percentages of sand, silt, and clay on a soil texture triangle (CSU, 2015).

4.6 Data Analysis

4.6.1 Location point mapping

The location points for tracked individuals, as well as nesting sites, were uploaded to a base map using ArcMap 10.3.1. The daily distances travelled were calculated for each individual by measuring the straight-line distance between two consecutive points, and dividing the distance (in metres) by the number of days between relocations (Paterson et al., 2012; Yagi & Litzgus, 2012). This was done for relocation points that were recorded within each month from May - October, for each individual, so that mean daily distances travelled could be calculated for each month (Paterson et al., 2012; Yagi & Litzgus, 2012). Data analysis can then reveal if the month (season) or sex of an individual influenced the daily distance travelled. It is important to note that the calculated daily distance travelled for each individual does not indicate exact turtle movement per day, because movement rates are not constant or the same distance each day. The distance a turtle travels each day varies and is influenced by things such as weather, temperature, proximity to predators, food availability, and time of year (Ernst et al., 1994; Yagi & Litzgus, 2012). For example, researchers have noted that turtles might be stationary for several days during the active season if they aestivate (Millar & Blouin-Demers, 2011; Yagi & Litzgus, 2012). The calculated daily distances travelled for each individual are approximate. The home range for each individual was determined by drawing a minimum convex polygon (MCP) around all data points for an individual, and then determining the area (in meters) of the polygon using ArcMap (Paterson et al., 2012; Yagi & Litzgus, 2012). MCPs were used to estimate home ranges instead of other competing methods, like kernel density estimation, because a minimum of 30 location points per individual is required to accurately calculate kernel densities and determine home ranges (K. Yagi, personal communication, Feb 17, 2016). Furthermore, a study by Row and Blouin-Demers (2006) revealed that kernel density estimations are inconsistent when determining the home range of herpetofauna because the home range size for an individual changes if the kernel density smoothing factor is increased or decreased. As a result, the researchers recommend using MCPs to calculate the home range of herpetofauna. Using MCPs to determine the home range of tracked individuals can sometimes result in the over-estimation of home range; however, because there were not a lot of location points for some individuals in this study, MCPs underestimated the home range size of individuals. The number of location points for individuals ranged from 3 to 24, with the average being approximately 14.2 location points, resulting in a slightly underestimated home range size using MCPs. Important nesting and habitat areas where turtles were sometimes observed from a distance, but not tracked due to lack of accessibility or time constraints, were located outside the boundaries of individual home range MCPs. To include these areas, a 15.4 meter buffer was added to all home range MCPs (Yagi & Litzgus, 2012; K. Yagi, personal communication, February 26, 2016). A buffer width of 15.4 meters was chosen because it was the minimum distance required to include important nesting locations and other habitat that turtles were observed using (Paterson et al., 2012). To determine the population range of tracked individuals, a MCP was drawn around all data points for all individuals, and the area of that polygon (in meters) was determined in ArcMap and later converted to hectares (Paterson et al., 2012; Yagi & Litzgus, 2012). Moreover, a 15.4 meter buffer was added to the population range MCP to include nesting sites found during surveying that were located outside the original MCP boundary produced from tracking points (K. Yagi, personal communication, February 26, 2016).

4.6.2 Macrohabitat identification and mapping

Macrohabitat is distinguished from microhabitat by being larger with more distinct differences that define plant communities or general ecozones (Stevens & Tello, 2009). Macrohabitats can affect the density of wildlife populations by influencing consumption and foraging patterns (Stevens & Tello, 2009). Moreover, the variation between macrohabitat types is usually greater than those among microhabitats within a macrohabitat, so microhabitats can have a limited ability to predict the presence or abundance of a particular species (Stevens & Tello, 2009). However, for indicator species like freshwater turtles that are impacted by subtle changes in their environment, microhabitat features are an important measurement for habitat use (Hartwig & Kiviat, 2007; Millar & Blouin-Demers, 2011). Therefore, analysis of both macro and microhabitat use was employed in this study.

Habitat use studies often compare the use of certain habitat types with the availability of each habitat type within an animal's home range or the defined study area to indicate habitat selection (Johnson, 1980). However, Johnson (1980) pointed out that if an animal has its home range in a certain area, it is already indicative that the animal made a selection. That being the case, habitat selection can be seen as hierarchical. Johnson (1980) identifies four levels of habitat selection. First-order selection is defined as the species' population range within a geographic area. Second-order selection is defined as the animal's home range within the population range. Third-order selection is the usage of specific habitat components within the home range. Lastly, food items or objects used by the animal from those available at the third-order selection area can be defined as fourth-order selection (Johnson, 1980; Yagi & Litzgus, 2012). Therefore, macrohabitats used by individuals in this study can be seen as third-order selection, and microhabitats used by individuals can be seen as fourth-order selection (Johnson, 1980; Yagi & Litzgus, 2012).

Macrohabitats were classified according to the Ecological Land Classification (ELC) field guide for Southern Ontario (Lee et al., 1998; Yagi & Litzgus, 2012). The ELC field guide classifies different habitats according to factors such as substrate type, dominant plant species, water depth, and tree or shrub cover (Lee et al., 1998). For the purpose of this study, water habitat was further defined as a canal, pond, creek, bay, or river. The available habitat was identified by determining habitat areas within the population range (Yagi & Litzgus, 2012). Table 5.7 on page 78 identifies available macrohabitat types within the radio-tracked turtles' population range, as classified by the ELC field guide of Southern Ontario. These macrohabitats were mapped over the Dunnville marsh base map in ArcMap 10.3.1. Location points and nesting sites were then plotted over the macrohabitat map to identify habitats occupied by tracked individuals and nests (Yagi & Litzgus, 2012).

4.6.3 Statistical analysis

Statistical analysis of home ranges was done in SPSS 23. Home range data normality was verified using a Shapiro-Wilk test (Yagi & Litzgus, 2012). Data that did not meet normality was log transformed (Paterson et al., 2012; Yagi & Litzgus, 2012). Log transformed data was then used in a one-way ANOVA test to examine if the sex of a tracked individual affects its home range size (Paterson et al., 2012; Yagi & Litzgus, 2012). Statistical analysis of daily distances travelled was done in R 3.1.2 software. The same methods were used to verify normality of data, and a repeated measures ANOVA test was used to examine if daily distance travelled was affected by month or by the sex of a turtle (Paterson et al., 2012; Yagi & Litzgus, 2012). Statistical analysis of this data was conducted because researchers have found that both season and the sex of an individual can affect the home range size and daily distances travelled by individuals, which ultimately affects their population range and areas of macro and microhabitat use (Millar & Blouin-Demers, 2011; Paterson et al., 2012; Yagi & Litzgus, 2012). For example, Millar & Blouin-Demers (2011) found that gravid female Blanding's turtles moved significantly more per day in June than males. Based on the findings of other researchers, it was hypothesized that the home range of females would be larger than that of males, indicating that home range size is affected by sex. Moreover, it was hypothesized that the mean daily distance travelled would be higher for females than males during the months of May, June, and July (during nesting season), indicating that the daily distance travelled is affected by season and sex.

Chapter 5 - Results

5.1 Introduction

Results from the 2015 field season provide baseline data regarding the population characteristics of freshwater turtles in the Dunnville marsh area. The results also provide information regarding distances travelled, home ranges, and the population range of tracked individuals. This tracking information reveals which macro and microhabitats were used by individuals, and which were not used. Although radio-tracked individuals were never tracked at a specific nesting site, several nesting sites were found within the home ranges of tracked individuals. Therefore, this chapter will also outline the microhabitat features of nesting sites where snapping turtle and painted turtle nests were found.

5.2 Species and Individuals Captured

During the 2015 field season, three different species of freshwater turtle were captured throughout the Dunnville marsh area. Table 5.1 provides details regarding the trapping area and method of capture for each species.

Table 5.1: *Number of Individuals Captured During the Field Season*

Year	Collection Period	Trapping Area	Type of Trap	Painted Turtles				Snapping Turtles		Blanding's Turtle	Total
				Adult Male	Adult Female	Unknown Juvenile	Juvenile Female	Adult	Juvenile	Juvenile Female	
2015	May 14 - October 8	A	Hoop Net	6	1	1	2	1	0	0	11
		B	Hoop Net	28	8	5	2	3	0	1	47
		C	Basking Trap	11	9	1	5	0	0	0	26
		D	Basking Trap	0	0	0	0	0	0	0	0
		Other*	Dip net or By hand	1	0	3	2	1	5	0	12
Total				46	18	10	11	5	5	1	96
				85				10		1	

*Refers to areas upstream and downstream from trapping area C, along the creek.

As seen in Table 5.1, 96 freshwater turtles were captured during the 2015 field season. The majority of freshwater turtles captured were painted turtles, with a total of 85. The majority of painted turtles captured were adult males (n = 46), followed by adult females (n = 18), juvenile females (n = 11), and unknown sex juveniles (n = 10). The second most common freshwater turtle species captured were snapping turtles, with a total of 10 captured with an equal number of adults and juveniles. Finally, one female juvenile Blanding's turtle was captured throughout the duration of the field study. The majority of turtles were captured in trapping area B (n = 47), followed by trapping area C (n = 26), other (n = 12), trapping area A (n = 11), and trapping area D (n = 0). The overall male to female ratio for adult painted turtles is 2.6:1, and the adult to juvenile size-class ratio is 3:1. The adult to juvenile size-class ratio for snapping turtles is 1:1. Table 5.2 outlines total recaptures throughout the field season.

Table 5.2: *Number of Individuals Recaptured during the Field Season*

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Collection Period</th><th colspan="4">Painted Turtles</th><th colspan="2">Snapping Turtles</th><th>Blanding's Turtle</th><th rowspan="2">Total</th></tr>
<tr><th>Adult Male</th><th>Adult Female</th><th>Unknown Juvenile</th><th>Juvenile Female</th><th>Adult</th><th>Juvenile</th><th>Juvenile Female</th></tr>
<tr><td>2015</td><td>May 14 - October 8</td><td>4</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td rowspan="2">6</td></tr>
<tr><td colspan="2">Total</td><td colspan="4">6</td><td colspan="2">0</td><td>0</td></tr>
</table>

As seen in Table 5.2, a total of six individuals were recaptured throughout the field season, which were all painted turtles. Two adult males were recaptured at trapping area A, and two were recaptured at trapping area B. One adult female was recaptured at trapping area B, and one unknown sex juvenile was recaptured at trapping area A.

5.3 Distances Travelled

Over the 2015 field season, 12 transmitters were added to freshwater turtles throughout the Dunnville marsh area. Table 5.3 outlines details regarding which turtle species received transmitters, as well as their sex, age, and in what area they were present.

Table 5.3: *Freshwater Turtles that Received Transmitters*

Date	Species	Channel No.	Sex	Age	Area
15-May-15	Blanding's	1	F	Juvenile	MSA Mid Canal
15-May-15	Painted	0	M	Adult	MSA Mid Canal
21-May-15	Painted	2	F	Adult	MSA Mid Canal
21-May-15	Painted	3	M	Adult	MSA Mid Canal
11-Jun-15	Painted	6	M	Adult	SSA Marina Pond
02-Jul-15	Painted	5	M	Adult	MSA Mid Canal
10-Jul-15	Painted	4	M	Adult	MSA Mid Canal
10-Jul-15	Painted	7	F	Adult	MSA Mid Canal
10-Jul-15	Painted	8	F	Adult	MSA Bay
10-Jul-15	Painted	9	M	Adult	MSA Bay
22-Aug-15	Painted	10	F	Adult	MSA Bay
27-Aug-15	Painted	11	F	Adult	MSA Bay

As seen in Table 5.3, transmitters were not attached to snapping turtles, but were added to 11 painted turtles and one Blanding's turtle. Snapping turtles were not chosen for attaching transmitters due to their aggressive behaviour. The goal was to add transmitters to 5 adult Blanding's turtles and add the rest of the transmitters to adult painted turtles. However, only one juvenile Blanding's turtle was captured during the field season, so the rest of the transmitters were added to adult painted turtles. It was important to try and add transmitters to an equal number of adult males and females so that movement and habitat use data could be compared between the sexes. *Figure 5.1* depicts the location point distribution of tracked individuals throughout the marsh area, and Table 5.4 outlines the mean daily distances travelled.

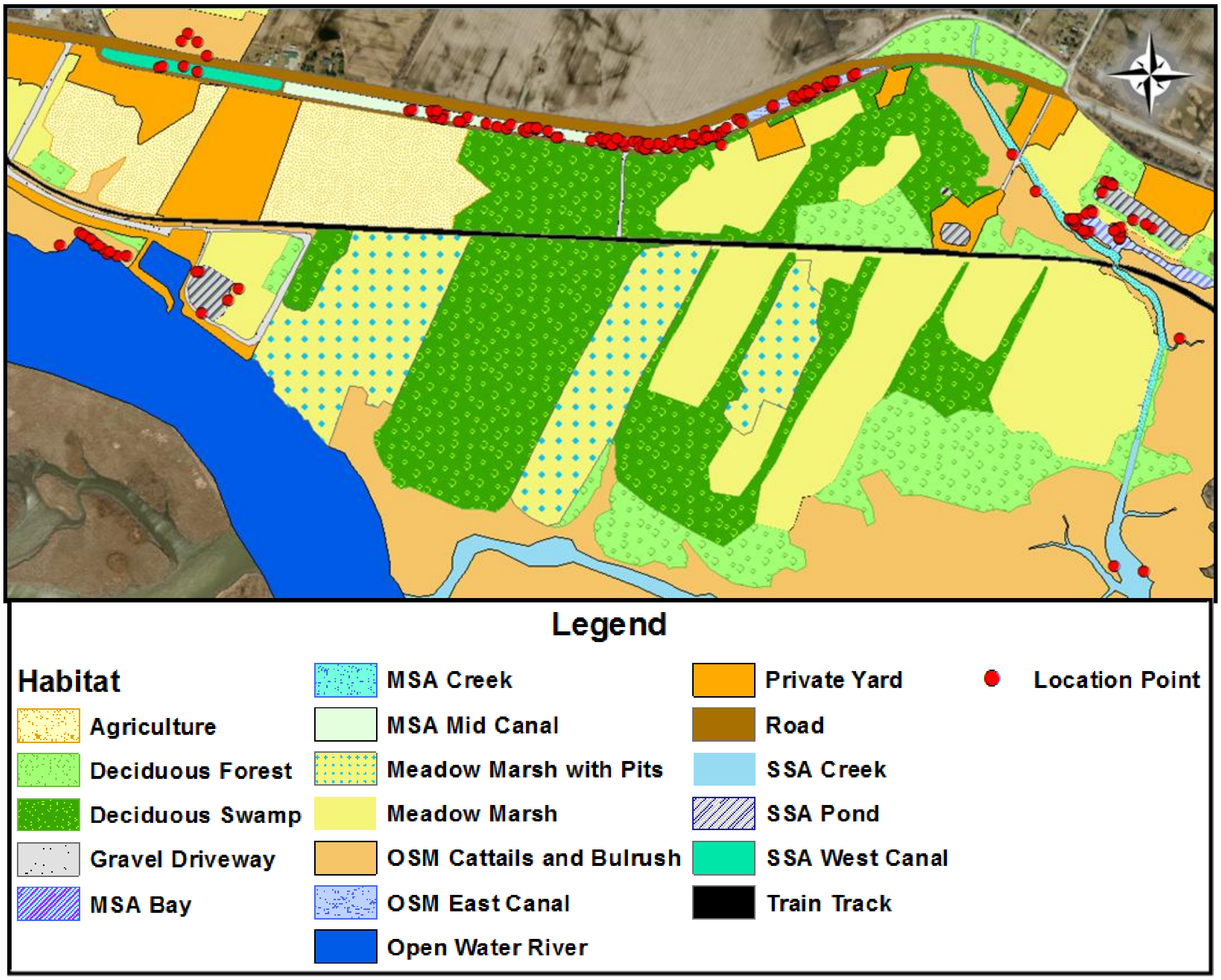

Figure 5.1: The distribution of location points for tracked individuals throughout the Dunnville marsh. Each red dot represents a relocation point for a tracked individual. Location points for individuals are abundant in the MSA Mid Canal, MSA Bay, OSM East Canal, and OSM Cattails and Bulrush.

Table 5.4: *Mean Daily Distances Travelled per Month for Female and Male Turtles*

Month	Mean daily distance moved by female PT's (m)	Mean daily distance moved by female PT's and BL (m)	Mean daily distance moved by male PT's (m)	Standard deviation for all females	Standard deviation for males
May	67.8	64.1	62.4	78.8	51.5
June	8.2	36.7	8.8	35.9	8.6
July	31.3	31.8	13.3	47.7	15.8
August	38.9	35.0	11.0	37.7	20.4
September	7.9	7.4	4.9	9.1	3.9
October	5.4	5.4	4.3	6.2	2.7

Average	**21.1**	**25.9**	**13.3**	**-**	**-**

Table 5.4 outlines the mean daily distances travelled per month for female and male freshwater turtles. The mean daily distances travelled per month for females were obtained by taking the average from the daily distances travelled (distance between two location points divided by the number of days between re-location) for all females during each month they were tracked. The same was done to obtain the mean daily distances travelled per month for males. The second column combines the female Blanding's with female painted turtles, since there was only one Blanding's tracked throughout the season. For the months of May and June, the second column reflects a more accurate average movement for female painted and Blanding's turtles because they often travel further distances during nesting season (Hughes & Brooks, 2006; Cosentino et al., 2010; Millar & Blouin-Demers, 2011; Paterson et al., 2012). The first column reflects a less accurate average movement for female painted turtles in May and June, because only one female painted turtle had a transmitter and was being tracked during those months. This particular female painted turtle was lost during mid-June, and the researcher was unable to pick up her signal for the rest of the season. She may have been hit by a car, due to remains that were found on the road near where she was last tracked. Two more transmitters were added to female painted turtles in early July, and another two in August (Table 5.3). Table 5.4 shows that the mean daily distances travelled for female painted and Blanding's turtles combined are greater than those of male painted turtles for each month. The overall average daily distance travelled for the field season is greater for female freshwater turtles than for male painted turtles.

A repeated measures ANOVA test was conducted to determine if daily distances travelled was affected by month (season) or the sex of a turtle. For the variable "Sex", F = 9.18

and P < 0.05, for "Time", F = 6.76 and P < 0.05, and for "Time x Sex", F = 11.54 and P < 0.01. The results indicate that the sex of a turtle as well as the time of year (month/season) significantly affects daily distances travelled. Table 5.5 outlines the maximum daily distances travelled by male and female freshwater turtles.

Table 5.5: *Maximum Daily Distances Travelled by Male and Female Freshwater Turtles*

Month	Maximum daily distance moved by a PT female (m)	Maximum daily distance moved by female BL (m)	Maximum daily distance moved by a male PT (m)
May	67.8	217.3	150.2
June	8.2	80.4	23.4
July	68.0	154.3	77.1
August	142.4	59.9	104.5
September	40.3	12.0	15.2
October	12.3	5.9	6.3

Table 5.5 shows the maximum daily distance that a male or female freshwater turtle travelled during each month. Again, it is important to note that only one female painted turtle was being tracked during May and June, so the maximum distance moved reflects her movement during those months. The month of June reflects only one relocation because this female painted turtle went missing in mid-June. Two male painted turtles were being tracked in May, and three were being tracked in June (Table 5.3). Table 5.5 shows that the furthest distance travelled by a male painted turtle in one day during May, June, and July is greater than the maximum distance a female painted turtle travelled. However, the female Blanding's turtle travelled the maximum distance in one day during May, June, and July, in comparison to male painted turtles. A female painted turtle travelled the furthest distance in one day during August, September, and October, followed by a male painted turtle. The female Blanding's turtle travelled the shortest maximum

distance in one day during August, September, and October in comparison to male and female painted turtles.

5.4 Home Ranges

Home ranges were calculated in ArcGIS 10.3, and a buffer of 15.4 meters was added to the home range area of each turtle, to encompass nesting areas. Table 5.6 shows the home ranges of each radio-tracked turtle.

Table 5.6: *Home Ranges for Each Radio-Tracked Turtle*

Species	Channel No.	Sex	Home range (ha)
Blanding's	1	F	16.7
Painted	2	F	3.1
Painted	7	F	3.1
Painted	8	F	9.5
Painted	10	F	2.1
Painted	11	F	1.2
Average			***5.9***
Painted	0	M	6.5
Painted	3	M	1.7
Painted	4	M	1.5
Painted	5	M	1.8
Painted	6	M	3.5
Painted	9	M	1.1
Average			***2.7***
Overall Average			**4.3**

When examining home ranges, it is important to note that not all transmitters were attached to turtles at the beginning of their active season (Table 5.3). This means that the home range for some individuals could have been recorded as spanning a larger area if all individuals had been tracked from the beginning of the active season. For example, the two adult female painted turtles on channels 10 and 11 did not receive transmitters until August, which is after their nesting season (May to mid-July). Therefore, their home range could be greater in area than recorded if they had received transmitters before the nesting season to record distances travelled to potential nesting sites. Based on the data obtained, Table 5.6 shows that the female Blanding's turtle had the largest home range, at 16.7 ha. A female painted turtle had the second largest home range, at 9.5 ha, and a male painted turtle had the smallest home range, at 1.1 ha. The overall average home range was 5.9 ha for females and 2.7 ha for males. The average home range for all freshwater turtles combined is 4.3 ha.

A one-way ANOVA test examined if the sex of a turtle affects its home range size. When the female Blanding's home range was included in the test, $F = 1.49$ and $P = 0.25$. When the female Blanding's was not included in the test, and only female and male painted turtles were included, $F = 0.49$ and $P = 0.50$. In either case, the test revealed that the sex of a turtle did not significantly influence its home range size ($P > 0.05$). *Figure 5.2* shows the home range averages for males and females.

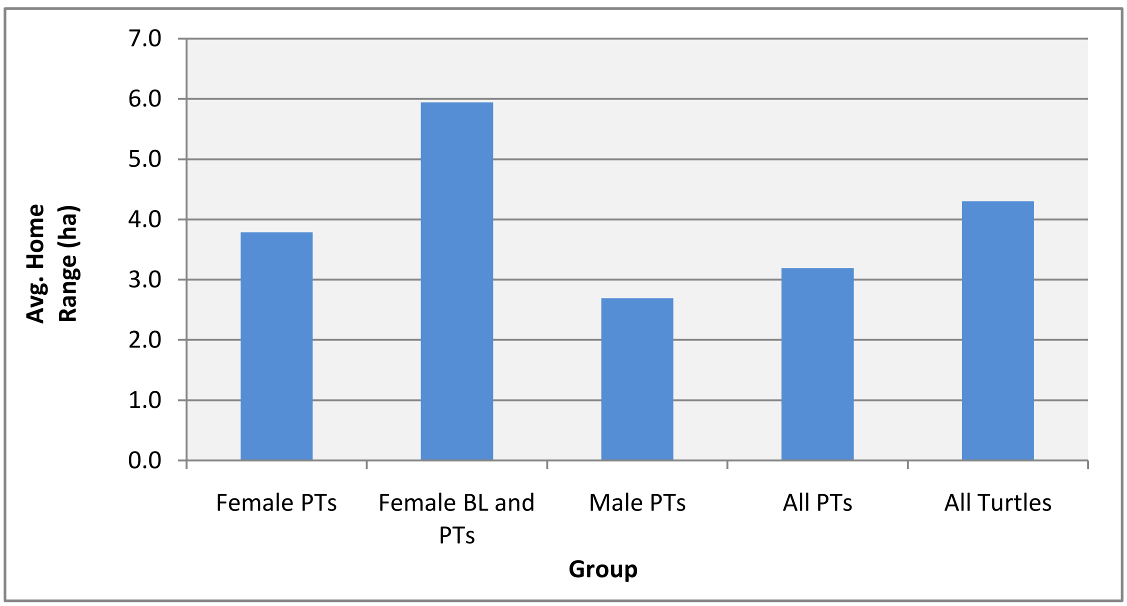

Figure 5.2: Average home ranges for female and male freshwater turtles, organized with and without the female Blanding's home range. At 3.8 ha, female painted turtles have a larger home range average than males (2.7 ha). When added to the average of female painted turtles, the female Blanding's home range (16.7 ha) greatly increases the average home range for female freshwater turtles (5.9 ha).

5.5 Available Habitat

Macrohabitats were classified according to the Ecological Land Classification (ELC) field guide for Southern Ontario (Lee et al., 1998; Yagi and Litzgus, 2012). Table 5.7 identifies available macrohabitat types within the radio-tracked turtles' 187.3 ha population range, as classified by the ELC field guide of Southern Ontario.

Table 5.7: *Macrohabitat Types Located within Radio-tracked Turtles' Population Range*

Habitat Acronym	Habitat Type	Habitat Description
AG	Agriculture	An area dedicated to growing crops
DF	Deciduous Forest	Tree canopy cover > 60%; Deciduous tree species > 75% of canopy cover
DS	Deciduous Swamp	Tree cover > 25%; deciduous tree species > 75% of canopy cover; water depth < 2 m; vernal pooling > 20% of ground coverage
MSA	Mixed Shallow Aquatic	water depth up to 2 m; water always present; dominated by a mix of submerged and floating aquatic vegetation (>25% cover)
MMP	Meadow Marsh with Pits	Tree and shrub cover < 25%; dominated by emergent hydrophytic macrophytes that are less tolerant of prolonged flooding; water depth < 2 m; seasonal flooding; Pits are present
MM	Meadow Marsh	Tree and shrub cover < 25%; dominated by emergent hydrophytic macrophytes that are less tolerant of prolonged flooding; water depth < 2 m; seasonal flooding
OSM	Organic Shallow Marsh	Dominated by emergent aquatic vegetation (>25%; e.g. cattail and bulrush); water up to 2 m deep; organic substrate
OW	Open Water River	No macrophyte vegetation; no tree or shrub cover; plankton dominated; water > 2 m depth
PY	Private Yard	A maintained private property; usually dominated by a mowed lawn
SSA	Submerged Shallow Aquatic	water depth up to 2 m; water always present; dominated by submerged aquatic vegetation (>25% cover)

Table 5.7 defines 10 different macrohabitat types within the radio-tracked turtles' population

range, according to the ELC field guide for Southern Ontario (Lee et al., 1998). As outlined in section 5.6, the macrohabitat classifications involving water were further defined as a canal, pond, creek, bay, or river to differentiate between water habitats used by turtles.

5.6 Habitat Areas Used by Tracked Individuals

Although 10 different macrohabitat types were identified within the 187.3 ha population range of radio-tracked turtles, only some of these habitat types were used by the turtles. *Figure 5.3* shows the average amount of time painted turtles spent in habitat types they used. This is based on the amount of times they were tracked in the habitat types each week.

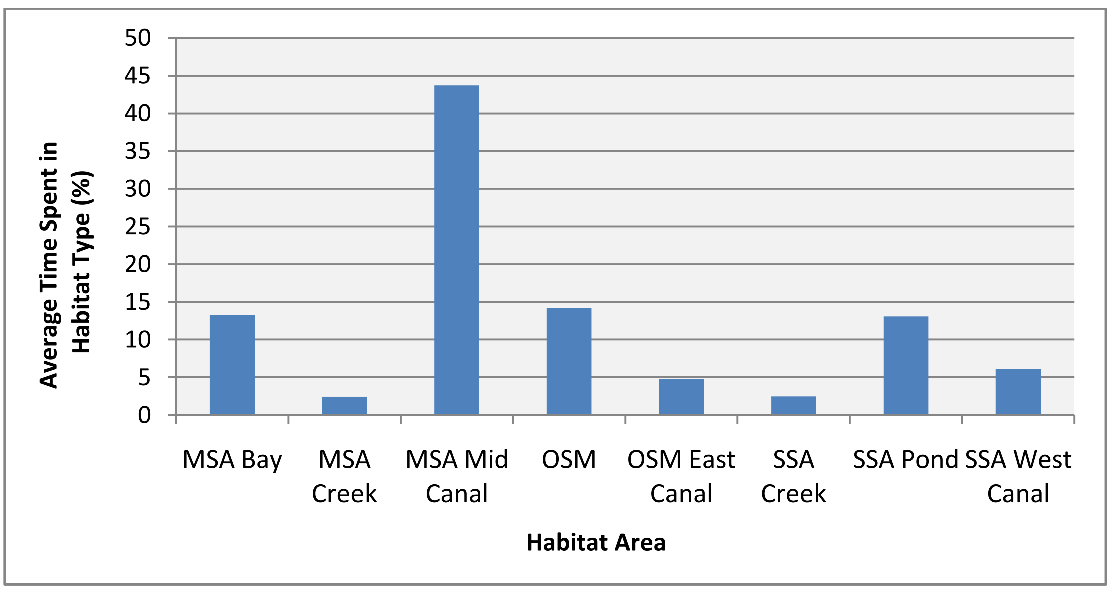

Figure 5.3: Average time painted turtles spent in macrohabitat types. The habitat used most often by painted turtles is the Mixed Shallow Aquatic (MSA) Canal.

As seen in Table 5.7, the MSA Canal habitat is characterized by having permanent standing water up to 2 m deep, and dominated by submerged and floating aquatic vegetation (>25% cover; Lee et al., 1998). The second type of habitat used most often by radio-tracked painted turtles is the Organic Shallow Marsh (OSM). This habitat type is characterized by the presence of cattails, bulrushes, and other hydrophytic grasses (>25% cover), as well as having standing or flowing water up to 2 meters deep for most or all of the growing season (Lee et al., 1998). The next habitat used most often is the MSA bay, which is very similar to the MSA Canal habitat type, except it is located in a bay area that has some flowing water, rather than still standing water. The fourth most frequently used habitat type is the Submerged Shallow Aquatic (SSA) Pond. This habitat type is characterized by having standing water always present up to 2 meters deep, dominated by submerged aquatic vegetation (>25% cover), with little to no tree or shrub cover. The habitat type that was used the least often of the occupied habitats is the MSA Creek. This habitat type's characteristics are very similar to the MSA Bay, except the water flows at a faster rate and the majority of floating and submerged aquatic vegetation is near the shoreline, rather than being spread throughout the water body. The habitat types within the population range that were not used by radio-tracked turtles will be covered in section 5.8. *Figure 5.4* outlines macrohabitat types used by the female Blanding's Turtle.

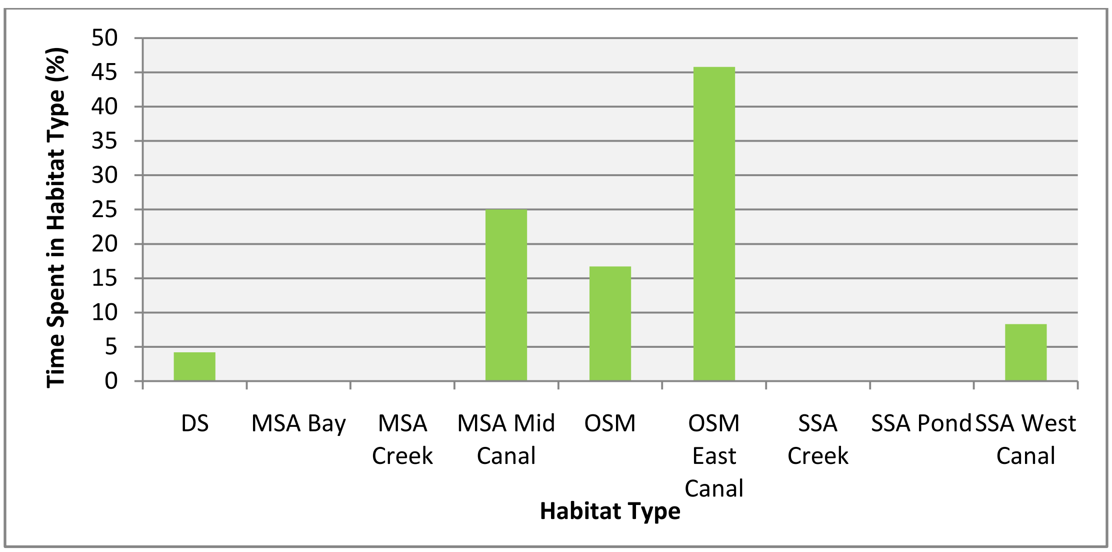

Figure 5.4: Macrohabitat types used by the female Blanding's turtle. Note that four habitat types not used by the Blanding's, but were used by painted turtles, appear on this figure to show the difference in habitat types used by the two species.

The habitat type used most often by the female Blanding's turtle is the OSM Canal. As seen in Table 5.7, this habitat type is characterized by having an organic substrate with standing water up to 2 meters deep, dominated by cattails, bulrushes, and other hydrophytic grasses (>25% cover; Lee et al., 1998). Moreover, in this case, the OSM is located in a canal with permanent standing water. The second habitat type most often used by the Blanding's is the MSA Canal. This habitat type is characterized by having permanent standing water up to 2 meters deep, and dominated by submerged and floating aquatic vegetation (>25% cover; Lee et al., 1998). The third most frequently used habitat type is the OSM, which is very similar to the OSM Canal habitat type, except it is located in a ground-level open landscape setting rather than inside a canal. Out of all habitat types used by the Blanding's, the deciduous swamp (DS) was used least often. The Blanding's was tracked in this habitat type on only one occasion and remained briefly before moving on to a different habitat type. The DS habitat type is characterized by having tree cover > 25%, with deciduous tree species being > 75% of the canopy cover (Lee et al., 1998). Moreover, this habitat type has variable flooding with a water depth < 2 meters, and vernal pooling or standing water > 20% of ground coverage.

Within the macrohabitats used by turtles, microhabitat variables were measured to further identify the habitat characteristics used by turtles. Table 5.8 outlines the monthly range and averages of microhabitat features measured within each habitat type for male and female painted turtles.

Table 5.8: *Average Monthly Microhabitat Variables for Radio-Tracked Painted Turtles*

Sex	Month	Air T (°C)	Water T (°C)	Water Depth (cm)	SAV Cover (%)
Male	**May**	**22.4**	**20.5**	**78.1**	**62.1**
Range		*15.5 - 28.5*	*17.7 - 23.7*	*45.7 - 120*	*55 - 70*
	June	**23.2**	**22.8**	**65.5**	**59.4**
Range		*20.5 - 24.5*	*18.2 - 25.5*	*36 - 113*	*26 - 68*
	July	**24.4**	**22.4**	**64.9**	**68.6**
Range		*18.3 - 32.3*	*18.8 - 26.1*	*23.5 - 98*	*35 - 85*
	August	**24.4**	**21.4**	**51.2**	**66.8**
Range		*19 - 30.8*	*19 - 24.4*	*21 - 96*	*35 - 85*
	September	**24.5**	**20.6**	**41.8**	**72.9**
Range		*16.1 - 31*	*16 - 28.3*	*23 - 79*	*45 - 80*
	October	**18.9**	**15.8**	**38.1**	**68**
Range		*15.4 - 21.9*	*13.3 - 18*	*27 - 60*	*45 - 80*
	Average	***23.8***	***21.1***	***54.5***	***68.1***
Female	**May**	**22.8**	**18.5**	**78**	**65**
Range		*n/a*	*n/a*	*n/a*	*n/a*
	June	**24.9**	**20.8**	**51.9**	**78.5**
Range		*24.1 - 25.7*	*20.1 - 21.5*	*45.7 - 58*	*77 - 80*
	July	**23.5**	**22.4**	**76**	**72.8**
Range		*21.6 - 26*	*21.3 - 23.8*	*68 - 85*	*70 - 75*
	August	**24**	**21.8**	**64.5**	**73.8**
Range		*18.8 - 30.6*	*19.2 - 24.6*	*43 - 97*	*68 - 82*
	September	**25.4**	**21.7**	**51**	**77.6**
Range		*16.3 - 31.2*	*16 - 28.5*	*24 - 76*	*65 - 85*
	October	**16.9**	**16.6**	**60.1**	**76.9**
Range		*15.4 - 21.7*	*15 - 17.8*	*31 - 79*	*70 - 80*
	Average	***23.3***	***20.8***	***59***	***74***

As seen in Table 5.8, four microhabitat variables were measured at the specific location where a turtle was tracked (normally within 1-2 m) within each of the macrohabitat types. These include air temperature, water temperature, water depth, and submerged aquatic vegetation (SAV) cover. The average air temperature throughout the active season where female and male painted turtles were tracked was at least 18.9 °C for males and 16.9 °C for females. The average maximum air temperature for males and females was 24.5 °C and 25.4 °C, respectively. The average water temperature ranged between 15.8 - 22.8 °C for males, and 16.6 - 22.4 °C for females. The average water depth ranged between 38.1 - 78.1 cm for males, and 51 - 78 cm for females. Finally, the average SAV cover ranged between 59.4 - 72.9% for males, and 65 - 78.5% for females. Table 5.9 outlines the monthly range and averages of microhabitat features measured within each habitat type for the female Blanding's turtle.

Table 5.9: *Average Monthly Microhabitat Variables for the Radio-Tracked Blanding's Turtle*

Sex	Month	Air T (°C)	Water T (°C)	Water Depth (cm)	SAV Cover (%)
Female	**May**	**20.8**	**20**	**61.4**	**57.5**
Range		*15.5 - 28.3*	*13.5 - 24.8*	*15.2 - 122*	*55 - 65*
	June	**22.4**	**23.6**	**65.3**	**69**
Range		*21.6 - 24*	*21.4 - 27.2*	*45.7 - 76.2*	*60 - 82*
	July	**26**	**22.9**	**35.3**	**73.5**
Range		*23 - 28*	*21 - 26*	*6.5 - 79*	*72 - 75*
	August	**24.5**	**21.4**	**43.3**	**70.5**
Range		*19 - 29*	*19.2 - 24.3*	*33 - 60*	*68 - 72*
	September	**23.8**	**20.4**	**28.4**	**70.5**
Range		*16.1 - 28.8*	*17.2 - 25.6*	*22 - 35*	*67 - 70*
	October	**21.6**	**17.5**	**37**	**67**
Range		*n/a*	*n/a*	*n/a*	*n/a*
	Average	***23.6***	***21.3***	***44.4***	***63.9***

As seen in Table 5.9, the same microhabitat variables were measured for the female Blanding's turtle. The average air temperature throughout the active season at locations where the female Blanding's was tracked ranged from 20.8 - 26 °C, while average water temperature ranged between 17.5 - 23.6 °C. The average water depth ranged between 28.4 and 65.3 cm, and the average SAV cover ranged between 57.5 and 73.5%. *Figures 5.5 to 5.8* show the average microhabitat variables compared side by side for male and female painted turtles, and the female Blanding's.

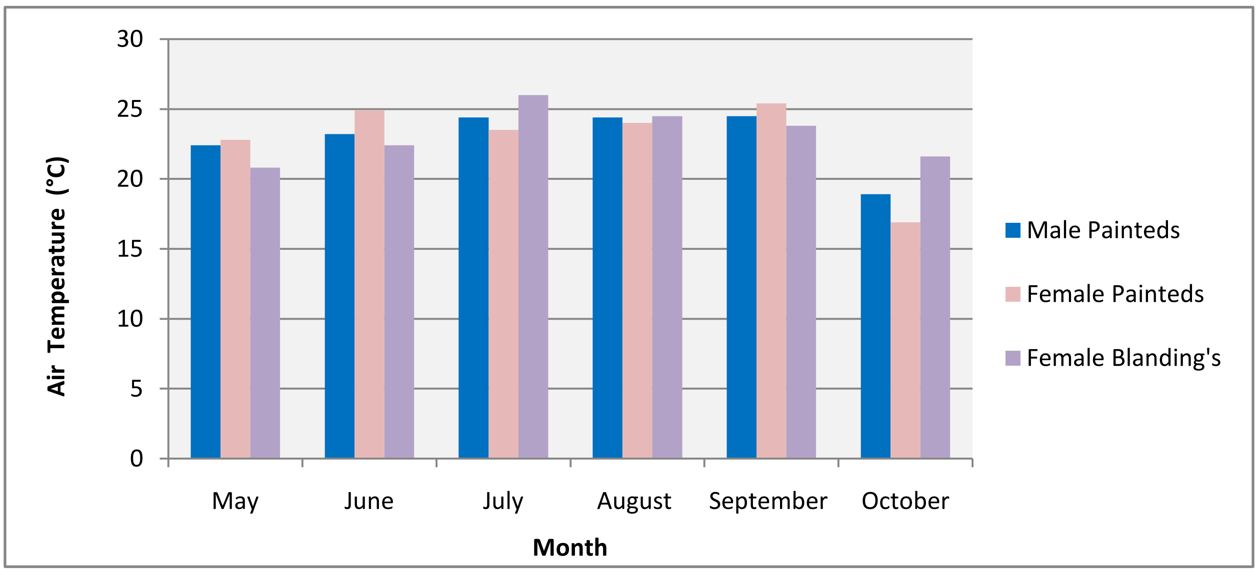

Figure 5.5: Average monthly air temperature within macrohabitats where turtles were tracked.

This figure shows the differences in average air temperature at locations where male and female painted turtles, and the female Blanding's turtle was tracked. There is not a significant variance between average air temperatures of males and females, or between painted turtles and the Blanding's. However, in October (up to October 15th), the female Blanding's remained in areas that had an average temperature above 20 °C. Notice that each group remained in areas with an average temperature above 20 °C for all months except October when average temperatures dropped. *Figure 5.6* compares average water temperatures.

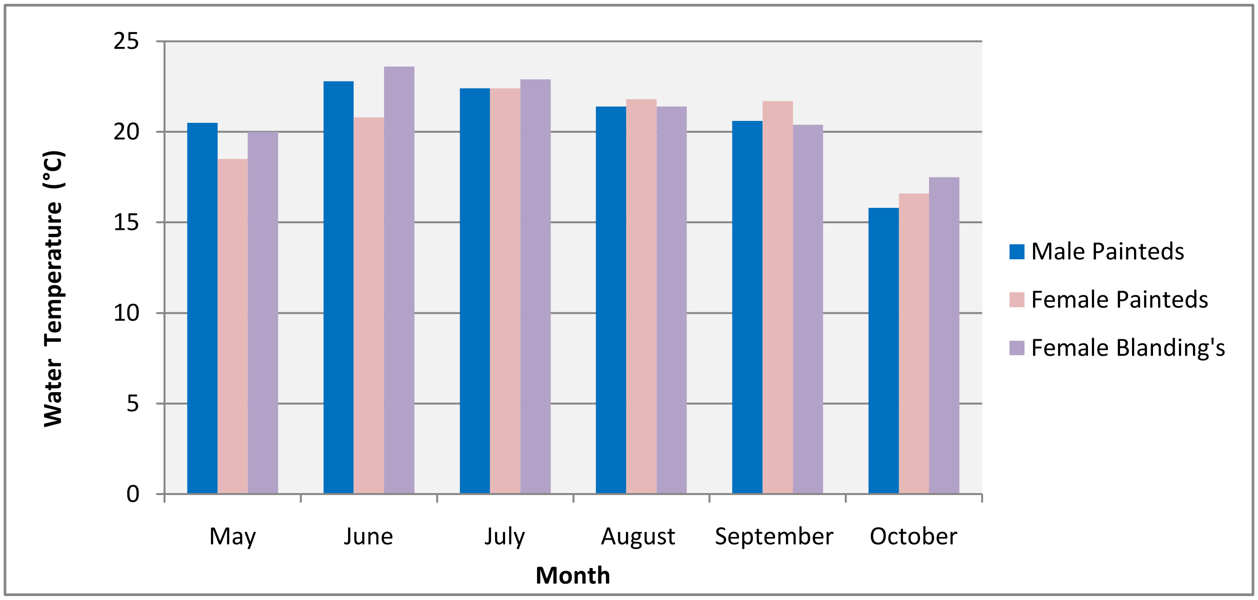

Figure 5.6: Average monthly water temperature within macrohabitats where turtles were tracked.

The Blanding's utilized areas that had a warmer average water temperature in June, July, and October. Male painted turtles utilized areas with a warmer water temperature than female painted turtles in May and June, but occupied areas with an equal or lesser water temperature for the rest of the active season. Notice how each group remained in areas with an average water temperature above 20 °C for the majority of the active season. *Figure 5.7* compares average water depths.

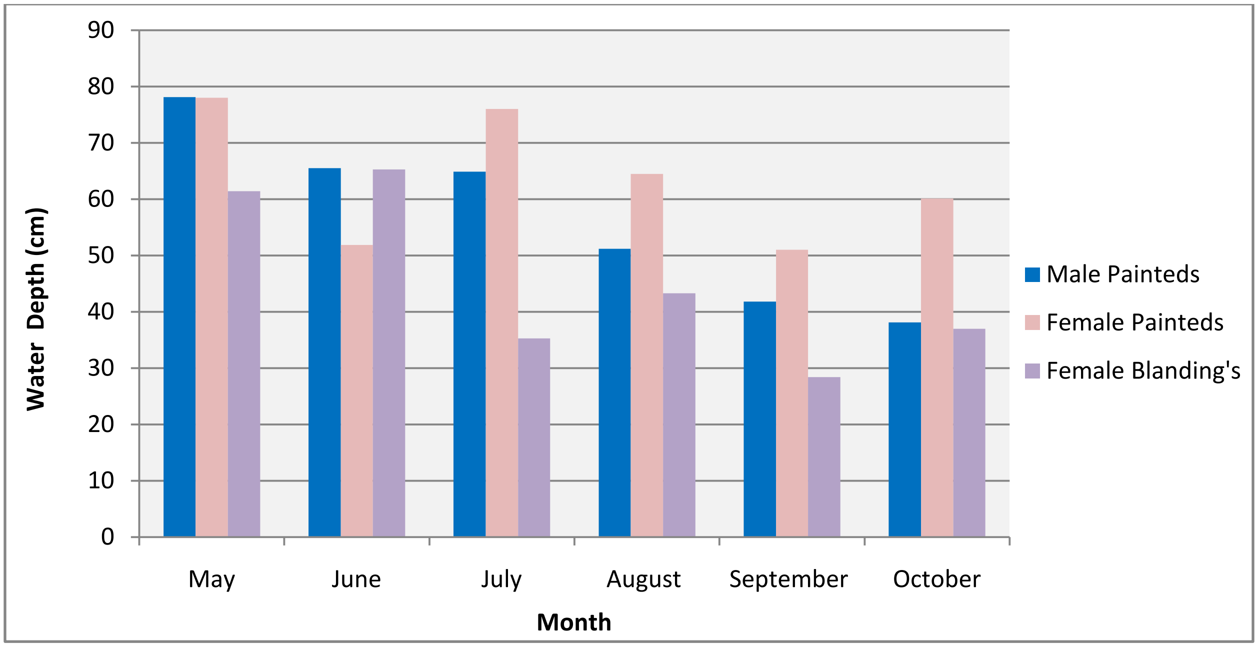

Figure 5.7: Average monthly water depths within macrohabitats where turtles were tracked.

The female Blanding's turtle occupied areas with a lower average water depth than male and female painted turtles for every month except June. Female painted turtles stayed in areas with a higher average water depth than males and the female Blanding's for every month except May and June. Female and male painted turtles did not occupy areas with an average water depth below 35 cm. However, in September, the female Blanding's occupied areas with an average water depth slightly below 30 cm. *Figure 5.8* compares average SAV cover.

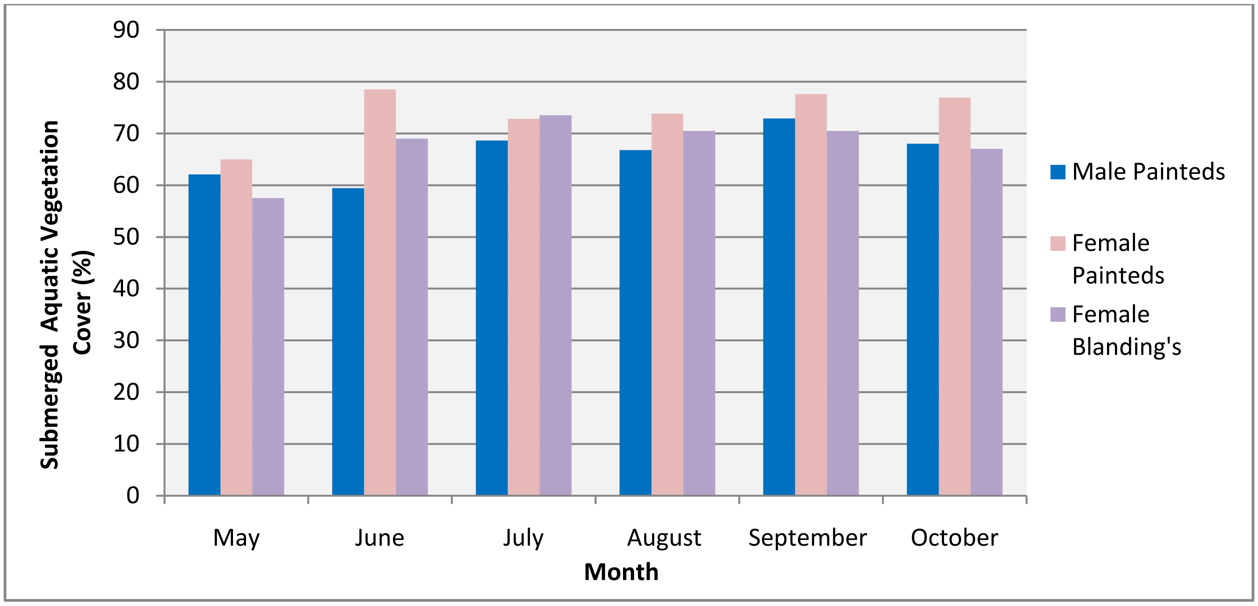

Figure 5.8: Average monthly SAV cover within macrohabitats where turtles were tracked. Notice that all groups occupied areas with an average SAV cover above 50% during the entire active season. Similarly, all groups did not occupy areas with an average SAV cover above 80% for the entire active season. Female painted turtles occupied areas with the highest SAV cover during the majority of the active season.

Although four microhabitat features were measured at a specific location where each turtle was radio-tracked (normally within 1-2 m), shoreline or surrounding vegetation density as well as canopy cover were also measured within macrohabitats. These variables were measured as the average for the entire macrohabitat area, rather than being measured each time a turtle was tracked. This method was less time consuming for the researcher and gave a more accurate overall picture regarding canopy cover and vegetation density throughout the macrohabitat areas where turtles were tracked. Table 5.10 summarizes the average vegetation density and canopy cover at each macrohabitat area where painted turtles were tracked.

Table 5.10: *Average Canopy Cover and Vegetation Density within Macrohabitats used by Painted Turtles*

Area Tracked	Canopy Cover (%)		Vegetation Density (stocks per Sq/m)	
	Average	Range	Average	Range
OSM East Canal	10	0 - 20	26	23 - 28
MSA Mid Canal	14	10 - 20	33.6	28 - 34
SSA West Canal	10	0 - 20	17.3	12 - 20
OSM West	0	n/a	29	20 - 37
SSA Marina Pond	4	0 - 10	19.5	12 - 25
SSA Private Pond	10	0 - 20	28	n/a
MSA Creek	0	n/a	34	19 - 49
SSA Creek	0	n/a	45	37 - 54
MSA Bay	5	0 - 10	34	19 - 49
OSM East	0	n/a	45	37 - 54

As seen in Table 5.10, the average canopy cover ranges between 0 - 14% for each macrohabitat type used by painted turtles. The average vegetation density for these areas ranges between 17.3 - 45 stocks per Sq/m, with the majority of macrohabitats having an average vegetation density above 25 stocks per Sq/m. Table 5.11 outlines these variables for macrohabitats where the Blanding's was tracked.

Table 5.11: *Average Vegetation Density and Canopy Cover within Macrohabitats used by the Blanding's*

Area Tracked	Canopy Cover (%)		Vegetation Density (stocks per Sq/m)	
	Average	Range	Average	Range
OSM East Canal	10	0 - 20	26	23 - 28
MSA Mid Canal	14	10 - 20	33.6	28 - 34
SSA West Canal	10	0 - 20	17.3	12 - 20
DS	70	n/a	24	n/a
OSM North	12.5	0 - 30	25	n/a

As seen in Table 5.11, the average canopy cover in macrohabitats used by the Blanding's ranged from 10 - 70%. The 70% canopy cover was within a deciduous swamp where the Blanding's briefly remained. *Figure 5.4* shows that the Blanding's spent the majority of her time in the OSM East Canal, which had an average canopy cover of 10%. The average vegetation density ranged between 17.3 - 33.6 stocks per Sq/m in macrohabitats used by the Blanding's. The majority of her time was spent in an area with an average vegetation density of 26 stocks per Sq/m, which contained bulrush and cattails.

5.7 Nesting Habitat

Although freshwater turtles were not tracked at a particular nesting site, there were a number of nests found next to macrohabitats used by tracked individuals. During surveys for turtle nests, some nests were found outside of macrohabitats used by tracked turtles, which were identified as snapping turtle nests. *Figure 5.9* shows nest site locations that were discovered throughout the marsh area, and Table 5.12 summarizes the habitat variables measured at each nest site.

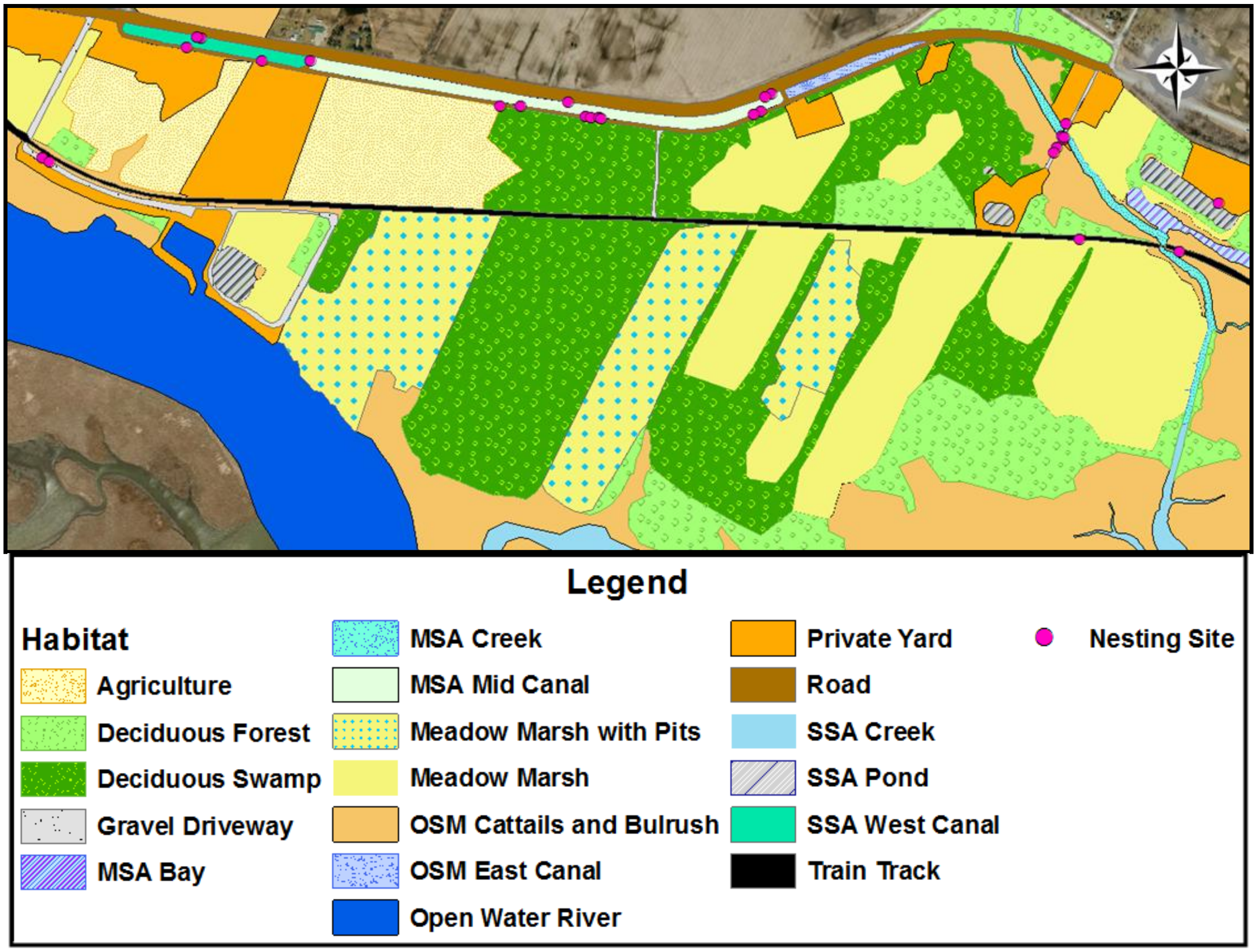

Figure 5.9: Nest site locations throughout the marsh area. Each pink dot represents a nesting site. One dot could represent more than one nest. Turtles nested along the SSA West Canal, MSA Mid Canal, the SSA Pond, the Train Track, and along gravel driveways.

Table 5.12: *Nesting Habitat Variables*

Nest Location	Turtle Species	Number of Nests	State of Nest(s)	Soil Texture	Canopy Cover (%)	Vegetation Cover (%)	Soil T (°C)
MSA Mid Canal North Shore	At least two are painted	6	Not eaten	Sandy loam	2.5	39.5	24.7
MSA Mid Canal South Shore	At least four are painted	13	10 eaten	Sandy clay	7.5	19.1	22.1

SSA West Canal	**n/a**	**4**	**3 eaten**	**Loam**	**2.5**	**46**	**26**
Marina Driveway	**Snapping**	**4**	**Not eaten**	**Gravel**	**0**	**11.5**	**33.2**
Private Driveway	**Three are Snapping**	**6**	**6 eaten**	**Gravel with loam**	**0**	**23.6**	**n/a**
Private Dock along MSA Creek	**One is a Snapping**	**16**	**15 eaten**	**Gravel with sand**	**0**	**9**	**n/a**
East Train Tracks	**Snapping**	**1**	**Not eaten**	**Gravel with sand**	**0**	**0**	**27.3**
West Train Tracks	**n/a**	**1**	**Not eaten**	**Silt loam**	**0**	**30**	**20**
SSA Private Pond shoreline	**Painted**	**9**	**9 eaten**	**Sandy clay loam**	**0**	**30**	**30.9**
Average	**-**	**-**	**-**	**-**	***3.0***	***25.5***	***25***

As seen in Table 5.12, nests were normally located in a variety of soil textures, but were mainly comprised of textures that drain water well (Finkler, 2006; Hughes & Brooks, 2006). Most soil textures at nest sites had a high percentage of gravel or sand. These soil textures differ from survey areas where no nests were found as seen in Table 5.13, which contained mainly silt loam soil and one area with sandy loam soil. The average canopy cover above nest sites was low, ranging between 0 - 7.5%; although, most nest sites had no canopy cover. Vegetation cover around nests ranged between 0 - 46%. Finally, soil temperature at nest sites ranged between 20 - 30.9 °C.

5.8 Habitat Areas Not Used by Tracked Individuals

The macrohabitat types where no turtles were tracked include Agriculture, Private Lawn, Meadow Marsh, Meadow Marsh with Pits, Open Water River, and Deciduous Forest. Moreover, no painted turtles were tracked within the Deciduous Swamp, and the female Blanding's was tracked in this area only once. There is a possibility that the Blanding's was erroneously tracked within the outer edge of the Deciduous Swamp, since the researcher was learning how to use the radio-tracking device at that time. In support of this theory, areas within the restored marsh that were surveyed throughout the active season consisted of Deciduous Swamp, within which no turtles were found or tracked (*Figure 5.1*). Since the survey areas represent some of the macrohabitat types where no turtles were tracked or found, average microhabitat variables measured within these areas are outlined in Table 5.13 to represent habitat not used by the turtles.

Table 5.13: *Average Microhabitat Variables within Macrohabitat Areas Not Used*

Survey Area	Air T (°C)	Water T (°C)	Water Depth (cm)	SAV Cover (%)	Canopy Cover (%)	Vegetation Density (stocks per Sq/m)	Soil Texture
A (North)	**21.5**	**17.3**	**5.2**	**0**	**75**	**17**	**Silt loam**
Range	*12.6 - 32.8*	*17.2 - 17.3*	*0 - 18*	*n/a*	*70 - 80*	*n/a*	*n/a*
A (South)	**19.4**	**17.2**	**4.8**	**0**	**75**	**12**	**Silt loam**
Range	*12.6 - 22.6*	*n/a*	*0 - 24*	*n/a*	*70 - 80*	*n/a*	*n/a*
B	**20.2**	**14.8**	**7**	**0**	**73**	**16**	**Silt loam**
Range	*10.6 - 32.7*	*12.3 - 17.3*	*0 - 21.4*	*n/a*	*70 - 80*	*n/a*	*n/a*
***C**	**n/a**	**n/a**	**39.8**	**0**	**0**	**n/a**	**Silt loam**
Range	*n/a*	*n/a*	*30.5 - 57*	*n/a*	*n/a*	*n/a*	*n/a*
D	**18.2**	**16.3**	**13.8**	**0**	**70**	**28**	**Sandy loam**
Range	*12 - 23.3*	*12.2 - 18.6*	*0 - 38.1*	*n/a*	*n/a*	*n/a*	*n/a*

*Variable measurements for survey area C were taken in November and were not taken for all variables.

As seen in Table 5.13, the average air temperature within survey areas ranged between 18.2 - 19.4 °C, and the average water temperature ranged between 14.8 - 17.3 °C. The average air and water temperature are lower in these areas in comparison to those in areas where turtles were tracked. The average water depth within survey areas ranged between 5.2 - 39.8 cm, which is lower than the average water depth in areas where turtles were tracked. There was no SAV cover in any of the flooded zones within survey areas. The average canopy cover at survey areas ranged between 0 - 75% canopy cover, and the vegetation density ranged between 12 - 28 stocks per Sq/m. These average variables represent the microhabitat features within some macrohabitat areas not used by the turtles. It should also be noted that no nests were found within survey areas A, B, C, or D. The soil texture of survey areas A, B, and C was silt loam, while survey area D's was sandy loam.

5.9 Average Variables at Trap Sites

Trap sites A, B, and C were successful at capturing turtles; however, trap site D did not catch any freshwater turtles throughout the entire active season (Table 5.1). There is a difference in averages of microhabitat variables measured at the trap sites. Table 5.14 outlines the average variables measured at each trap site.

Table 5.14: *Average Microhabitat Variables at Trap Sites*

Trap Site	Air T (°C)	Water T (°C)	Water Depth (cm)	SAV Cover (%)	Canopy Cover (%)	Vegetation Density (stocks per Sq/m)
Trap A	**21.4**	**24.2**	**67.5**	**38**	**4**	**19.5**
Range	*13.3 - 27.5*	*19.1 - 29.2*	*63 - 76*	*n/a*	*0 - 10.0*	*12 - 25.0*
Trap B	**21.6**	**20.2**	**68.4**	**70**	**14**	**33.6**
Range	*16.3 -*	*13.6 - 28.3*	*43 - 122*	*n/a*	*10 - 20.0*	*28 - 34*

	24.8					
Trap C	**25.1**	**21.5**	**71.6**	**70**	**5**	**34**
Range	*22 - 29.5*	*19.2 - 24.6*	*43.5 - 88*	*n/a*	*0 -10.0*	*19 - 49*
Trap D	**24.5**	**22.6**	**105.5**	**22**	**36.7**	**38**
Range	*20.5 - 29.5*	*19.1 - 28.8*	*68.5 - 133*	*n/a*	*30 - 50*	*n/a*

As seen in Table 5.14, there are a few important differences in average habitat variables between trap site D, where no turtles were captured, and trap sites A, B, and C. The average water depth was much higher at trap site D (105.5 cm) than at trap sites A (67.5 cm), B (68.4 cm), and C (71.6 cm). Similarly, the average overall canopy cover was much higher at trap site D (36.7%) than at trap sites A (4%), B (14%), and C (5%). The SAV cover was much lower at trap site D (22%) than at trap sites A (38%), B (70%), and C (70%). Therefore, the difference between these three habitat variables could indicate their influence on used and unused habitats.

Chapter 6 - Discussion

6.1 Population Characteristics

This section will discuss results that help to answer the first three research questions of this study, which include 1) How many different species of freshwater turtle are present within and adjacent to the restored marsh; 2) Which turtle species are more abundant than others within and adjacent to the restored marsh; and 3) What are the population characteristics of the species (male to female ratio; juvenile to adult ratio).

6.1.1 Turtle species present

During the study period, there were no freshwater turtles present within the ecologically restored areas of the marsh. According to tracking data, they did not travel to the ecologically restored areas for temporary use during the active season. Reasons for this are outlined in section 6.4, which covers habitat areas not used. However, the findings indicate that there are three species of freshwater turtle that occupy areas adjacent to the restored marsh. These species include the midland painted turtle, common snapping turtle, and Blanding's turtle. It was expected that each of these three species would be present in the Dunnville marsh area, since land surveys and population range maps indicate that these species are present in wetland areas between Lake Ontario and Lake Erie (MacCulloch, 2002; Yagi, Brant, & Tervo, 2009). Other freshwater turtle species, such as the wood turtle, spiny softshell, spotted turtle, stinkpot, and northern map turtle, have population ranges that extend to wetlands between Lake Ontario and Lake Erie; however, two of these species are listed as endangered within Ontario, while the others are either threatened or a species of special concern (MacCulloch, 2002; MNRF, 2016).

Furthermore, these five species are present in small isolated populations throughout Southern Ontario, making them rare in this area of the province (Yagi et al., 2009; MNRF, 2016).

6.1.2 Turtle species abundance

In regard to turtle species that are most abundant in the Dunnville marsh area, 85 painted turtles, 10 common snapping turtles, and 1 Blanding's turtle were caught over the 5 month study period (Table 5.1). These capture numbers can indicate that painted turtles are most abundant, followed by common snapping turtles, and Blanding's turtles are the least abundant of the three species. Trapping areas were selected in habitats that could support each of these species, however, trapping bias could potentially impact capture numbers of different species. For example, hoop nets as well as basking traps were used in this study to reduce bias related to male and female or juvenile and adult captures in some species of freshwater turtles (Ream & Ream, 1966). Hoop nets are a sufficient method for capturing snapping turtles, but basking traps are not because snapping turtles do not bask on objects outside water as often as most other freshwater turtle species (Weber & Layzer, 2011).

A study by Weber & Layzer (2011), found that snapping turtles were the least likely to openly bask, out of four freshwater turtles species studied. Moreover, their trapping methods resulted in zero snapping turtles being captured by basking trap, yet 39 were caught by hoop net. This is reflected in the Dunnville marsh study's results which show that snapping turtles were never captured by basking trap, but were captured by hoop net, dip net, and by hand. This could potentially have skewed capture results for snapping turtles. It is possible that more snapping turtles would have been captured throughout the season if hoop nets were used in trapping areas C and D. However, basking traps were chosen for these areas to prevent bycatch of large fish species (pike, suckers, and walleye) that are known to spawn in these areas, and because the water is too deep for hoop nets during most of the season (DMMP, 1997; Robertson et al., 2013).

Although a higher number of snapping turtles may have been caught throughout the season with the use of hoop nets in trapping areas C and D, it is unlikely that snapping turtle capture numbers would have increased past those of painted turtles. This is based on capture rates in areas where hoop nets were used, in which a much higher number of painted turtles were still captured in comparison to snapping turtles (Table 5.1). Therefore, regardless of the trapping method used, painted turtles were likely to be the most abundant species of the three present in the area. This was expected, since painted turtles are the only turtle species in Ontario not listed as a species at risk, meaning their population numbers are more abundant throughout Ontario (MNRF, 2016).

A study done by DeCatanzaro and Chow-Fraser (2010) in the Great Lakes region found that painted turtles were most abundant in degraded wetlands, and the probability of their occurrence decreased as wetland quality increased. The researchers also found that although common snapping turtles were present in degraded wetlands, they were most abundant in wetlands with intermediate water quality (DeCatanzaro & Chow-Fraser, 2010). Moreover, the common musk turtle was completely absent from degraded wetlands. The researchers classified wetlands according to water quality, and found that the degraded wetlands were located in the lower great lakes region (Lake Erie and Lake Ontario; DeCatanzaro & Chow-Fraser, 2010). Their findings are consistent with turtle species abundance located in the Dunnville marsh area (located between Lake Erie and Lake Ontario), where painted turtles appear to be the most abundant, followed by common snapping turtles, and the common musk turtle was not captured or observed at the site. These consistent findings support the theory that some reptile species can be used as indicators of habitat quality (Mifsud, 2014).

6.1.3 Sex ratios and size-class

Findings related to the population characteristics of each species show that, for painted turtles, adult males were most abundant (n = 46), followed by adult females (n = 18), then juvenile females (n = 11), and lastly unknown sex juveniles (n = 10). Snapping turtles were not sexed in this study; however, five adults and five juveniles were captured (Table 5.1). Finally, one juvenile female Blanding's turtle was captured. The overall male to female ratio for adult painted turtles was 2.6:1, and the adult to juvenile size-class ratio was 3:1. The adult to juvenile size-class ratio for snapping turtles was 1:1. A study by Ream and Ream (1966) discovered that trapping methods for painted turtles can cause bias in the estimation of sex ratio and size-class (juvenile or adult) distribution. The researchers found that baited hoop nets yielded more males than females, and few juveniles. Basking traps yielded a higher percentage of females than hoop nets, and captured more adults than juveniles. Hand capture resulted in a sample with a high percentage of juveniles and a 1:1 sex ratio for adults (Ream & Ream, 1966). The study showed that different trapping methods will reveal different population characteristics for the same population of painted turtles (Ream & Ream, 1966).

In an attempt to lesson this degree of bias in the Dunnville marsh study, a combination of trapping methods were used which include baited hoop nets, baited basking traps, and hand capture (with and without dip nets). Since Ream and Ream's (1966) study showed that baited hoop nets yielded more males, and basking traps yielded more females, it was thought that the use of both these methods could even out sex ratio bias for the Dunnville marsh study. Moreover, since hand capture yielded more juveniles than other capture methods, hand capture was also chosen as a trapping method. As seen in Table 5.1, the use of baited hoop nets did result in the capture of more adult male than female painted turtles at trap locations A and B. Trapping area A caught 6 adult males and 1 adult female (6:1 ratio), and trapping area B captured 28 adult males and 8 adult female painted turtles (3.5:1 ratio). The use of baited hoop nets at trapping areas A and B also resulted in the capture of more adults than juveniles (4.3:1 ratio).

These findings are consistent with Ream and Ream's (1966) findings; however, the reason for capturing more males than females could also be influenced by road density surrounding the Dunnville marsh (Steen et al., 2006; DeCatanzaro & Chow-Fraser, 2010). Although Ream and Ream (1966) discovered that basking traps yielded more adult females than males, this finding was not consistent with capture numbers at the Dunnville marsh, since more adult males (n = 11) than females (n = 9) were captured by basking trap (1.2:1 ratio). Similar to Ream and Ream's (1966) findings, more adults than juveniles were captured by basking trap and more juveniles than adults were captured by hand or dip net.

In relation to road density's influence on sex ratios of freshwater turtles, DeCatanzaro and Chow-Fraser (2010) discovered that areas with a high road density can result in painted turtle sex ratios that are significantly male biased. Whereas, less developed regions with a low road density had painted turtle sex ratios that did not differ significantly from 1:1 (DeCatanzaro & Chow-Fraser, 2010). This is because female turtles often travel further and more frequently than males during nesting season (May - mid-July) in search of suitable nesting habitat (Hughes & Brooks, 2006; Cosentino et al., 2010; Millar & Blouin-Demers, 2011; Paterson et al., 2012). Regions that are more developed can result in fewer areas with suitable nesting habitat, as well as a more fragmented landscape that is intercepted by roads. This results in high road mortality rates for female turtles in developed areas, as they cross roads in search of nesting habitat, causing a male biased sex ratio (Steen et al., 2006; DeCatanzaro & Chow-Fraser, 2010).

Since trapping area B was located directly beside a busy highway, with only a 10-12 foot buffer zone between the two areas, it is likely that road mortality of female painted turtles influenced the population's sex ratios in this area, resulting in the capture of more males than females. A female turtle was tracked crossing the highway early in the field season, and locals reported helping painted turtles across the highway. Furthermore, an adult female painted turtle that was last tracked near the busy road went missing during nesting season, and it is thought that she was hit by a car because painted turtle remains were found on the road near where she was last tracked. Trap site A was also located in an area surrounded by roads, and yielded more males than females. Since the sex ratio did not differ greatly in capture areas where a basking trap was used, it is possible that the use of a baited hoop net in trap site B also caused more males than females to be caught. However, trap site C, where a basking trap was used, is also located further from the highway and is connected to a large natural habitat with corridors leading to potential nesting sites, meaning females traveling to nest in this area could have a lower chance of road mortality than at trap site B (Cosentino et al., 2010; Steen et al., 2006). Overall, it is possible that both road density and trapping methods influenced the sex ratio of captured painted turtles, but road density is likely to be the greater influence at trap sites A and B. Since capture numbers for juveniles are within a similar range for each capture method, it is unlikely that a particular capture method greatly influenced the number of juveniles captured.

6.2 Habitat Use

This section will discuss and evaluate the findings that help to answer research questions four to six, which include 1) How are freshwater turtles dispersed or concentrated throughout the area; 2) In what type of macrohabitats are individuals located; and 3) What are the microhabitat characteristics of the area where each tracked turtle is located. Distances travelled and home ranges will also be addressed in this section, since these topics are directly related to population dispersal and habitat use.

6.2.1 Distances travelled and home ranges

The discussion of distances travelled and home range will focus on the 11 painted turtles and 1 Blanding's turtle that were radio-tracked during the field study. Transmitters were not attached to snapping turtles, and they were not radio-tracked. Snapping turtles are an aggressive species, and the researcher was not experienced enough with snapping turtles to handle them in such a way.

As seen in Table 5.4, the mean daily distance travelled by female painted turtles (21.1 m/day) was greater than that travelled by males (13.3 m/day) throughout the field season. The same is true when the female Blanding's daily distance travelled is included with the female painted turtles (25.9 m/day). This finding differs from other studies which note that males travelled greater daily distances than females for the entire season (Yagi & Litzgus, 2012). For example, Yagi and Litzgus (2012) found that the daily distance travelled for spotted turtles was greater for males than females during the active season for two years. The difference in findings could be due to the two different species studied.

When examining mean daily distances travelled between male and female painted turtles, it is important to note that only one adult female painted turtle was radio-tracked during May and June, and was lost by mid-June. However, two adult males were tracked in May and three were tracked in June. This makes female painted turtle tracking data for June incomplete, which is the cause of the low mean daily distance travelled for that month (8.2 m/day). For this reason, mean daily distances travelled each month by females, including the female Blanding's, will be used for analysis against males because it is likely a more accurate representation. Although females travelled greater mean daily distances than males in every month, they travelled significantly more than males in June, July, and August. This finding was expected, because female freshwater turtles are known to travel further distances then males during nesting season from May to mid-July, and especially in June (Hughes & Brooks, 2006; Millar & Blouin-Demers, 2011; Paterson et al., 2012). Statistical analysis of daily distance travelled indicates that sex ($P < 0.05$) and season ($P < 0.05$) had a significant effect on daily distances travelled. The analysis indicates that males travelled significantly less than females as the season progressed. The distances travelled by females did not become significantly smaller until September and October; whereas males travelled significantly less by June (Table 5.4). A study on the spatial ecology of Blanding's turtles revealed that reproductive class did not have a significant effect on mean daily distances travelled by turtles in May, July, and August. However, in June, gravid females moved significantly more than males (49:22 m/day). Researchers have noted that male freshwater turtles sometimes travel greater distances than females during mating season in search of mating opportunities (Paterson et al., 2012). Some male snapping turtles travel to migration areas or nesting sites used by females to increase their chances of mating (Paterson et al., 2012). This could explain why mean daily distance travelled for adult males was significantly greater in May (62.4 m/day) than any other month, since May is also a part of the pre-nesting season when mating occurs (Ernst et al., 1994; Yagi & Litzgus, 2012). This finding is similar to Millar and Blouin-Demers (2011) study, which found that male Blanding's travelled a closer mean daily distance to that of females in May than any other month.

As seen in Table 5.6, females had a larger average home range (5.9 ha) in comparison to males (2.7 ha), and the overall average home range for all turtles was 4.3 ha. Average home ranges were not compared by month between sexes because not enough location points were collected for female and male turtles during each month to accurately calculate home range per month rather than for the entire season. Although the average home range of females is greater than that of males, statistical analysis of home range data indicates that sex has no significant affect on home range size. This was the result when home ranges of only painted turtles were included in the analysis ($P = 0.502$), and when the female Blanding's was included ($P = 0.251$). This finding was unexpected because researchers often predict that sex will significantly affect home range size, where home ranges for females will be greater than those of males (Millar & Blouin-Demers, 2011; Paterson et al., 2012). For example, a study by Paterson et al (2012) predicted that female snapping turtles would have larger home ranges than males. In contrast to the Dunnville marsh findings, the researchers discovered that sex significantly affected the home-range size of individuals. The average annual home range for females was significantly larger than that of males, and home ranges for females were larger than males' in the pre-nesting, nesting, and post-nesting seasons (Paterson et al., 2012). Millar and Blouin-Demers (2011) found that gravid female Blanding's turtles had significantly larger annual home ranges than both males and non-gravid females. However, Yagi and Litzgus (2012) found that there was no significant difference in annual home range size between male and female spotted turtles, and home range size did not differ between the sexes in any season. There are many factors that can influence the home range size of individuals, such as the species studied, weather conditions (drought or flooding, air temperature etc.), sex, reproductive class, and available habitat (Millar & Blouin-

Demers, 2011; Yagi & Litzgus, 2012). Any combination of these factors could account for the different findings regarding home range size of freshwater turtles.

In the case of the Dunnville marsh study, it is important to note that some transmitters were added to female painted turtles late in the active season; two which were added to females late in the nesting season, and two that were added to females post-nesting season (Table 5.3). This means the movement of these four females was not tracked throughout the entire pre-nesting and nesting seasons. It is possible that this resulted in a smaller calculated home range size for females than what would have been calculated if females were tracked for the entire active season. Therefore, the finding which indicates no significant affect of sex on home range size could be explained by the fact that four females were not tracked during the entire nesting season when they are known to travel the furthest. If all females had received transmitters at the start of the active season, it is possible that statistical analysis would indicate a significant affect of sex on home range size.

6.2.2 Macrohabitat use

Although the population range of tracked individuals encompassed 187.3 ha of marsh habitat, the observed painted turtle population was mainly concentrated along the north and north-east perimeter of the restored marsh area. Individuals also dispersed in water bodies along the east and west sides of the marsh, but the observed populations in these areas were much less dense (*Figure 5.1*). Due to the high concentration of individuals throughout specific macrohabitats, the population density for painted turtles cannot be calculated for the entire marsh area or population range. Macrohabitats were identified according to the Ecological Land Classification (ELC) for Southern Ontario (Lee at al., 1998; Yagi & Litzgus, 2012). Throughout this section, macro and microhabitat use will be mentioned together because they are interrelated. Characteristics of the identified macrohabitats are outlined in Table 5.7.

Mixed shallow aquatic habitat

As shown in *Figure 5.3*, painted turtles spent the most time in MSA habitats, whereas the female Blanding's spent the second most amount of time in this habitat. These habitats are dominated by a mix of submerged and floating aquatic vegetation, with permanent water up to a depth of 2 m. Submerged aquatic vegetation (SAV) includes species like coontail and Eurasian watermilfoil, while floating aquatic vegetation (FAV) includes species like duckweed and water lily. Within this macrohabitat type, painted turtles spent the most time in the MSA Mid-Canal, followed by the MSA Bay, and the MSA Creek (*Figure 5.3*). The MSA Mid-Canal may have been a preferred MSA habitat above the bay and creek because the canal's water is very still, whereas the water flows somewhat in the bay, and flows at higher speeds in the creek. Some turtle species (such as painted and Blanding's turtles) are poor swimmers and prefer still or very slow moving water (MacCulloch, 2002).

Water lilies and submerged aquatic vegetation are key habitat features that provide basking areas, cover from predators, and food sources for freshwater turtles (Millar et al., 2011; Weiten et al., 2012). This may explain why painted turtles in the Dunnville marsh were found to spend the most time in areas containing an abundance of water lilies and SAV. Painted turtles were often observed basking on lily pads and mats of free-floating SAV. Millar et al. (2010) found that a 25% increase in floating vegetation on a water body resulted in a 28% increase in the probability of habitat selection by Blanding's turtles. Moreover, floating and submerged aquatic vegetation, as well as filamentous algae, contain high densities of macroinvertebrates, which are a main food source for freshwater turtles (Ernst et al., 1994; Millar et al., 2012). Yagi and Litzgus (2012) found that spotted turtles preferred shallow flooded zones during the active season, which are characterized as having mixed aquatic vegetation (submerged and floating) with a water depth <40 cm. For hibernation, individuals would travel to areas with a deeper water depth (>70 cm) to hibernate in muck beneath the water (Yagi & Litzgus, 2012).

Organic shallow marsh habitat

Painted turtles spent the second most amount of time in OSM habitats (*Figure 5.3*). This macrohabitat is dominated by emergent aquatic vegetation (EAV; mainly cattail and bulrush) with an organic (muck) substrate, and water up to 2 m deep. An abundance of EAV is important habitat for Blanding's turtles (Hartwig & Kiviat, 2007). As seen in *Figure 5.4*, the female Blanding's turtle spent the most time in OSM habitats, with the majority being spent in the OSM East Canal. Similarly, Yagi and Litzgus (2010) found that spotted turtles commonly select habitat dominated by EAV during the active season. As a main feature of OSM habitats, organic muck substrate is an important habitat feature for freshwater turtles. Individuals are often radio-tracked hiding or hibernating in organic muck substrate beneath the water's surface (Hartwig & Kiviat, 2007; Yagi & Litzgus, 2010; Millar et al., 2011). During the Dunnville marsh study, in mid-October, several painted turtles were tracked beneath organic muck substrate in areas containing permanent water. Based on the findings of other literature, it is possible that individuals chose these specific habitats to hibernate for the winter (Ernst et al., 1994; Yagi & Litzgus, 2010).

Individuals might choose to spend time in an OSM habitat due to the amount of coverage cattail and bulrush provide without blocking out a lot of sunlight from above. Wieten et al. (2012) found that freshwater turtles were abundant among areas containing cattails, and more abundant in cattails than areas containing bulrush. Cosentino et al. (2010) found that habitats containing a high canopy cover (eg. mature trees) and low EAV cover (hydrophytic grasses; cattails and bulrush) had a low occupancy level of painted turtles and a higher probability for extinction. However, habitats containing a low canopy cover and a high EAV cover had a high occupancy level of painted turtles and little to no extinction probability. These findings are consistent with those found at the Dunnville marsh because OSM habitats containing little to no canopy cover and an abundance of EAV were frequently occupied by individuals during the active season (Tables 5.10 & 5.11).

Submerged shallow aquatic habitat

The macrohabitat type where painted turtles and the female Blanding's spent the third most amount of time is SSA habitat (Figures 5.3 & 5.4). This habitat type is dominated by SAV and permanent water, with depths that can reach up to 2 m. During the field study, two female painted turtles travelled from the MSA Bay area to the SSA Private Pond, and likely used the intercepting forested habitat as a travel corridor. The two females were often observed openly basking on logs or cryptic basking on SAV mats in the SSA Private Pond area. When startled, the turtles would dive into the water and hide within or underneath free-floating SAV. As mentioned previously, studies have shown that SAV is an important habitat feature that provides basking areas, cover from predators, and food sources for freshwater turtles (Millar et al., 2011; Wieten et al., 2012). Wieten et al. (2012) sampled freshwater turtle populations from six vegetation types and found that painted turtles were caught second most often in SAV, which fell only slightly behind catch numbers among cattail vegetation. Blanding's turtles were also caught second most often in SAV, at catch numbers only slightly below those among cattails.

Deciduous swamp

As shown in *Figure 5.4*, the macrohabitat used least often by the Blanding's turtle, and not at all by painted turtles, is the Deciduous Swamp (DS). This macrohabitat is characterised by having a tree cover >25%, of which >75% is deciduous trees. Moreover, DS has vernal pools or flooding > 20% of ground coverage with water depths < 2 m. In the Deciduous Swamp area where the Blanding's turtle was tracked, average canopy cover was 70%. As discussed in the section titled *Canopy cover* on page 113, this amount of canopy cover is much higher than in other macrohabitats where turtles spent the most time. It is unclear why the Blanding's entered this habitat type. It is possible that tracking her to this location was an error, since the researcher was learning to use the radio-tracking receiver. Nevertheless, other researchers have noted freshwater turtles that normally use aquatic habitats do sometimes use forest habitat (Obbard & Brooks, 1980; Paterson et al., 2012; Yagi & Litzgus, 2012). For example, some snapping turtles make extensive overland trips through forest, which is used as a travel corridor (Obbard & Brooks, 1980; Paterson et al., 2012), and spotted turtles have been found to aestivate in forests (Yagi & Litzgus, 2012). However, forest habitat is not commonly documented to be used by painted or Blanding's turtles.

6.2.3 Microhabitat use

Air temperature

Air temperature is an important microhabitat variable to consider in relation to turtle habitat. Air temperature is impacted by canopy cover, because areas with a high canopy cover are shaded from the sun and usually have a lower air temperature than areas in full sun. Turtles are exothermic and rely on warm air to increase their body temperature so bodily functions like food digestion can occur (FAP, 2005). *Figure 5.5* shows that female painted turtles were tracked in areas that had a slightly higher average air temperature than areas where males were tracked during May and June. This could be because females were raising their body temperatures to promote eggshell development during nesting season (FAP, 2005; Beehler, 2007; Millar & Blouin-Demers, 2011). Average air temperatures in areas occupied by females dropped slightly after nesting season, then gradually increased until the end of September. Unlike adult female painted turtles, the female Blanding's turtle used areas with a lower average air temperature during May and June before using areas of a higher average air temperature during July and August. The same pattern is shown for average air temperatures in areas used by male painted turtles. This could be because the female Blanding's turtle was a Juvenile and non-gravid, meaning she did not need to raise her body temperature to help with developing eggshells during nesting season (Beehler, 2007). Similarly, adult males would not need to increase their body temperatures during May and June to help with eggshell development. All freshwater turtles occupied areas with an average air temperature above 20 °C from May - September. In October, when air temperature dropped, average air temperature in areas used by turtles also dropped. Turtles prepare to hibernate during this time by clearing their digestive tract and lowering their body temperatures to slow metabolic activity (Ernst et al., 1994).

Water temperature

Water temperature is directly related to water depth. Normally, shallow water is warmer than deep water, due to the ability of sunrays to penetrate the water's surface (Snyder, 2016). However, water temperature is also affected by canopy cover and floating or submerged free-floating aquatic vegetation cover (Snyder, 2016). Freshwater turtles are cold blooded creatures and prefer warmer water temperatures during the active season to maintain their thermoregularity needs (Ernst et al., 1994; Millar et al., 2011). Table 5.8 shows the average water temperature used by male painted turtles ranged at 15.8 - 22.8 °C. The average water temperature used by female painted turtles ranged at 16.6 - 22.4 °C, and the average water temperature used by the female Blanding's ranged at 17.5 - 22.9 °C (Table 5.9). Freshwater turtles might choose areas with warmer water temperatures during the cooler spring months, and areas with cooler water temperatures during the hot summer months to maintain their body temperatures (Millar et al., 2011). *Figure 5.6* shows that this was not the case with regard to female painted turtles or the female Blanding's; however, male painted turtles chose cooler water temperatures during July and August than in May and June.

There was no significant difference between water temperatures occupied by painted turtles and the female Blanding's; however, the female Blanding's occupied habitats that contained a slightly higher average water temperature than those occupied by painted turtles during the majority of the active season. This finding is contrary to Millar's (2011) study which found that Blanding's selected colder water temperatures. The warmer average water temperatures are likely related to shallow areas used by the female Blanding's. Hartwig and Kiviat (2007) found that Blanding's turtles occupied areas with an average water temperature of 20°C, which is similar to the overall average water temperature occupied by the female Blanding's (21.3 °C) and painted turtles (20.9 °C) at the Dunnville Marsh.

Water depth

Water depth is an important microhabitat variable when it comes to turtle habitat selection. The selection of a sufficient overwintering site can mean the difference between life and death (Paterson et al., 2012). Freezing temperatures and low oxygen levels that occur in water with thick ice cover can cause metabolic and respiratory acidosis in hibernating freshwater turtles (Paterson et al., 2012). Therefore it is important for turtles to select overwintering habitats beneath permanent water bodies that will not freeze too close to the substrate level. In mid-October, several painted turtles were radio-tracked beneath organic muck substrate in MSA habitats with water depths of 35 - 58 cm. The female Blanding's was last tracked in mid-October in the OSM East Canal, in a water depth of 37 cm. Table 5.8 shows the average water depth used by male painted turtles ranged at 38.1 - 78.1 cm. Average water depth used by female painted turtles ranged at 51 - 78 cm. Water depth used by both species was as deep as 120 cm in the early spring when water levels were high, and as low as 24 cm in September when water levels dropped (Table 5.8 & Table 5.9).

The female Blanding's used water bodies with an average water depth of 28.4 - 65.3 cm throughout the active season. The shallowest recorded water depth for the female Blanding's was 15.2 cm in May, while the deepest was 122 cm also in May (Table 5.9). Early in the summer, the female Blanding's travelled from a SSA habitat to a shallow flooded OSM. Later in the summer, when water dried up in the OSM, she travelled back to the SSA and MSA habitats where the water source is permanent. Freshwater turtles depend on permanent water sources to forage during drought, but will travel to forage in temporarily flooded wetland habitats when inundated (Cosentino et al., 2010). This may explain the behaviour of the female Blanding's turtle that travelled to the temporarily flooded OSM before heading to more permanent aquatic habitat later in the summer. As seen in *Figure 5.7*, female painted turtles used habitat areas with the highest average water depths throughout the season, occupying areas with an average water depth of 50 cm or higher. Male painted turtles occupied habitats with average water depths above 35 cm. The female Blanding's used habitats with the shallowest average water depths throughout the season, with average water depths above 25 cm and below 70 cm. This finding is consistent with other studies which show that Blanding's turtles normally inhabit shallow waters (Ernst et al., 1994; MacCulloch, 2002; Millar et al., 2011).

Submerged aquatic vegetation cover

During the spring season, before SAV cover was prominent within macrohabitats, it was observed that painted turtles would openly and cryptic bask along shorelines, adjacent to cattails. Later in the summer, when SAV cover increased, painted turtles would disperse throughout the water, further from the shoreline, and cryptic bask on thick mats of free-floating SAV. This finding is consistent with Gamble's (2006), who observed similar painted turtle behaviour throughout the season. Hartwig and Kiviat (2007) found that turtle association with SAV peaked in late July and August, which is likely when SAV cover increased. Table 5.8 shows that the average SAV cover in areas used by painted turtles ranged from 59.4 - 72.9% for males and 65 - 78.5% for females. Table 5.9 shows that the female Blanding's used areas with an average SAV cover that ranged from 57.5 - 73.5%.

As seen in *Figure 5.8*, female painted turtles used areas with a higher SAV cover than males and the female Blanding's for most of the active season. Interestingly, all areas used by turtles had an average SAV cover greater than 50% throughout the entire season. Although macrohabitats contained areas where little or no SAV cover was present in the water, turtles were tracked to be in the areas where SAV cover was at least 26% and seemed to avoid areas that had no SAV. Similarly, Millar et al. (2011) found that a 25% increase in SAV resulted in a 70% increase in the probability of habitat selection by Blanding's turtles. These findings indicate that SAV cover is an important habitat feature for both painted and Blanding's turtles, and may be among the most important habitat features for their survival.

Canopy cover

Canopy cover is another important habitat feature to consider in regard to freshwater turtle habitat (Cosentino et al., 2010). Most freshwater turtle species prefer aquatic habitat with a sparse to low amount of canopy cover because a majority of their time is spent basking in full sun during the active season (Ernst et al., 1994; Cosentino et al., 2010; Millar & Blouin-Demers, 2011). Table 5.10 shows that painted turtles used macrohabitats with an average canopy cover of 0-14%. Painted turtles spent the most time in the MSA Mid Canal which had an average canopy cover of 14%, and the least amount of time in the SSA creek which had 0% canopy cover. Table 5.11 shows that the Blanding's used macrohabitats with an average canopy cover of 10-70%. The Blanding's spent the most time in the OSM East Canal with an average canopy cover of 10%, and the least amount of time in the DS with an average canopy cover of 70%. The Blanding's was present in the DS very briefly and spent the majority of her time in habitats with a canopy cover of 10-14%.

As mentioned previously, Cosentino et al. (2010) had a similar finding which showed that areas colonized by painted turtles had little canopy cover (<25%) and the probability of extinction increased in wetlands with high canopy cover (>50%). In addition to lack of sunlight, forested areas with a high canopy cover are home to land predators like the raccoon, which could also deter freshwater turtles from occupying these areas (Cosentino et al., 2010). Other studies have found that gravid female turtles bask most often in full sun during the pre-nesting and nesting season to raise their body temperatures and assist with eggshell development (FAP, 2005; Beehler, 2007; Millar & Blouin-Demers, 2011). Therefore, there are several reasons why freshwater turtles at the Dunnville marsh use habitats with little canopy cover.

Ground vegetation and emergent aquatic vegetation

The amount of EAV in macrohabitats at the Dunnville marsh was measured as density (number of stocks per square meter) rather than cover. Table 5.10 combines the average vegetation density measured at different macrohabitats. Some of the macrohabitats did not contain EAV (eg. MSA Mid Canal and SSA West Canal), so the density of other shoreline vegetation was measured instead. The density of shoreline vegetation is an important habitat feature because it provides a buffer zone between land and water and provides cover from land predators (Roe & Georges, 2007; Sterrett et al., 2011). As shown in Table 5.10, macrohabitats used by painted turtles contained a minimum average shoreline vegetation density of 17.3 stocks per Sq/m. The highest shoreline vegetation density in macrohabitats used was measured for cattails in the SSA Creek and OSM East macrohabitats at 45 stocks per Sq/m. The MSA macrohabitats where painted turtles spent the most time contained a lower average shoreline vegetation density of around 34 stocks per Sq/m. The average shoreline vegetation density where painted turtles spent the least amount of time was in the SSA Creek with a cattail density of 45 stocks per Sq/m. Table 5.11 shows that the female Blanding's used macrohabitats with a lower average shoreline vegetation density than those used by painted turtles. The highest average shoreline vegetation density in a macrohabitat used by the Blanding's was 33.6 stocks per Sq/m, and the lowest was 17.3 stocks per Sq/m. Shoreline vegetation density where the Blanding's spent the most time was measured for cattails and bulrushes in the OSM East canal and had an average density of 26 stocks per Sq/m.

The Blanding's and painted turtles might spend more time in habitats with a medium shoreline or EAV density (26-34 stocks per Sq/m) rather than habitats with a higher average density (45 stocks per Sq/m) because it is easier for them to manoeuvre in vegetation that is not so dense, but still dense enough to provide sufficient cover from predators (Mifsud, 2014). For example, Mifsud (2014) conducted a survey of herpetofauna throughout the Saginaw Bay area and found that reptiles and amphibians were less abundant in areas containing the invasive species *Phragmites australis.* Mifsud (2014) theorised this was because stands of *Phragmites australis* grow very dense and restrict reptiles and amphibians from manoeuvring between sunny and shaded areas needed for thermoregulation, or between land and open water. This could explain why freshwater turtles at the Dunnville marsh spent the most time in habitats with a medium density of 26-34 stocks per Sq/m rather than a higher density of 45 stocks per Sq/m.

6.3 Nesting Habitat

This section will discuss and evaluate the findings which help to answer research questions seven and eight. These include 1) How many nests are present in the area of study, if any; and 2) What are the macro and microhabitat characteristics in areas where nests are located. Answering these questions will help to understand where turtles are nesting in the marsh, and what habitat characteristics are chosen at nesting sites. This information can help conservationists create suitable nesting habitat in ecologically restored areas for freshwater turtles.

6.3.1 Macrohabitat nesting sites

Table 5.12 outlines the number of nests that were found throughout the Dunnville marsh area, along with macrohabitat descriptions of locations where they were found. A total of 60 nests were found throughout the marsh area. Based on the shape of eggshells that were dug up by predators, some nests were identified as snapping turtle nests, and some as painted turtle nests. Snapping turtle eggs are spherical, while painted turtle eggs are oblong and oval in shape (MacCulloch, 2002). Non-predated nests could not be identified as belonging to a certain species without disturbing the nest to expose eggs, and were not identified. *Figure 5.9* depicts the location of nesting areas throughout the marsh. Some location points on the map represent more than one nest at the site. No nests were found within the ecologically restored areas of the Dunnville marsh.

Macrohabitats where turtles nested include the north and south shorelines of the MSA Mid Canal and SSA West Canal, and the north shoreline of the SSA Private Pond. Other areas include private unpaved driveways, areas along train tracks, and near a private dock along the MSA Creek's south shoreline. Researchers have found that when suitable natural nesting habitat is not available, turtles will commonly nest along modified habitats like unpaved driveways, road shoulders, gravel pits, and along train tracks (Steen et al., 2006; Beehler, 2007; MNRF, 2010). Some researchers have discovered that nests along road shoulders have higher survival rates than those located in natural areas among urban environments because predators are less likely to spend time looking for food along busy roads (Dorland et al., 2014). However, it is not safe for turtles to nest along busy roads due to a higher risk of road mortality among adult females (Steen et al., 2006; MNRF, 2010).

6.3.2 Microhabitat features at nesting sites

Table 5.12 outlines the microhabitat variables that were measured at each nest's location. These variables include canopy cover, vegetation cover, soil temperature, and soil texture. Researchers typically describe turtle nesting habitat as having little to no canopy cover, low to moderate vegetation cover, a soil temperature at 20 - 32 °C, and soil texture that is either sandy, loamy, or gravelly (Ernst et al., 1994; FAV; 2005; Hughes & Brooks, 2006; Beehler, 2007; MNRF, 2010). These variables are interrelated and affect each other. For example, higher canopy cover at a nest site can result in a lower soil temperature.

Canopy cover

As seen in Table 5.12, the canopy cover at each nesting site ranged from 0 - 7.5% and six out of nine sites had no canopy cover. The overall average canopy cover is low, at 3.0%. This finding is consistent with those described in the literature. A low canopy cover is important for turtle nesting habitat because nests need to maintain a certain temperature (Ernst et al., 1994; FAV, 2005). Ground temperatures that are too cool will prevent turtle embryos from developing (FAV, 2005; Hughes et al., 2009). Therefore, turtles normally choose to nest in areas where sun exposure is maximized and there is little to no shade caused by tree canopy or ground vegetation (FAV, 2005; Hughes & Brooks, 2006). Hughes and Brooks (2006) reported that low canopy cover was a significant feature among painted turtle nests sites, which had an average canopy cover of 17%. This average canopy cover is much higher than that among nesting sites at the Dunnville marsh. However, the Dunnville marsh is located in a more urban area, whereas Hughes and Brooks' (2006) study was conducted in Algonquin Park where tree canopy is abundant.

Ground vegetation cover

Low to medium ground vegetation cover is also common among nesting sites. As seen in Table 5.12, ground vegetation cover ranged from 0 - 46% at nesting sites, with an overall average of 25.5% cover. Similar to canopy cover, a low ground vegetation cover is important to allow maximum sun exposure on soil so nest temperatures can reach 20 - 32 °C (Ernst et al., 1994; Hughes & Brooks, 2006). Hughes and Brooks (2006) found that a low ground vegetation cover was significantly related to painted turtle nest sites, and did not exceed 40% at chosen nest sites. Other researchers have found that Blanding's turtles will nest in areas containing ground vegetation if it is tilled, weeded, or mowed; although they prefer tilled plots due to the loose soil texture (Dowling et al., 2010). Interestingly, when nests were observed among higher amounts of ground vegetation cover at the Dunnville marsh, they were among grass that had been mowed in a private lawn, along a road shoulder, and along a train track. Moreover, although no nests were found within ecologically restored areas of the Dunnville marsh in 2015, a snapping turtle hatchling was found on a mowed pathway within a restored area (Meadow Marsh) in October 2014. This could indicate that a snapping turtle nest was somewhere nearby on the mowed pathway.

Ground vegetation cover can also affect the texture of soil. Soil with high vegetation cover has higher organic matter content than soils with less vegetation cover. Soil with high organic matter content tends to hold more water, which can potentially suffocate turtle embryos (Finkler, 2006; Delmas et al., 2008). Freshwater turtle eggshells are porous and take in water as well as oxygen, meaning soil that is moist but still allows oxygen and carbon dioxide exchange is ideal for nesting (Ernst et al., 1994; Finkler, 2006; Delmas et al., 2008; Anderson & Horne, 2009). Hughes and Brooks (2006) found that nests in soil with less organic matter exhibited greater survival to hatch than nests in soil with a higher organic matter content. Lower organic matter content not only allows water to drain easier from soil, but also increases its heating capacity, which helps incubate embryos (Hughes & Brooks, 2006; Hughes et al., 2009). Therefore, a lower vegetation cover is an important feature of turtle nesting habitat, and is reflected in data gathered at the Dunnville marsh nesting sites.

Soil temperature

As mentioned previously, soil temperature at nesting sites needs to be warm enough to incubate eggs and promote healthy embryo development (FAV, 2005; Hughes et al., 2009). Incubation temperatures close to or above 20 °C is sufficient for embryo development (Ernst et al., 1994). Table 5.12 shows that soil temperature at nest sites ranged from 20 - 33.2 °C. Soil temperatures were usually higher at nest sites where there was no canopy cover, except for the nest site located along the West Train Tracks which had a higher ground vegetation cover at 30%. Soil temperature is not only important for embryo incubation and development, but also determines the sex of hatchlings (Ernst et al., 1994; FAP, 2005). For example, soil temperature at 22 - 27 °C will produce 100% males, and soil temperature at 30 - 32 °C will produce 100% females (Ernst et al., 1994). Both sexes are produced from one clutch when incubated at 20 °C and 28 °C (Ernst et al., 1994). This information is important for conservationists who want to create nesting habitat for freshwater turtle species. Nesting habitat can be created to include a variety of habitat features that create nesting sites with ground temperatures. This would allow both males and females to be produced at a nesting site, rather than clutches of 100% males or females which could alter the sex ratio of a turtle population.

Soil texture

Soil texture is another important feature of nesting habitat. As mentioned previously, soil texture properties, such as grain size or amount of organic matter, affects water drainage, gas exchange, and heating capacity of soil (Hughes & Brooks, 2006; Anderson & Horne, 2009; Hughes et al., 2009). Table 5.12 shows the soil textures determined for each nesting site. Four out of the nine nesting sites were found to contain mainly gravel with some sand or loam. These four nesting sites contained snapping turtle nests, as determined by eyewitness accounts and eggshells dug up by predators. This finding was expected, since most freshwater turtles nest in sandy, loamy, or gravelly soil that drains water well and warms easily in the sun (Ernst et al., 1994; Costanzo et al., 2001; MacCulloch, 2002; FAP, 2005; Hughes & Brooks, 2006). Painted turtle nests were identified at three nesting sites, which had sandy loam, sandy clay, and sandy clay loam textures.

Unlike snapping turtle hatchlings, which emerge from their nest in October, painted turtle hatchlings overwinter in their nest and emerge the following spring (Costanzo et al., 2001; FAP, 2005). Costanzo et al. (2001) found that painted turtles will nest in soils containing a higher clay and organic matter content in regions with a colder climate where hatchlings overwinter in the ground. Overwintering painted turtles have a higher incidence of mortality by freezing in sandy soils than in soil containing higher amounts of clay and organic matter (Costanzo et al., 2001). The susceptibility to freezing is influenced by moisture content in frozen soil. Clay soils bind to moisture and keep turtle hatchlings from freezing because there is less ice nuclei coming into contact with them (Costanzo et al., 2001). This may explain why painted turtle nests at the Dunnville marsh were located in soil containing more clay and loam in comparison to snapping turtle nests, which were often located in gravel with some sand or loam.

This information is important for conservationists conducting ecological restoration for freshwater turtle species. The findings indicate that different soil textures are suitable for different turtle species. While sandy soil is important for turtle species that incubate during the summer and emerge in the fall, clay soils are more useful for overwintering species to prevent hatchlings from freezing (Costanzo et al., 2001; Anderson & Horne, 2009).

6.4 Habitat Areas Not Used by Tracked Individuals

This section will help to answer the final research question, which is 1) What are the differences in habitat characteristics between areas of habitat use and areas that are not utilized by turtles in the marsh. The answer to this question will reveal why turtles do not appear to utilize habitats within the restored marsh, and spend the majority of their time in different habitats adjacent to the restored areas. Moreover, the answer can help determine what macro and microhabitat features an ecologically restored wetland should have in comparison to others if the goal is to provide sufficient habitat for freshwater turtle species.

6.4.1 Macro and microhabitats not used

Macrohabitats that were within the population range of tracked individuals, but were not used include Agriculture, Private Yards, Open Water River, Meadow Marsh, Meadow Marsh with Pits, and Deciduous Forest (*Figure 5.1*). Furthermore, no painted turtles were tracked to the Deciduous Swamp, and only the female Blanding's was briefly tracked there.

Agriculture

As seen in Table 5.7, agriculture can be defined as an area dedicated to growing crops, and is a part of cultural habitat in Southern Ontario's Ecological Land Classification Guide (Lee et al., 1998). Agricultural areas are usually monocultures that are very low in biodiversity, making them unsuitable living habitat for wildlife. Some turtle species have been found to nest in agricultural areas; however, mortality of both nests and adult females can occur from agricultural equipment when fields are tilled, ploughed, or harvested (Dowling et al., 2010). Tracked individuals at the Dunnville marsh were not found to utilize these areas.

Private Yards

Private yards within the population range can be described as maintained private properties, dominated by a mowed lawn. A maintained mowed lawn is another form of monoculture that is low in biodiversity and does not provide suitable habitat for wildlife. However, some researchers have found that turtles will nest on mowed properties (Dowling et al., 2010). At the Dunnville marsh, painted turtle nests were found at the very edge of a mowed lawn, along the shoreline of an SSA pond. No nests were found anywhere else on the private yard, but were concentrated along the SSA pond's shoreline. Although turtles were never tracked within a private yard, this is a sign that individuals might choose to nest along the edge of ponds located adjacent to private yards.

Open Water River

This type of macrohabitat has no macrophyte vegetation (large aquatic plants) that can be seen from the surface of the water, no tree or shrub cover, is plankton dominated, and has a water depth greater than 2 m (Table 5.7; Lee et al., 1998). Due to the deep water depth, cooler water temperatures, strong current, and lack of emergent, submerged, or floating aquatic vegetation, it is unlikely that freshwater turtles would use this type of macrohabitat (MacCulloch, 2002; Millar & Blouin-Demers, 2011). Likewise, tracked individuals were never tracked within Open Water River habitat.

Meadow Marsh

Meadow marsh macrohabitat can be described as having less than 25% tree and shrub cover, dominated by hydrophytic macrophytes that are less tolerant of prolonged flooding, with seasonal flooding at a water depth less than 2 m (Lee et al., 1998). Due to the shallow seasonal flooding with a lack of submerged or floating aquatic vegetation, freshwater turtles are less likely to utilize these areas. Tracked individuals at the Dunnville marsh were not found to utilize Meadow Marsh habitat. However, as mentioned previously, in October 2014 a snapping turtle hatchling was found on a mowed pathway within Meadow Marsh habitat near train tracks. This could mean that a snapping turtle travelled to the Meadow Marsh to nest on the mowed pathway. However, the mowed pathways tend to grow back in the spring and summer, during the off-season for hunters. It is more likely that a snapping turtle nested along the train track (which they are known to do) and the hatchling travelled inside the Meadow Marsh in search of water or muck to hide in. Snapping turtles have better defence against land predators and are known to travel further distances on land in search of nesting habitat (Obbard & Brooks, 1980; Paterson et al., 2012). Therefore, it is possible that they would choose to nest in a mowed area of the Meadow Marsh; however, no sign of painted or Blanding's turtles were found in this area.

Meadow Marsh with Pits

As seen in Table 5.7, this macrohabitat is the same as Meadow Marsh habitat, except pits are present. Pit and mound topography was created as part of the ecological restoration in this area (GRCA, 2012). The pits are flooded seasonally and provide breeding habitat for amphibians (GRCA, 2012). This macrohabitat was chosen as a survey area due to the open canopy (0% canopy cover) and deeper water provided by pits. It was thought that individuals might temporarily forage or nest in this area. However, individuals were not tracked within this macrohabitat type, and no nests or individuals were found during surveys. The Meadow Marsh with Pits macrohabitat is likely unsuitable for nesting due to high vegetation cover (Hughes & Brooks, 2006). Although a mowed pathway surrounds the outer boundary of this area in the fall to accommodate hunters, the vegetation grows back during spring and summer when turtles are nesting. Therefore, it is unlikely that turtles would choose to nest in a field with such high vegetation cover containing tall hydrophytic macrophytes that shade the ground from sunlight (Hughes & Brooks, 2006). The soil type in this area was identified as silt loam, which is not ideal nesting material for some species, such as snapping turtles, due to the capacity for silt loam to hold water. However, silt loam could be a good nesting soil for painted turtles. Painted turtles might choose to nest in this macrohabitat if ground vegetation was kept short or removed from soil in some areas. The average water depth for pits in this macrohabitat is 39.8 cm, and ranges from 30.5 - 57 cm in different pits when water is present during the spring and fall (Table 5.13). Water in the pits is temporary and completely dries up during the summer months. The average size of pits is 10.5 ft in diameter, and ranges from 8 - 12.5 ft in diameter for different pits. Moreover, there is no SAV or FAV in pits to provide cover for turtles. The small size of pits, shallow temporary water, and lack of aquatic vegetation cover make it unlikely that freshwater turtles would use this habitat feature long-term, if at all.

Deciduous forest

Deciduous forest macrohabitat is described as having a tree canopy cover greater than 60%, with deciduous tree species making up greater than 75% of the canopy cover (Lee et al., 1998). Some researchers have noted that certain turtle species will use forest habitat as travel corridors when travelling over lands, or as a place to aestivate under woody debris (Obbard & Brooks, 2006; Paterson et al., 2012; Yagi & Litzgus, 2012). Although this macrohabitat is within tracked individuals' population range, no turtles were tracked within this habitat type. The high canopy cover makes it highly unlikely that turtles would nest in this area. Moreover, the lack of water combined with high canopy cover makes it unlikely that freshwater turtles would use this habitat long-term.

Deciduous swamp

Deciduous swamp macrohabitat is described as having a tree cover greater than 25%, with deciduous tree species making up more than 75% of the canopy cover. Furthermore, this macrohabitat has vernal pooling or flooding covering greater than 20% of the ground, with a water depth less than 2 m (Lee et al., 1998). Due to the presence of water, patches of open canopy, and presence of fallen logs as potential basking sites, areas within this microhabitat were chosen as survey areas (*Figure 3.11*). Although no nests or individuals were ever found within survey areas, the female Blanding's was tracked to have briefly entered this habitat before heading back to the canal. However, no painted turtles were tracked within this macrohabitat. Table 5.13 shows the microhabitat features that were measured throughout the active season at survey sites A, B, and D, located within Deciduous Swamp. The average air temperature at survey sites ranged from 18.2 - 21.5 °C, and average water temperature ranged from 14.8 - 17.3 °C. Average air and water temperatures at survey sites are lower than those in macrohabitats used by tracked individuals (Table 5.8 & Table 5.9). The average water depth at survey sites ranged from 4.8 - 39.8 cm, and no SAV cover was present in the water. The average canopy cover at survey sites ranged from 70 - 75%, and the ground vegetation density ranged from 12 - 28 stocks per square meter. Soil texture was identified as silt loam at survey areas A and B, and sandy loam at survey area D. The average water depth is lower in these areas compared to those at sites used by tracked individuals. The shallow water and lack of SAV cover in vernal pools and flooded zones makes it unlikely that freshwater turtles would inhabit these areas long term, since permanent water and SAV cover appear to be significant habitat features to freshwater turtles (Millar & Blouin-Demers, 2011). Canopy cover within Deciduous Swamp survey areas is sparse and lets in sunlight during the spring months; however, the canopy cover thickens by summer and does not let in a lot of sunlight. Therefore, this is not an ideal area for freshwater turtles to bask or nest. The average ground vegetation density is lower than that in macrohabitats used by tracked individuals, and might not provide sufficient cover from land predators. Finally, although silt loam soil textures within the Deciduous Swamp have a higher capacity to hold water, they could be used as a nesting medium for certain turtle species like painted turtles. Soil texture at survey area D was identified as sandy loam, which could potentially be used for nesting by snapping turtles and painted turtles. However, due to the high canopy cover in this macrohabitat throughout the summer months, it is highly unlikely that freshwater turtles would nest in this area (Hughes & Brooks, 2006).

Trap site D: SSA creek

Since freshwater turtles were not caught at trap site D throughout the entire active season, this area can be considered an area not used by individuals. The macrohabitat area at trap site D was identified as a SSA creek. A female painted turtle was tracked several times within the southern area of the SSA creek; however, the southern area had a wider stream with more SAV cover, more emergent aquatic vegetation, no canopy cover, shallower water, and a slower current. Therefore, microhabitat variables will be examined to explain why turtles did not use the habitat at trap site D within the SSA creek.

Microhabitat variables were measured at trap site D each week throughout the active season. As seen in Table 5.14, the average air temperature at trap site D was 24.5 °C, and the average water temperature was 22.6 °C. The average water depth was 105.5 cm, with a SAV cover of 22%. Moreover, the average canopy cover at this site was 36.7%, and shoreline vegetation density was 38 stocks per square meter. Average measurements for water depth, SAV cover, and canopy cover differ in this area compared to those used by tracked individuals. Not only is the water depth much higher, but SAV cover is much lower. Low SAV cover in this area could be caused by the deeper water and faster current in comparison to areas with a high SAV cover. The lack of SAV cover and other aquatic vegetation likely deters individuals from using this habitat. Similarly, since most freshwater turtles are poor swimmers, they prefer still water and avoid areas with faster water current (MacCulloch, 2002). Although basking sites are prevalent and canopy cover is not significantly high in this area (36.7%), the narrow northern aligned stream causes the area to be shaded by shoreline trees due to the sun's angle before 9:00 am and after 4:00 pm. The early onset of shade in this area could deter individuals from choosing it as basking habitat, since turtles have been seen basking in other habitats until sunset.

6.5 Limitations and Recommendations

There are some limitations to this study. As previously discussed, trapping bias could affect sex ratios as well as which turtle species are caught. Studies have shown that hoop nets typically attract adult male painted turtles and juveniles, while basking traps attract adult females and males more than juveniles (Ream & Ream, 1966). Basking traps are unlikely to catch snapping turtles, since they rarely bask on objects outside of water; however, hoop nets are efficient for catching snapping turtles (Weber & Layzer, 2011). The use of basking traps, hoop nets, and dip nets (or hand capture) would be beneficial to use at the same trap site to avoid trapping bias. Such an abundance of resources was not available for the four different trap sites used in this study.

The frequency that traps were set up could also have impacted the study's results. At the start of the season (in May) traps were set up a few times a week. Once the field season progressed and several turtles were being tracked, along with surveying, traps were set up once a week. However, if no turtles were captured, the traps were left until some turtles entered them. If traps had been set up more than once or twice each week, it is possible that more turtles would have been captured. Moreover, it is possible that a higher number of Blanding's turtles or other rare turtle species would have been captured if the traps had been set up more frequently; although, only two Blanding's turtles were observed in the area for the entire season. In this case, more than one researcher would be beneficial for the time required to set up and check traps more frequently.

Using paint as the main marking method for mark and recapture is also a limitation. Although some studies have noted that paint can last an entire season (Beehler, 2007; Gordon & MacCulloch, 1980), this was not the case for this study. Some paint markings lasted several weeks or months, but others chipped off the carapace of turtles after one week. This could cause a turtle that has already been captured to be recorded as a new capture rather than a recapture. However, it is unlikely that occurred in this study since all carapace and plastron measurements, as well as weights were cross referenced to determine if a recaptured turtle was recorded as a new capture. Notching marginal scutes is a more reliable marking method that can be used for long-term studies on the same population (Robertson et al., 2013).

Field studies that examine the population range, home range, and daily distances travelled by freshwater turtles should ensure that transmitters are attached to male and female individuals at the start of the active season. This allows for a more accurate data representation of home range size and daily distances travelled for each period of the active season (e.g. pre-nesting, nesting, post-nesting, aestivation, site chosen for hibernation etc.). Since all 12 transmitters were not placed on male and female turtles at the start of the active season (beginning of April), data gathered on the population range, home ranges, and mean daily distances travelled are limited for this study. For example, home range size might have been larger for some females if they had been tracked during the pre-nesting and nesting periods early in the active season. For future research, all transmitters should be added to individuals in April.

There are limitations regarding radio-tracking individuals. Upon relocation, it is important to see the individual being tracked before recording their location. Although this is difficult because they are often hiding under water or muck, this is the best way to ensure the individual has been accurately tracked. If the gain is turned up too high on a receiver, it can result in an inaccurate relocation. The researcher suspects this could be the case when the female Blanding's was tracked inside Deciduous Swamp habitat, since the Blanding's was not actually observed in the habitat. However, it is possible that the Blanding's did enter Deciduous Swamp habitat to forage or aestivate. Future research should ensure an individual is seen upon relocation, and its behaviour is noted.

Finally, there is a limitation when surveying for nests and freshwater turtles throughout the marsh. Although surveys were conducted carefully and extensively, it is possible that the researcher overlooked nests or freshwater turtles in areas where no nests or individuals were recorded. The use of several people conducting field surveys simultaneously would be beneficial for surveying an area the size of the Dunnville marsh.

6.6 Implications for Policy and Practice

The findings outlined in this study add to the research knowledge for conservationists and government agencies that develop projects or policy related to wildlife, endangered species, natural resources, land development, and ecological restoration. The Dunnville marsh study was the first study conducted in relation to freshwater turtle habitat use in the Dunnville area. Previous to this study, government agencies like the Ministry of Natural Resources and Forestry had an idea regarding what freshwater turtle species were present in the area, but they did not have any data related to actual species presence, species numbers, sex ratios, population range, home range size, or what habitats are being used. The finding's outline in this study provide baseline data regarding what turtle species inhabit the area, which are more abundant, and what habitats or areas they are using. This knowledge may help reveal which habitats or areas should be protected from human interference or development in order to preserve species diversity and protect species at risk like Blanding's and snapping turtles.

Knowing what species inhabit the area gives insight to the overall quality of the environment. Since freshwater turtles are sensitive to their environment, they can be used as an indicator species (Mifsud, 2010). Other research has demonstrated that some turtle species are more sensitive to their environment than others, and will be absent from wetlands that contain a lower water quality (DeCatanzaro & Chow-Fraser, 2010). The Dunnville marsh is largely dominated by painted turtles, which have been recorded as the most tolerant turtle species of low water quality (DeCatanzaro & Chow-Fraser, 2010). Moreover, turtle species that are more sensitive to water quality, like musk turtles, are absent from the Dunnville marsh. This could indicate that further restoration of the Dunnville marsh or surrounding area is needed to improve water quality and support species diversity.

Another finding that could help shape policy and practice is threats to turtle species that were identified during this study. For example, there appears to be a high predation rate of turtle nests at the Dunnville marsh. Out of 60 turtle nests found, 43 were eaten by predators (Table 5.12). Similarly, turtle mortality by motorized vehicles was observed. Mortality by motorized vehicles occurred on commonly used roads, and on abandoned roads where all terrain vehicles (ATVs) were used. This information, combined with that of future studies, could influence practices and policies that can mitigate such threats in the area. For example, more turtle crossing signs could be used to warn drivers about turtle crossings, and speed limits could be lowered in areas where road mortality rates are high. Further restoration of the Dunnville marsh could include the construction of turtle nesting habitat, causing nesting sites to be spread out which could potentially reduce predation rates (Roosenburg et al., 2014). Finally, the findings presented in this study help to reveal which habitat features (macro and micro) to include in ecological restoration, when one of the goals is to support freshwater turtle species.

For future research, studies could examine successful ways to reduce nest predation rates. For example, the effectiveness of reducing nest predation rates could be examined for nest site construction on mainland, island nest site construction, or through encouraging community members to put protective caging over nests on their property. Studies could also examine the use of travel corridors and connectivity between habitats used by freshwater turtles in the area, or if construction of such corridors would affect home range sizes and population distribution. Lastly, studies could analyze the water and soil quality of the restored marsh, and examine how quality can be improved, as well as their affects on the health of hatchlings and adults.

Chapter 7 - Conclusion

7.1 Overview

Understanding the habitat preferences and needs of freshwater turtle species is required to conserve land that protects the species' population, and to successfully restore land that meets their habitat needs. Previous to this study, there was no solid information regarding what freshwater turtle species inhabit the Dunnville marsh, their population characteristics, and what habitats they use. Moreover, it was not known whether or not freshwater turtles were using ecologically restored areas of the Dunnville marsh. This study was successful at answering research questions that address these topics. The findings regarding freshwater turtle habitat use in the area gives insight to which habitat areas should be protected to conserve the species, and how the marsh can be further restored to provide important habitat features for freshwater turtles.

The study's findings reveal that three species of freshwater turtle are present in the Dunnville marsh area, which include painted turtles, snapping turtles, and Blanding's turtles. The most abundant species at the marsh is painted turtles, followed by snapping turtles, and Blanding's turtles. The overall male to female ratio for adult painted turtles was 2.6:1, and the adult to juvenile size-class ratio was 3:1. The adult to juvenile size-class ratio for snapping turtles was 1:1. Only one female juvenile Blanding's was captured throughout the field season; although, an adult unknown sex Blanding's turtle was observed openly basking in the MSA Mid Canal. The mean daily distance travelled by radio-tracked freshwater turtles was 25.9 meters for females and 13.3 meters for males. A repeated measures ANOVA test revealed that the sex, as well as month (season) significantly influenced daily distances travelled. Average home ranges for radio-tracked turtles were 5.9 hectares for females, and 2.7 hectares for males. A one-way

ANOVA test indicated there is no significant influence of sex on home range size. However, not all transmitters were added to female turtles at the beginning of the active season, causing a limitation for gathered data, which could have underestimated home range size for females.

Radio-tracking, trapping, and survey data revealed that individuals were concentrated along the north, north-east, and western perimeters of the Dunnville marsh area, and individuals were abundant in the MSA Mid Canal, MSA Bay, OSM East Canal, and OSM Cattails and Bulrush. Furthermore, individuals did not appear to use the interior marsh or the ecologically restored areas. Out of the habitats used by tracked painted turtles, they spent the most time in MSA habitats, such as the MSA Mid Canal, MSA Bay, and MSA Creek. They also spend time in SSA habitats, such as the SSA Pond, SSA West Canal, and SSA Creek. Finally, they used OSM habitats, including the OSM East Canal. Out of all the habitats painted turtles used, they spent the least amount of time in creeks (MSA Creek and SSA Creek). Unlike painted turtles, the female Blanding's spent the most time in OSM habitats, with the majority of her time spend in the OSM East Canal. The Blanding's spent the second most amount of time in the MSA Mid Canal, followed by the SSA West Canal, and the DS.

For microhabitat variables, male painted turtles used habitats throughout the season with an average air temperature at 23.8 °C, water temperature at 21.1 °C, water depth at 54.5 cm, and SAV cover at 68.1%. Female painted turtles used areas with an average air temperature at 23.3 °C, water temperature at 20.8 °C, water depth at 59 cm, and SAV cover at 74%. The female Blanding's used areas with an average air temperature at 23.6 °C, water temperature at 21.3 °C, water depth at 44.4 cm, and SAV cover at 63.9%. Overall, it seems to be important for the turtles to use habitats throughout the majority of the season that have an average air temperature above 20 °C, an average water temperature above 18 °C (except in October when they are preparing to hibernate), and habitat with abundant SAV cover (>57% average). For water depth, the Blanding's used shallower areas than painted turtles (approx. 28 - 65 cm). The average water depth used by painted turtles ranged at approximately 38 - 78 cm. Finally, habitats used by painted turtles had an average canopy cover between 0-14%, and an average EAV or shoreline vegetation density at around 31.1 stocks per square meter (10-70% and 25.2 stocks per square meter for the Blanding's). Microhabitat for nesting areas had a variety of soil textures such as gravel, gravel with loam, sandy loam, sandy clay loam, and sandy clay, which accommodates different species of nesting freshwater turtles. Moreover, nesting sites had a low average canopy cover (0-7.5%), a low to medium vegetation cover (0-46%), and were located in areas where average soil temperatures were above 20 °C (20 - 33.2 °C).

The macrohabitat types where no turtles were tracked included Agriculture, Private Lawn, Meadow Marsh, Meadow Marsh with Pits, Open Water River, and Deciduous Forest. Moreover, no painted turtles were tracked within the Deciduous Swamp, and the female Blanding's was tracked in this area only once. Microhabitat variables which were not used by freshwater turtles at the marsh include areas with cooler average air and water temperatures (< 20 and 18 °C), shallow average water depths (<30 cm), little to no SAV cover, a medium to high canopy cover (36.7 - 75%), and a lower EAV or shoreline vegetation density (12 - 28 stocks per Sq/m). These findings provide information regarding which macro and microhabitat variables to construct and which to avoid when conducting ecological restoration for freshwater turtles. The findings also reveal which habitats in the Dunnville marsh are used by freshwater turtles, and should be protected in order to conserve the local population.

7.2 Recommendations for Conservation and Restoration

To help conserve the population of freshwater turtles at the Dunnville marsh, it is recommended that the used habitat areas are protected, and the restored marsh areas are further restored to accommodate freshwater turtles. Firstly, it is recommended that the canal is protected from development and habitat degradation. The canal appears to be an important habitat area for the local population of freshwater turtles, and it is the main habitat area where Blanding's turtles were tracked and observed. Particularly, the MSA Mid Canal is an important habitat for painted turtles and Blanding's turtles; however, the OSM East canal is also an important habitat area for Blanding's turtles. The MSA Mid Canal, OSM East Canal, and SSA West Canal are each used by painted, snapping, and Blanding's turtles. Each of these canal sections offer different habitat types that are important to the turtles and provide food, shelter, nesting areas, basking areas, and overwintering sites. Unfortunately, the canal is located directly beside a busy highway that is a threat to the turtle population, and might have influenced the painted turtle sex ratio to be male biased due to female road mortality (DeCatanzaro & Chow-Fraser, 2010; MNRF, 2010).

7.2.1 Mitigation of road mortality

Although a turtle road crossing sign is located along the highway next to the canal to warn drivers, the sign is placed near the east end of the MSA Mid Canal, which is located beyond a turtle crossing hotspot. Several locals observed turtles crossing the highway between the SSA West Canal and the OSM Cattails and Bulrush field. Similarly, the female juvenile Blanding's was tracked to have travelled across the highway from the SSA West Canal to the OSM Cattails and Bulrush field, and then back again (*Figure 5.1*). Remains of a painted turtle which was hit by a car, and is suspected to be the female painted turtle on channel 02 that went missing, were also found on the road in this area. Therefore, it is recommended that the turtle crossing sign is moved further west along the highway, and placed at or before the intersection located at the west end of the SSA West Canal. A report by the MOT (2012) revealed that 13% of municipal turtle crossing signs across Ontario were not located at validated turtle crossing hotspots, so it is possible that this sign would be more affective at the recommended location. Furthermore, speed limits could be reduced along the stretch of highway located beside the canal to help prevent road mortality (MNRF, 2010).

In addition to road mortality caused by on-road vehicles, the researcher observed road mortality of wildlife by all terrain vehicles (ATVs) inside and just outside the marsh. On one occasion, the researcher observed a snapping turtle hatchling that was killed by an ATV. The unpaved road located between the canal and the northern boundary of the marsh is used as a nesting site by turtles. This is an abandoned road that contains deep potholes which fill up with water throughout the spring and summer, resulting in large muddy puddles along the road that are used by frogs, toads, and turtle hatchlings. Unfortunately, this road is frequently used by people on ATVs during the spring, summer, and fall, causing road mortality of amphibians, turtle hatchlings, and destruction of nests. For this reason, it is recommended that the recreational use of ATVs and other motorized vehicles is prohibited within the marsh and on the abandoned road between the canal and marsh where freshwater turtles nest (Darst et al., 2013; DMMP, 1997; MNRF, 2010). Interestingly, the prohibition of motorized vehicles being used inside the marsh was outlined in the Dunnville Marsh Management Plan (1997) but was never enforced. It is recommended that this law is enforced to protect freshwater turtles and other wildlife that utilize the Dunnville marsh area.

7.2.2 Mitigation of habitat degradation

A second threat to the canal habitat is pollution from locals and drivers. Throughout the field season, the researcher witnessed several people throw garbage out their car window into the canal as they drove by. The canal is littered with paper and plastic food containers, plastic bottles, Styrofoam waste, and empty oil containers. The canal is also littered with unwanted items such as car tires, old furniture (cushions, chairs, tables), and large paper bags full of lawn debris. For this reason, it is recommended that signs are placed along the canal to warn locals of a fine that will be issued to anyone who litters or dumps waste into the canal (MNRF, 2010). It would be beneficial if conservation officers or law enforcement officers are present along that area of the highway more often to deter locals from speeding, littering, or dumping garbage by the canal. Other issues observed include oil run-off from the road into the canal, and broken car parts from car accidents that are eventually washed into the canal by rain. To mitigate this issue, a more affective buffer zone between the canal and the highway would be beneficial (Roe & Georges, 2007; Sterrett et al., 2011). Vegetation grows along the highway between the road and the canal, but this vegetation is mowed down by Haldimand County and locals who live next to the canal. Although some of the vegetation next to the road might need to be mowed to accommodate traffic, most of the vegetation appears to be mowed too close to the canal and should be left in place to act as a buffer zone. This buffer zone could prevent garbage and other debris from littering the canal, and could filter other road pollution from storm water-runoff before it enters the canal water (Sterrett et al., 2011).

Other important habitats that should be protected from development and degradation include the MSA Bay, MSA Creeks, SSA Creeks, SSA Ponds, and OSM habitats. One way to protect these habitats from degradation is to improve the overall water quality for the region.

Water runoff from the region drains into Maple Creek, which flows throughout the marsh and eventually empties into the Grand River (DMMP, 1997). This means chemical pollutants from private lawns, agricultural fields, and roads, eventually make their way into the MSA Bay, MSA Creek, and SSA Creek (i.e. Maple Creek) habitats that are used by freshwater turtles. To improve water quality, natural greenspace which acts as a filter for these pollutants could be preserved throughout the region. It is also important to ensure buffer zones are large enough between natural areas and roads, agricultural fields, and housing developments (Roe & Georges, 2007; Sterrett et al., 2011). Bylaws that reduce the use of private lawn and agricultural pesticides or herbicides could also be beneficial (De Solla et al., 2014; Sparling et al., 2006).

7.2.3 Nesting habitat construction

Nest surveys throughout the marsh revealed that there are not many suitable nesting sites. The marsh has a high vegetation cover which is not ideal for nesting habitat (Dowling et al., 2010; Hughes & Brooks, 2006). Shoreline areas are dominated by EAV which prevents erosion that could otherwise provide nesting habitat. Due to the lack of suitable nesting habitat throughout the marsh, it is recommended that nesting habitat is constructed. The construction of nesting habitat spread throughout the marsh could help to reduce high nest predation rates that occur in other areas where nests are concentrated (Roosenburg et al., 2014). As discovered by Dowling et al. (2010), one cost-effective way to provide nesting habitat for turtles is to till plots of land. This loosens the soil and breaks up vegetation, providing a suitable nesting medium for turtle species like the Blanding's turtle (Dowling et al., 2010). A second way to provide nesting habitat is to remove patches of vegetation from land near the shoreline, and add sandy or loamy soil to the surface (MNRF, 2010). Furthermore, to ensure that nests are protected from common predators like raccoons, nesting habitat could be constructed on the small islands along Maple

Creek (Roosenburg et al., 2014). Suitable nesting habitat that reduces nest predation rates is crucial for the survival of freshwater turtles.

7.2.4 Aquatic habitat construction

Surveys of the marsh revealed that there is a lack of suitable aquatic habitat for freshwater turtles throughout restored areas. Water within the restored areas is shallow, temporary, and does not contain SAV. Although the pits constructed within Meadow Marsh habitat are useful for amphibians, they are too small and shallow for freshwater turtles to inhabit. Furthermore, vernal pools throughout the marsh that contain deeper water are located within Deciduous Swamp which has a high canopy cover, making it unsuitable living habitat for the local freshwater turtle population. For these reasons, it is recommended that suitable aquatic habitat is constructed for freshwater turtles within restored marsh areas. MSA or SSA Ponds could be constructed within Meadow Marsh habitats, which reach depths that ensure a permanent water source. Water deep enough to not freeze completely during winter could also be used as an overwintering site for turtles (Paterson et al., 2012). To provide an effective food source and shelter from predators, SAV and FAV could be seeded in constructed ponds (Millar et al., 2011; Weiten et al., 2012). Finally, basking areas such as logs could be added to the ponds. The construction of MSA and SSA ponds within restored areas of the marsh could encourage freshwater turtles to move from canal habitats to areas within the restored marsh, located away from the highway and the threats associated with it (MNRF, 2010).

A second recommendation to provide aquatic habitat within the restored areas is to block off agricultural drains that remain in the marsh from before it was restored. The drains prevent the Meadow Marsh habitat areas from flooding beyond a certain depth. Although freshwater turtles would not live in shallow flooded habitats long-term, they have been found to temporarily forage in these areas (Cosentino et al., 2010). In addition to future research recommendations mentioned in Chapter 6, future research at the Dunnville marsh could examine if these conservation and restoration efforts have a positive impact on the local freshwater turtle population.

In conclusion, the findings in this study reveal which freshwater turtle species are present at the Dunnville marsh, their population characteristics, and what macro and microhabitats they use. This information, combined with knowledge from other studies, can be used to guide conservation and restoration efforts both within the Dunnville marsh and other regions containing freshwater turtle populations.

References

Anderson, N., & Horne, B. (2009). Observations on the nesting ecology of the Mississippi mud turtle, *Kinosternon subrubrum hippocrepis* gray. *Southeastern Naturalist, 8*(3), 563-565.

Beaudry, F., deMaybadier, P., & Hunter Jr. (2008). Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. *Biological Conservation, 141*, 2550-2563. doi:10.1016/j.biocon.2008.07.016

Beehler, K. (2007). An investigation of the abundance and key habitat parameters of the northern map turtle (*Graptemys geographica*) in an eastern Ontario bay. Retrieved from University of Waterloo Electronic Theses and Dissertations. http://hdl.handle.net/10012/3027

Bennett, A., & Litzgus, J. (2014). Injury rates of freshwater turtles on a recreational waterway in Ontario, Canada. *Journal of Herpetology, 48*(2), 262-266. doi:10.1670/12-161

Bishop, C., & Gendron, A. (1998). Reptiles and amphibians: Shy and sensitive vertebrates of the Great Lakes Basin and St. Lawrence River. *Environmental Monitoring and Assessment, 53*, 225-244.

Boarman, W., Goodlett, T., Goodlett, G., & Hamilton, P. (1998). Review of radio transmitter attachment tachniques for turtle research and recommendations for improvement. *Herpetological Review, 29*(1), 26-33.

Boitani, L., & Fuller, T. (2000). *Research techniques in animal ecology: Controversies and consequences*. New York, NY: Columbia University Press.

Bone, R. (2014). *The regional geography of Canada*. Don Mills, ON: Oxford University Press.

Bower, D., & Hodges, K. (2013). Salinity of incubation media influences embryonic development of a freshwater turtle. *Journal of Comparative Physiology B, 183*, 235-241. doi:10.1007/s00360-012-0695-2

Bowne, D., Bowers, M., & Hines, J. (2006). Connectivity in an agricultural landscape as reflected by interpond movement of a freshwater turtle. *Conservation Biology, 20*(3), 780-791. doi:10.1111/j.1523-1739.2006.00355.x

Browne, C., & Hecnar, S. (2007). Species loss and shifting population structure of freshwater turtles despite habitat protection. *Biological Conservation, 138*, 421-429. doi:10.1016/j.biocon.2007.05.008

Burgin, S., & Ryan, M. (2008). Comparison of sympatric freshwater turtle populations from an urbanized Sydney catchment. *Aquatic Conservation: Marine and Freshwater Ecosystems, 18*, 1277-1284. doi:10.1002/aqc.945

Cagle, F. (1939). A system of marking turtles for future identification. *Copeia, 1939*(3), 170-173. Retrieved from http://www.jstor.org/stable/1436818

City of Kingston (COK). (2013). *Information report to environment, infrastructure & transportation policies committee* (Report No. EITP 13-017). Kingston, ON: Canada.

Colorado State University (CSU). (2015). *Estimating soil texture: Sand, silt, or clayey?* Retrieved from http://www.ext.colostate.edu/mg/gardennotes/214.html

Cosentino, B., Schooley, R., Phillips, C. (2010). Wetland hydrology, area, and isolation influence occupancy and spatial turnover of the painted turtle, *Chrysemys picta. Landscape Ecology, 25*, 1589-1600. doi:10.1007/s10980-010-9529-3

Costanzo, J., Litzgus, J., Larson, J., Iverson, J., & Lee, R. (2001). Characteristics of nest soil, but not geographic origin, influence cold hardiness of hatchling painted turtles. *Journal of Thermal Biology, 26*, 65-73.

Darst, C., Murphy, P., Strout, N., Campbell, S., Field, K., Allison, L., & Averill-Murray, R. (2013). A strategy for prioritizing threats and recovery actions for at-risk species. *Environmental Management, 51*, 786-800. doi:10.1007/s00267-012-0007-3

Delmas, V., Bonnet, X., Girondot, M., & Prevot-Julliard, A. (2008). *Physiological and Biochemical Zoology, 81*(3), 345-355. Retrieved from http://www.jstor.org/stable/10.1086/529459

DeCatanzaro, R., & Chow-Fraser, P. (2010). Relationship of road density and marsh condition to turtle assemblage characteristics in the Laurentian Great Lakes. *Journal of Great Lakes Research, 36,* 357-365. doi:10.1016/j.jglr.2010.02.003

De Solla, S., & Martin, P. (2007). Toxicity of nitrogenous fertilizers to eggs of snapping turtles (*Chelydra serpentina*) in field and laboratory exposures. *Environmental Toxicology and Chemistry, 26*(9), 1890-1895.

De Solla, S., & Martin, P. (2011). Absorption of current use pesticides by snapping turtle (*Chelydra serpentina*) eggs in treated soil. *Chemosphere, 85,* 820-825. doi:10.1016/j.chemosphere.2011.06.080

De Solla, S., Palonen, K., & Martin, P. (2014). Toxicity of pesticides associated with potato production, including soil fumigants, to snapping turtle eggs (*Chelydra serpentina*). *Environmental Toxicology and Chemistry*, *33*(1), 102-106. doi:10.1002/etc.2393

Dorland, A., Rytwinski, T., & Fahrig, L. (2014). Do roads reduce painted turtle (*Chrysemys picta*) populations? *PLOS ONE*, *9*(5), 1-12. doi:10.1371/journal.pone.0098414

Dowling, Z., Hartwig, T., Kiviat, E., & Keesing, F. (2010). Experimental management of nesting habitat for the Blanding's turtle (*Emydoidea blandingii*). *Ecological Restoration, 28*(2), 154-159.

Dunnville Marsh Management Plan (DMMP). (1997). *Dunnville marsh management plan*. Retrieved from http://agrienvarchive.ca/download/Dunnville_marsh_man_plan97.pdf

Dunnville Marsh Management Plan (DMMP). (1997). Section III - Management plan. In *Dunnville marsh management plan* (section 3, p.13). Retrieved from http://agrienvarchive.ca/download/Dunnville_marsh_man_plan97.pdf

Erb, L., & Jones, M. (2011). Can turtle mortality be reduced in managed fields? *Northeastern Naturalist, 18*(4), 489-496.

Ernst, C., Lovich, J., & Barbour, R. (1994). *Turtles of the United States and Canada*. Washington, DC: Smithsonian Institution Press.

Fidelibus, M., & MacAller, R. (1993). *Methods for plant sampling*. Retrieved from http://www.sci.sdsu.edu/SERG/techniques/mfps.html

Finkler, M. (2006). Does variation in soil water content include variation in the size of hatchling snapping turtles (*Chelydra serpentina*)? *Copeia, 4*, 769-777.

Freedman, B. (2010). *Environmental science: A Canadian perspective*. Toronto, ON: Pearson Canada Inc.

Friends of Algonquin Park (FAP). (2005). *Painted turtle research in Algonquin Provincial Park*. Retrieved from http://www.sbaa.ca/projects.asp?cn=316

Gamble, T. (2006). The relative efficiency of basking and hoop traps for painted turtles (*Chrysemys picta*). *Herpetelogical Review, 37*(3), 308-312.

Gibbs, J., Marquez, C., & Sterling, E. (2007). The role of endangered species reintroduction in ecosystem restoration: Tortoise-cactus interactions on Espanola Island, Galapagos. *Restoration Ecology, 16*(1), 88-93. doi:10.1111/j.1526-100X.2007.00265.x

Gordon, D., & MacCulloch, R. (1980). An investigation of the ecology of the map turtle, *Graptemys geographica* (Le Sueur), in the northern part of its range. *Canadian Journal of Zoology, 58*(12), 2210-2219. doi:10.1139/z80-303

Grand River Conservation Authority (GRCA). (2012). *Dunnville marsh: Coastal biodiversity restoration project* (Brochure). ON: Canada.

Gunson, K., Ireland, D., & Schueler, F. (2012). A tool to prioritize high-risk road mortality locations for wetland-forest herpetofauna in southern Ontario, Canada. *North-Western Journal of Zoology, 8*(2), 409-413. Retrieved from http://biozoojournals.3x.ro/nwjz/index.html

Hartwig, T., & Kiviat, E. (2007). Microhabitat association of Blanding's turtles in natural and constructed wetlands in southeastern New York. *The Journal of Wildlife Management, 71*(2), 576-582. Retrieved from http://www.jstor.org/stable/4495218

Holcomb, S., & Carr, J. (2013). Mammalian depredation of artificial alligator snapping turtle

(*Macrochelys temminckii*) nests in North Louisiana. *Southeastern Naturalist, 12*(3), 478-491.

Hughes, G., Greaves, W., & Litzgus, J. (2009). Nest-site selection by wood turtles (*Glyptemys insculpta*) in a thermally limited environment. *Northeastern Naturalist*, *16*(3), 321-338.

Hughes, E., & Brooks, R. (2006). The good mother: Does nest-site selection constitute parental investment in turtles? *Canadian Journal of Zoology, 84*, 1545-1554. doi:10.1139/Z06-148

Johnson, D. (1980). The comparison of usage and availability measurements for evaluating resource preference. *Ecology*, *61*(1), 65-71. Retrieved from http://www.jstor.org/stable/1937156

Jones, R., & Hartfield, P. (1995). Population size and growth in the turtle *Graptemys oculifera*. *Journal of Herpetology, 29*(3), 426-436. Retrieved from http://www.jstor.org/stable/1564994

Jones, S., & Ferguson, G. (1980). The effect of painted marking on mortality in a Texas population of *Sceloporus undulatus*. *Copeia, 4*, 850-854. Retrieved from http://www.jstor.org/stable/1444464

Lamb, J., Ennen, J., & Qualls, C. (2013). Environmental characteristics of nest sites selected by gopher tortoises (*Gopherus polyphemus*) in Southern Mississippi. *Chelonian Conservation and Biology, 12*(2), 227-234.

Lee, H., Bakowsky, W., Riley, J., Bowles, J., Puddister, M., Uhlig, P., & McMurray, S. (1998). *Ecological land classification for Southern Ontario: First approximation and its application*. North Bay, ON: Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. SCSS Field Guide FG-02.

Lescher, T., Tang-Martinez, Z., & Briggler, J. (2013). Habitat use by the alligator snapping turtle (*Macrochelys temminickii*) and eastern snapping turtle (*Chelydra serpentina*) in southeastern Missouri. *American Midland Naturalist, 169*, 86-96.

MacCulloch, R. (2002). *The ROM field guide to amphibian and reptiles of Ontario*. Toronto, ON: The Royal Ontario Museum and McClelland & Stewart Ltd.

Micheli-Campbell, M., Baumgartl, T., Booth, D., Campbell., H., Connell, M., & Franklin, C. (2013). Selectivity and repeated use of nesting sites in a freshwater turtle. *Herpetologica, 69*(4), 383-396.

Mifsud, D. (2014). A status assessment and review of the herpetofauna within the Saginaw Bay of Lake Huron. *Journal of Great Lakes Research Supplement, 40*, 183-191. Retrieved from http://dx.doi.org/10.1016/j.jglr.2013.09.017

Millar, C., & Boulin-Demers, G. (2011). Spatial ecology and seasonal activity of Blanding's turtles (*Emydoidea blandingii*) in Ontario, Canada. *Journal of Herpetology, 45*(3), 370-378.

Ministry of Natural Resources and Forestry (MNRF). (2010). *Recovery strategy for the Wood Turtle (Glyptemys insculpta) in Ontario: Ontario recovery strategies series*. ON: Canada. Queen's Printer for Ontario.

Ministry of Natural Resources and Forestry (MNRF). (2015). *Species at risk in Ontario list*. Retrieved from https://www.ontario.ca/environment-and-energy/species-risk-ontario-list

Ministry of Natural Resources and Forestry (MNRF). (2016). *Snapping turtle*. Retrieved from https://www.ontario.ca/page/snapping-turtle

Ministry of Natural Resources and Forestry (MNRF). (2016). *Blanding's turtle*. Retrieved from https://www.ontario.ca/page/blandings-turtle

Ministry of Natural Resources and Forestry (MNRF). (n.d.). *Invasive species fact sheet: Invasive Phragmites* (*Phragmites australis subsp. australis*). Retrieved from http://www.web2.mnr.gov.on.ca/mnr/Biodiversity/Invasive_Species/Phragmites_Fact_Sheet.pdf

Ministry of Transportation (MOT). (2012). *Placement of species at risk crossing signs* (Report No. HIIFP-115). ON: Canada. Retrieved from https://www.library.mto.gov.on.ca/SydneyPLUS/Sydney/Portal/default.aspx?lang=en-US

Moldowan, P. (2014). *Sexual dimorphism and alternative reproductive tactics in the Midland Painted Turtle (Chrysemys picta marginata)*. Retrieved from http://www.researchgate.net/publication/277028515

Murphy, S. (2010). *State of the science on habitat suitability modelling (HSM) report on the CASIOPA HSM workshop 18 February 2010*. Retrieved from http://casiopa.mediamouse.ca/2015/01/2010-casiopa-workshop-on-habitat-suitability-modelling/

Neumann, M. (2012). Coastal wetlands restoration at Dunnville Marsh. In *Ontario wetlands conference: The history and future of our wetlands*. Retrieved from http://www.ontarionature.org/protect/habitat/PDFs/Wetlands_Conference_poster_abstracts.pdf

Obbard, M., & Brooks, R. (1980). Nesting migrations of the Snapping Turtle (*Chelydra serpentina*). *Herpetologica*, *36*(2), 158-162. Retrieved from http://www.jstor.org/stable/3891480

Paterson, J., Steinberg, B., & Litzgus, J. (2012). Generally specialized or especially general? Habitat selection by snapping turtles (*Chelydra serpentina*) in central Ontario. *Canadian Journal of Zoology, 90*, 139-149. doi:10.1139/Z11-118

Pittman, S., & Dorcas, M. (2009). Movements, habitat use, and thermal ecology of an isolated population of bog turtles (*Glyptemys muhlenbergii*). *Copeia*, *4*, 781-790. Retrieved from http://www.bioone.org/doi/full/10.1643/CE-08-140

Proulx, C., Fortin, G., & Blouin-Demers, G. (2014). Blanding's turtles (*Emydoidea blandingii*) avoid crossing unpaved and paved roads. *Journal of Herpetology, 48*(2), 267-271. doi:10.1670/12-176

Ream, C., & Ream, R. (1966). The influence of sampling methods on the estimation of population structure in painted turtles. *American Midland Naturalist*, *75*(2), 325-338.

Retrieved from http://www.jstor.org/stable/2423395

Row, J., & Blouin-Demers, G. (2006). Kernels are not accurate estimators of home-range size for herpetofauna. *Copeia, 4*, 797-802.

Roe, J., & Georges, A. (2007). Heterogenous wetland complexes, buffer zones, and travel corridors: Landscape management for freshwater reptiles. *Biological Conservation, 135*, 67-76. doi:10.1016/j.biocon.2006.09.019

Rollinson, N., & Brooks, R. (2007). Marking nests increases the frequency of nest depredation in a northern population of painted turtles (*Chrysemys picta*). *Journal of Herpetology, 41*(1), 174-176.

Roosenburg, W., Spontak, D., Sullivan, S., Matthews, E., Heckman, M., Trimbath, R., Dunn, R., Dustman, E., Smith, L., & Graham, L. (2014). Nesting habitat creation enhances recruitment in a predator-free environment: *Malaclemys* nesting at the Paul S. Sarbanes Ecosystem Restoration Project. *Restoration Ecology, 22*(6), 815-823. doi:10.1111/rec.12147

Ryan, T., Peterman, W., Stephens, J., & Sterrett, S. (2014). Movement and habitat use of the snapping turtle in an urban landscape. *Urban Ecosystems, 17*, 613-623. doi:10.1007/s11252-013-0324-1

Science & Plants for Schools (SPS). (2016). *Questions about quadrats*. Retrieved from http://www.saps.org.uk/secondary/teaching-resources/260-questions-about-quadrats

Selman, W., & Qualls, C. (2007). The impacts of Hurricane Katrina on a population of yellow-blotched sawbacks (*Graptemys flavimaculata*) in the Lower Pascagoula River. *Herpetological Conservation and Biology, 3*(2), 224-230.

Simon, C., & Bissinger, B. (1983). Paint marking lizards: Does the color affect survivorship? *Journal of Herpetology, 17*(2), 184-186. Retrieved from http://www.jstor.org/stable/1563463

Snyder, G. (2016). *Water temperature influences in rivers and streams*. Retrieved from http://www.watercenter.org/physical-water-quality-parameters/water-temperature/water-temperature-ranges-in-rivers-and-streams/

Sparling, D., Matson, C., Bickham, J., & Doelling-Brown, P. (2006). Toxicity of glyphosate as Glypro and LI700 to red-eared slider (*Trachemys Scripta Elegans*) embryos and early hatchlings. *Environmental Toxicology and Chemistry, 25*(10), 2768-2774.

Steen, D., Aresco, M., Beilke, S., Compton, B., Condon, E., Dodd, C., . . . Gibbs, J. (2006). Relative vulnerability of female turtles to road mortality. *Animal Conservation, 9*, 269-273. doi:10.1111/j.1469-1795.2006.00032.x

Steen, D., Gibbs, J., Buhlmann, K., Carr, J., Compton, B, Congdon, J., . . . Wilson, D. (2012). Terrestrial habitat requirements of nesting freshwater turtles. *Biological Conservation, 150*, 121-128. Retrieved from http://dx.doi.org/10.1016/j.biocon.2012.03.012

Sterrett, S., Smith, L., Golladay, S., Schweitzer, S., & Maerz, J. (2011). The conservation implications of riparian land use on river turtles. *Animal Conservation, 14,* 38-46. doi:10.1111/j.1469-1795.2010.00394.x

Stevens, R., & Tello, S. (2009). Micro- and macrohabitat associations in Mojave Desert rodent communities. *Journal of Mammalogy, 90*(2), 388-403. Retrieved from http://jmammal.oxfordjournals.org/

Stumpf, K. (1993). The estimation of forest vegetation cover descriptions using a vertical densitometer. Retrieved from http://www.grsgis.com/publications/saf_93.pdf

Tryfonas, A., Tucker, J., Brunkow, P., Johnson, K., Hussein, H., & Lin, Z. (2006). Metal accumulation in eggs of the red-eared slider (*Trachemys scripta elegans*) in the Lower Illinois River. *Chemosphere, 63,* 39-48. doi:10.1016/j.chemosphere.2005.07.080

Weber, A., & Layzer, J. (2011). A comparison of turtle sampling methods in a small lake in Standing Stone State Park, Overton Country, Tennessee. *Journal of the Tennessee Academy of Science, 86*(2), 45-52.

Wieten, A., Cooper, M., Parker, A., & Uzarski, D. (2012). Great Lakes coastal wetland habitat use by seven turtle species: Influences of wetland type, vegetation, and abiotic conditions. *Wetlands Ecological Management, 20*, 47-58.

doi:10.1007/s11273-011-9240-4

Wilson, M. (2007). *Measuring vegetation characteristics per area.* Retrieved from http://oregonstate.edu/instruct/bot440/wilsomar/Content/HTM-perarea.htm

Wilson, J. (2011). Cover plus: Ways of measuring plant canopies and the term used for them. *Journal of Vegetation Science*, *22*, 197-206. doi:10.1111/j.1654-1103.2010.01238.x

Yagi, A., Brant, A., & Tervo, R. (2009). *Niagara Region Natural Areas Inventory Reptile and Amphibian Study 2006 to 2008*. Ontario Ministry of Natural Resources and Land Care Niagara unpublished report for the Natural Areas Inventory prepared for the Niagara Peninsula Conservation Authority 78 pp.

Yagi, K., & Litzgus, J. (2012). The effects of flooding on the spatial ecology of spotted turtles (*Clemmys guttata*) in a partially mined peatland. *Copeia*, *2*, 179-190.