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TRAVELING LANDSCAPES: MINIMIZING URBAN SPRAWL THROUGH THE USE OF LOW IMPACT DEVELOPMENT TO INCREASE MIGRATORY SPECIES HABITAT IN TEXAS

A Master Thesis

Submitted to the Faculty

of

American Public University

by

Verma V. Villegas

In Partial Fulfillment of the Requirements for the Degree of

Master of Science

September 2016

American Public University

Charles Town, WV
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DEDICATION

I dedicate this thesis to my mother, who provided her lifelong support and unending encouragement to succeed; to my daughter, who has stood by me patiently through day and night during frustrations and achievements and has always known I would triumph; to my fiancé, who near the end pushed me to do my best and never give up on my goal because he had faith in my abilities; and to my dearest best friend who was patient in knowing this was part of who I had become and where I wanted to be in the future. For all the love, support, and understanding of everyone who is close to me during the completion of this project I thank you from the bottom of my heart.
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I found my coursework here at APUS to be a unique opportunity to complete a major part of my life’s dream and found myself immersed in a stimulating environment that challenged me in ways I never thought or imagined. This experience has given me tools, skills and talents that will guide and enhance my professional and social surroundings.
ABSTRACT OF THE THESIS

TRAVELING LANDSCAPES: MINIMIZING URBAN SPRAWL THROUGH THE USE OF LOW IMPACT DEVELOPMENT TO INCREASE MIGRATORY SPECIES HABITAT IN TEXAS.

by

Verma V. Villegas

American Public University System, September 2016

Charles Town, West Virginia

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Migratory animals travel along specific corridors and through landscapes across state borders and countries. Due to urban sprawl and fragmentation, these migrants have lost much-needed habitat along these corridors, which they have traveled for centuries. With the use of Low Impact Development and Ecosystem Restoration strategies, many of these landscapes along migrant corridors can become connected again naturally. Additionally, these strategies will promote ecosystem services that benefit the human population. There is a positive relationship between the restoration of natural areas, human welfare, and wildlife biodiversity. This paper shows that relationship through a literature review and a Habitat Sustainability Index analysis. More studies are indicated in order to provide a stronger relationship between these subjects.

Key Words: Biodiversity, Low Impact Development, Ecosystem Restoration, Ecosystem Services, Migration, Whooping Crane, Mexican Free-Tailed Bat, Monarch Butterfly.
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I. INTRODUCTION:

Some of the most amazing creatures in this world are those who travel from one place to another in order to find the optimal conditions in which to grow and mature, nest, breed and reproduce. Instinctual factors usually associated with seasonal changes, food supply and reproduction needs, create conditions in which the animal knows when it is time to make incredible journeys across state and country lines. These species move through corridors that have been established for millions of years, some stopping at the same places each time, while some halt in similar or an equivalent general area.

Today, many of those places have become a haven for another species, *Homo sapiens*. The human population has increased at such a rate that much of the natural areas surrounding all wildlife has diminished to the point where species reproduction is no longer an option, and survival is a luxury left only to man (Mirrahimi, Ibrahim & Surat, 2015). Migratory animals have suffered the most since they rely on a multitude of habitat areas in order to make their journeys, and each year more of that specified habitat is lost to human development and anthropogenic factors. However, people can also be amazing and as they become more aware of the impact inflicted on the environment by urban sprawl and land development, they have learned to work with nature in order to prevent future decay. The result is the evolution and use of Low Impact Development and Ecosystem Restoration.

These land strategies are known to be prevalent by only a few communities, however studies have shown the need for the urban growth process to alter its traditional methods and to make room for less destructive techniques; the hopes is that this type of development can become standard in order to increase biodiversity and offset humanity’s carbon footprint (Groot, Blignaut, ...& Farley, 2013). This paper will focus on the usable habitat in Texas for the following migratory species, the whooping crane, the Mexican free-tailed bat and the monarch
butterfly; and will show through the utilization of Low Impact Development and ecosystem restoration within urban communities how migratory stopover habitat and ecosystem services will increase.

Focusing only on the migratory aspect of this study would be erroneous. Therefore, population factors for Texas will be discussed and observations on how the benefits that Low Impact Development and Ecosystem Restoration contribute to both humanity and wildlife in the state of Texas and surrounding areas will be made.

A. Texas

The Texas populace is one of the quickest expanding populations in the nation. Currently the residents within its boundaries are flourishing to record levels. According to the U. S. Census Bureau ([USCB ], 2016), five out of the top ten cities in the nation with the largest increase in population are in Texas. Between the years of 2014 and 2015 Galveston passed the 50,000 population mark, San Angelo passed the 100,000 threshold, and Austin/Round Rock area reached a population of just over two million; additionally Dallas/Fort Worth, Houston and San Antonio added approximately 30,000 or more for that same time period (USCB, 2016).

Similar to many states in America, as the population increases the landowners in Texas develop the cities around their water supply in the traditional way through the expanded use of impervious surfaces that fragment natural areas; this results in an increase loss of critical species habitat and overall landscape deterioration (Mirrahimi, Ibrahim & Surat, 2015). Nearly a decade ago, Texas had almost 84% of its land owned by private ranchers and farmers, however within several years, one million hectares of that private land was converted for urban uses (Kjelland, Kreuter, ...& Grant, 2007), which were typically not regulated by land commissioners. Accelerated population growth in any area yields low density urban sprawl that not only brings land fragmentation from roadways and exurban communities, but also from
water irrigation and damming, industry land ownership, and agricultural land conversion; all of which limits riparian growth along many of the waterways (York, Shrestha,... & Skaggs, 2011). The loss of riparian areas leads to increased threats from flooding and loss of biodiversity. As the natural areas are minimized, so too are the number of wildlife that visits those areas.

Consequently, a reduced number of migration rates and population levels are common throughout the state due to the many urban communities (Adams, 2005). Wild animals prefer to stay away from areas where there are a large number of people, unless there is sufficient habitat that could protect them. Texas is in the mainstream of where that essential habitat is needed. The Central Flyway is a migratory corridor that is utilized by numerous species and it runs directly through Texas (See Image 1: Central Flyway). Migratory corridors are distinct pathways that have been distinguished over time according to the topographical aspects of the landscape, climate of the region, and other environmental factors (Shackelford, Rosenberg, Hunter, & Lockwood, 2005). In Texas alone, 98% of the categorized 338 North America Nearctic-Neotropical migratory bird species travel through or breed in this vast state through the Central Flyway corridor (Shackelford et al., 2005). However, birds are not the only migratory species that travel through or stopover in Texas; other migratory animals include bats and butterflies. According to Shackelford et al. (2005), the unique geographic position of Texas also allows the state to receive migrants from the Atlantic Flyway, Mississippi Flyway and Pacific Flyway. Due to the loss of many natural spaces, migratory animals along these corridors no longer have the necessary habitat and access to the amount of food needed for energy to travel throughout their path and therefore diminish in numbers each progressing year. As migratory population numbers decline so too does the amount of ecosystem services provided by each animal. Each landscape within any city, including the residential communities along the path of
a migrant animal, have the potential to become a stopover site which can provide the necessary shelter and nutrients needed for the species to complete its trip (Mehlman, Mabey, ... & Woodrey, 2005). One purpose of this paper is to show how the need for stopover sites can be met through the use of Low Impact Development and Ecosystem Restoration land strategies, which in turn will increase ecosystem services in the area for the human population.

Image 1: Central Flyway

(Shackelford et al., 2005)

B. Ecosystem Services

Ecosystem services (ES) are those ecological systems that provide valuable services that humanity does not have to pay for in monetary terms, yet are still accomplished regardless by natural functions or by wildlife (Goldman, 2010). ES not only includes those performed by wildlife such as pollination and seed dispersal, but also those that happen passively within the environment such as carbon sequestration, watershed operations, riparian protection from
flooding, and water quality; many of which are usually managed through publicly funded systems (Olenik, Kreuter & Conner, 2005). According to Wenny, DeVault, ...& Whelan (2011), the Millennium Ecosystem Assessment of 2003 divides ES into four categories: provisioning services, cultural, recreational and supporting services. Provisioning services include all products that are naturally derived such as cotton or fruit that is used directly by humans, while services that provide for circumstances such as recreation, art, and music or give spiritual value are considered cultural services (Wenny et al., 2011). There are regulating services that incorporates the decomposers and pest control; and lastly but most importantly are services that provide crucial assistance to the human population and those are called supporting services, which covers a vast array of actions such as the purification of water, pollination, nutrient cycling, and seed dispersal (Wenny et al., 2011).

Ecosystem services (ES) are not only critical to supplementing and strengthening the lives of millions of people, but also in producing and saving consumers billions of dollars every year. Without these services, much of the world’s tourist economy would shatter and the planet wide agricultural system would significantly collapse and will have a difficult time recovering. For example, coffee is considered both a commodity and an export; one-third of the world’s coffee crops are dependent on the pollination that is performed only by wild species (Reynolds & Clay, 2011). These Wild species include migratory animals, which are key in the majority of seed dispersal throughout the United States. Additionally, migratory species also provide nutrient cycling, pest control, and cultural benefits. Migratory animals have the unique opportunity to provide ES throughout the year and in multiple states and countries. Mexican Free-Tailed bats provide the Southern United States alone an average of almost 12 million dollars in the pollination of just cotton (Hoffman, Wiederholt, ...& Semmens, 2014). That is not
counting the propagation of agave for tequila or the millions of dollars worth of tourist dollars received from cities that host bat colonies.

The problem is there is currently not a standard method to include these ES dollar amounts into whole numbers that can be utilized by economic cost-benefit analysis. Kjelland et al., (2007) explain that nearly 60% of the ecosystem services provided by the planet are not used sustainably, are rarely included in economic cost-benefit analyses, and will eventually create a significant loss of biodiversity and bio-functionality, all while decreasing the benefits the human population achieves by these services. Essentially, ecosystem dollars are virtual dollars that are never counted. ES affects all aspects of the human population, if 60% of services are not being used properly or included in future plans, then that is only 40% that that can move into future generations. More than half of these free services are lost and end up being compensated by consumer dollars. Much of the problem lies in the lack of quantitative value given to ES by land managers and economists. There are many arguments involved in giving ES a monetary value and until that happens the loss of ES will still remain significant. However, according to Hoffman et al., (2014) there are market based plans being discussed to include financial motivation to conserve those economically productive ecosystem functions. It is beyond the scope of this paper to contemplate the complexity of how ES are calculated or not included in economic configurations, and will require further investigation in order to be established within society as the norm. Once systems are in place that includes ES as part of an economic plan, only then will society see the significance ES has on daily life. Additionally, ES are not only provided by wildlife; both Low Impact Development and Ecosystem Restoration utilize the natural functions of the planet to provide ES to local communities through natural functions.
C. Low Impact Development

Low Impact Development (LID) is a process by which land developers design landscapes in such a way that stormwater runoff is retained on the land and filtered into groundwater or allowed to run into a storm drain unpolluted by imitating the natural functions of the water cycle; this in turn provides water quality measurements, contributes to flood control and establishes natural native habitat (USEPA, 2016). As early as the 1990’s, scientists had observed and started addressing the issues involving urban sprawl by including in their studies considerations on fragmented metapopulations, watershed science, plant formation, nutrient cycling, water catchment techniques, and landscape aesthetics (Li & Mander, 2009). LID takes into account all of these aspects and brings them together to create methods that creates functionality into traditional landscapes that are aesthetically pleasing.

One of the main goals of LID strategies is to limit the number of impervious surfaces used in land development (Dorman et al., 2013). Instead of implementing asphalt or concrete in landscape design, permeable pavement and permeable asphalt is utilized to increase groundwater infiltration and limit stormwater runoff. However, traditional methods of land development include extensive use of impervious surfaces. According to the National Land Cover Database, Texas had the largest impervious cover with over 920 km2 of land concealed in impervious surfaces in 2001, and by 2006 that number increased by almost 550 km2, which is a 5.97% expansion (Xian et al., 2011). With Texas having one of the fastest growing populations, the use of impervious surfaces will only increase and with it extensive land fragmentation. Land fragmentation brings with it a multitude of other issues such as loss of biodiversity, loss of native vegetation, loss of agriculture, loss of water quality, increased invasive species, increased erosion, and increased public fees (Kjelland et al., 2007). By utilizing LID techniques in land development, it will help minimize the negative effects of land fragmentation.
Other goals for LID strategies are to increase storm water retention and filtration on land through the use of rain barrels, rain gardens, green roofs, planter boxes, sand filters, constructed wetlands and bio-swales (Dorman et al., 2013). Each of these bio-retention methods keeps small or large amounts of stormwater on site to minimize the amount of water running off urban landscapes and into storm drains. According to Dorman et al., (2013), the Clean Water Act and the National Pollutant Discharge Elimination System (NPDES) instructs the more populated cities through a permit system that requires them to limit the amount of polluted stormwater runoff that enters local waterways through the storm drain or Municipal Separate Storm Sewer System (MS4). LID strategies are a viable solution for any city required to follow NPDES regulations. These methods both limit and reduce pollution, and when populated with native vegetation and other filtering techniques LID standards promote the filtration of biological, heavy metal, organic, trash and oil contamination (Dorman et al., 2013). The beauty of LID procedures is the simplicity in how utilizing one or more options per site will thereby increase the amount of water held on site to undergo decontamination with each different strategy used.

The use of native plants in multiple areas around an urban landscape will also provide native habitat for local and migrating wildlife. Native plants are vegetation that naturally occurs in a region and has had a chance to evolve in that region for over thousands of years (Butler, Butler, & Orians, 2005). Native vegetation typically does not require pesticides, fertilizers or much water because they have reformed to the local environment and can enrich the local ecosystem and wildlife (Butler et al., 2005). Since migratory stopover sites for wildlife can be large or small and are utilized by numerous species in order to increase survival of long distance flights, the use of native plants in residential and local landscaping is ideal to produce wildlife habitat (Melman et al., 2005). For this reason, green infrastructure such as LID will provide
much-needed additional stopover habitat for migratory species. Additionally, increasing the amount of natural areas within an urban city will also increase the welfare and happiness of the human population. Compared to the quintessential suburban neighborhood, those communities that have had opportunities to design their own neighborhoods do so with greener spaces and less impervious surfaces, which in turn promotes an overall heightened sense of community and increases behaviors of positive neighborly conduct (Rogers & Sukolratanametee, 2009). As more natural spaces are included into the development of cities, more positive outcomes for both humans and wildlife can be attributed to those greener areas.

D. Ecosystem Restoration

Ecosystem restoration (ER) is a method that takes larger areas of damaged or destroyed ecosystems and restores them through processes that assist nature towards recovery: ER utilizes deliberate actions in order to accelerate biodiversity and the natural growth of an area through time (Gann & Lamb, 2006). According to Gann & Lamb, (2006) there are certain elements that are characteristic of a successful ER project and they include community empowerment, increased biodiversity, expanded ecosystem services, and improved lives of the surrounding human population. These are not easy goals to achieve and more often than not, increasing biodiversity counteracts with improving human lives mainly because humanity tends to choose the easy path over biodiversity when it comes to continually improving livelihoods. However, if the community can invest in the restoration efforts and see value in how it can bring them a multitude of benefits including ecosystem services, personal worth and pride in their community, than the goals for a successful restoration effort can be achieved.

One example of a successful ER project is the San Antonio River Improvement Project (SARIP) or what is more commonly referred to as the Museum and Mission Reach sections of the San Antonio River in San Antonio, Texas. The two sections of SARIP are vastly different.
yet still utilize ER techniques in order to merge both human and nature together in a seamless junction of increased recreation, outstanding beauty, cultural pride, economic improvement and biological success. The project was achieved in many phases throughout the years by implementing an ER strategy called fluvial geomorphology, which mimics the natural functions of a river while maintaining flood control, increasing water quality, restoring native vegetation, and increasing biodiversity (SARA, 2016). This project shows its early success through the increased tourism to the area in addition to the expanded list of Neotropical and Nearctic migrants that have returned to the river as a stopover site, or as their breeding grounds.

Further down the river along the watershed, the endangered whooping crane has the potential to benefit from the increased water quality produced by the SARIP project that exists further upstream and is another example of how ER can help migratory species. The macrobenthics population in an estuary such as that found at the end of the San Antonio River, is directly related to water quality and in turn is directly related to predator populations such as the blue crab, which is one of the main food sources of the whooping crane (Kim & Montanga, 2009). Water quality is a huge advantage derived from ER because this process allows the biological success of an area to thrive. Good quality water is required for all living things including people. Without good water quality, many ES such as recreational swimming, kayaking and fishing could not occur.

ER projects can benefit an area is many other ways. San Antonio has enjoyed an improved river environment that expanded on the already popular tourist site of the River Walk, and as the SARIP project grows to maturity, more residents and tourists are utilizing its banks for recreation and are enjoying the natural landscapes and wildlife. The Convention on Biological Diversity (CBD) claim there are multiple links between the preservation of biological diversity,
community economic success and ES, proving that six out of nine restored ecosystems have potential for economic profit (Groot et al., 2013). Globally, ER plans are being included in international declarations where conservation, sustainability, and restoration of natural spaces are utilized to enrich ES and biodiversity in order to enhance the livelihoods of the human population (Aronson & Alexander, 2013). The success of the ER plan comes from planning and development; all aspects of the project must be accounted for before ground breaks in order to ensure against future economic failures.

E. Species Overview

In order to understand the importance of the study, information about the species listed in this study will be observed. The following is a detailed review of each of the species and required habitat needed in order to survive. In their differences, one thing remains similar throughout each of the three species listed; habitat loss is one of the main issues involved in why population numbers are diminished or declined. Additionally, each of them resides or migrates to Texas throughout the year, and utilizes many different landscape features in order to survive.

**Whooping Crane:**

![Whooping Crane](Image 2: Butler, Strobel & Eichhorn, 2016)

The whooping crane (*Grus americana*) is a white bird with black tipped wings (seen only during flight), black legs, black head and a red crown (*See Image 2*). The tallest bird in North America, it stands nearly five feet tall, with a seven to eight-foot wingspan and weighs
approximately 15 pounds (NWF, 2016). As a 60-million-year old bird species (Operation Migration, 2016), the whooping crane have a lifespan of approximately 25 to 30 years, and live in marshy wetlands, fields and prairies. Its primary food is the blue crab found on the Texan Coast at the Aransas National Wildlife Refuge (ANWF), however they are opportunist omnivores taking pleasure in rats, fish amphibians, reptiles, marsh plants, acorns and grains (NWF, 2016). The whooping cranes migrate 2,400 miles along the Central Flyway from the ANWF to the Wood Buffalo National Park in Canada twice a year (See Image 3: Whopping Crane Migration Corridor); after enjoying a population of thousands for centuries, the crane plummeted to only 15 birds in 1941 due to mainly habitat loss, hunting and loss of water quality (NWF, 2016). As of July of 2010 there are a total of 535 birds; with about 383 wild birds, the remaining are in captivity spanning 12 locations (ECOS, n.d. a).

Image 3: Whooping Crane Migration Corridor

(ECOS, n.d. a).

The whopping crane was originally protected in the United States under the Endangered Species Act in 1967, however it was also a protected species under several other governmental and international treaties; included in this protection are the Migratory Bird Treaty Act of 1916,

Whooping cranes require stopover habitat along the entire 2,400 miles as they only travel during the day and rest at night. They are not particular at to the type and amount of space used for migratory habitat as they are for nesting or breeding habitat. Whooping cranes have one mate and nest in areas that vary in size from 1.3 to 47.1 km2 (Travsky & Beauvais, 2004); the average nesting habitat is approximately 4.1 km2 and with a 1 km2 distance between neighboring nesting pairs (ECOS, n.d. a). During the winter family units are very territorial regarding their average one-km2 (117 ha) wintering habitat, while individual adults utilize the non-claimed patches of land (Travsky & Beauvais, 2004). Habitat usually consists of open areas of marshes, bays, estuaries, and tidal flats which are overshadowed by various species of grasses (See Figure 1: Whooping Crane Habitat Tree Chart).

Factors limiting population size is mainly due to fragmentation and loss of wintering habitat (Travsky & Beauvais, 2004). Studies have shown a positive population growth rate with various 10-year negative growth trends over the course of 73 years (Butler et al., 2013), proving that the whooping crane can rebound in numbers if given time and space. The ANWF is a limited area that may only be able to sustain approximately 200 cranes in the winter (Travsky & Beauvais, 2004); urban communities and the Gulf of Mexico surround and confine the refuge from further growth. Additionally, the Gulf is prone to severe oil spills and algae blooms, while the urban side is prone to significant contribution to water quality degradation and freshwater flow restrictions. To date additional threats besides habitat loss to the wild migrating population numbers include power lines, wind farms, predator, disease, and loss of genetic variability.
In addition to seed dispersal, every year hundreds of tourists gather for the festival of the cranes, in addition to viewing the migration arrivals and takeoffs at the ANWR in Texas. Whooping cranes are a sought after by many tourists looking to get a sight of the majestic bird. Every year hundreds of citizen scientists gather to help count whooping crane pairs in order to help determine appropriate numbers in the area (Butler et al., 2016). Each of these aspects brings about a cultural service to the community in the form of recreation, satisfaction and pride. Additionally, it also brings tourism dollars to the region and the state.

**Monarch Butterfly:**

The monarch butterfly (*Danaus plexippus*) is a brightly orange and black winged butterfly with small white dots (*See Image 4*) whose diet consists of mostly nectar as an adult and milkweed as a caterpillar (DOW, 2016). The unique lifespan of this butterfly is linked to its
TRAVELING LANDSCAPES

migration pattern. Each year, the migration is undertaken by four new generations. Most of the nation’s monarchs overwinters in Mexico and migrate 3000 miles in the spring (See Image 5: Migration Path of Monarch Butterfly), breeding and producing four generations over the migration before the last generation travels back to Mexico for the winter (DOW, 2016). The initial three generations live only for about 6 weeks before producing the next generation which travels the next leg in the migration; the last generation travels the entire 3000 miles back and lives for up to 9 months during the winter (DOW, 2016). Additionally, monarchs are on the International Union for Conservation of Nature (IUCN) red list as threatened and remain in danger by loss of habitat, climate change, pesticide use, threat by parasites, loss of milkweed along the migration path, and illegal logging in Mexico (DOW, 2016).

Image 5: Migration Path of Monarch Butterfly

![Migration Path of Monarch Butterfly](Map Retrieved from TPWD, 2016)

The critical factor regarding population decline in the monarch is the loss of milkweed plant, in addition to other native flora along the migratory corridor. Monarchs require milkweed in order to reproduce, and nectar producing plants in order to sustain themselves throughout their
travels. Studies have shown that monarch females prefer to lay eggs on milkweed by 99% when given a choice between the milkweed and similar vegetation, additionally 60% of the monarch larvae removed themselves from other plants in order to attach themselves to a milkweed (Mattila & Otis, 2003); those that did not reestablish themselves on a milkweed plant were dead within a few days. This shows that the milkweed plays a critical part in the monarch survival and that other exotic or invasive species can become deadly. The milkweed is needed throughout the migratory path of the monarch and can be planted in any rain garden, roadway, natural or green space throughout the corridor. However, the agricultural industry has long reduced the amount of milkweed through various methods including producing “glyphosate-tolerant genetically modified crops” to decrease the amount of milkweed present in fields (Diffendorfer, Loomis, …& Thogmartin, 2013). This loss of potential habitat in cropland has limited the prospective for milkweed to only residential areas and public green spaces. Since monarchs produce several generations throughout their travels, they require milkweed during the entire migratory pathway in order to reproduce and survive.

According to citizen science data collected over breeding seasons, monarchs inhabit a breeding area of nearly 4.5 million km² (Flockhart, Wassenaar, …& Norris, 2013). This makes it difficult for land managers to establish critical habitat for the monarch. This habitat can hold hundreds to thousands of monarchs at one time. They include different types of landscape throughout the United States and vary from region to region. In Texas (See Figure 2: Monarch Habitat Tree Chart), monarchs have been sighted roosting on various types of forest, urban areas, cropland, wetland, grassland, and near open water (Davis, Nibbelink, & Howard, 2012). The only solution is to encourage all states and countries involved in the monarch migration to create space within their region that can host thriving monarch populations, especially those
areas that play a critical role in monarch breeding habits. For breeding the monarch requires milkweed in order for their larvae to survive (Mattila & Otis, 2003). The two vital breeding areas for the monarch are in the Midwest expanse of the United States, and Texas. The Midwest is important due to the significant influence the agricultural industry has over that region. That impact can minimize the use of genetically altered crops to increase milkweed in fields; most of the monarchs that travel to the Midwest originate from Texas, therefore Texas will also need to recolonize spaces with milkweed in order to increase monarch population (Flockhart, et al., 2013). Currently in Texas, land managers are already creating action plans to standardize, restore or enhance already existing potential monarch habitat with native pollinator friendly vegetation into roadways, parks, newly developed landscaping, restored green spaces and waterways, and residential areas (TPWD, 2016).

The monarch migration incorporates a high cultural value through recreational viewing and tourism and is not the only ES provided by the species. Monarchs also fulfill one of the most vital ES roles to the economy, which is that of supporting services. Monarchs help with
pollination of several species of wildflowers and seed dispersal. Without these supporting services, none of the other ecosystem services could function and humanity would lose multiple million-dollar industries and their products. However, due to the difficulty in establishing protected habitat, it is up to partners and collaborative management techniques, in addition to private landowners to ensure the viability of the species. Some studies have shown that 70% of the private landowner population in the United States believe the monarch to be either ‘important’ or ‘very important’ to them and would be willing to pay up to $933 per household to ensure milkweed and nectar producing plants were planted throughout the country (Diffendorfer et al., 2014). If approached to help, private and public landowners would invest financially in order to protect habitat and restore areas for the monarch to thrive and to continue to provide ES to the human population.

**Mexican Free-Tailed Bat:**


The medium sized Mexican free-tailed bat (*T. b. mexicana*) (MFB) is a subspecies of the Brazilian free-tailed bat (*T. brasiliensis*) sporting short black to red fur, big feet, wide ears and a free tail (not connected to the body) (*See Image 6*); they roost in dark spaces closely together in
many southern states including Texas in caves, hollow trees, old wells, buildings, mine tunnels and bridges, only migrating along the Central Flyway back to Mexico when the weather turns colder (TPW, n.d.). They live approximately 11 years, eat mostly insects and have one live pup a year, which is flightless and hairless at birth (TPW, n.d.). These are one of the fastest, highest flying bats in the world; flying at speeds close to 60 miles per hour they can reach heights of up to 10,000 feet (Tuttle, 1994). Their numbers are not at risk of extinction, however they are shrinking due to habitat loss, disruption, pesticide accumulation in their diet, and purposeful destruction of roost areas (TPW, n.d.).

Bats are unique in the habitat they require for survival. Though the traditional cave is still utilized as a roosting spot in many regions, bats have adapted to urban life and are now significantly developing buildings and bridges within city limits into roosting areas (See Figure 3: Mexican Free-Tailed Bat Habitat Tree Chart). Among Texan residents are several of the most abundant bat colonies in the country (See Image 7: Ten Popular Bat Roosts in Texas), one such colony found in the Bracken Cave in Central Texas hosts approximately 20 million bats in one roost (Tuttle, 1994). Out of the 47 bat species found in the U. S. approximately 31 are found in Texas, and MFBs are the most popular in the state (TPWD, 2007). It is found that typically the maternity MFB colonies inhabit the caves, while the bachelors gather in buildings and bridges. Two bridges in Texas are famous for housing MFB, one is Congress Avenue Bridge in Austin and the other is I-35 and Camden bridge in San Antonio have two of the largest bat colonies to inhabit a bridge. Studies show that bats occupy bridges that are close to bodies of water, and mostly in the warmer months while very few remain throughout winter; additionally, bridges that have construction similar to caves where the bats can hide within narrow spaces are utilized more than various other bridge designs (Geluso & Mink, 2009). It is difficult to determine the
amount of habitat needed for a single MFB because each individual bat can fit into such a small, narrow area it is obsolete to try and determine individual habitat requirements.

Bats are some of the best ES providers in the animal kingdom by providing ES services in each of the four categories. Their services range from cultural and recreational services in regards to tourist opportunities, photography enthusiasts, education opportunities, and
celebratory events to supportive services through pollination and pest control; MFB are insectivores and can travel up to 50 km from their roosting sites and provide an annual $11.67 million service to the cotton industry alone (Wiederholt, et al., 2014). Overall, bats in general provide provisional services through the propagation of multiple species of flowering plants and fruits, which includes three major commodities: agave, cotton and coffee.

Even guano is beneficial to man in the form of fertilizer, and beneficial bacterial that can be utilized in insecticides, breaking down of industrial waste and possible sources for new antibiotics (Tuttle, 1994). However, bat habitats are specifically susceptible to disturbances, vandalism, urban sprawl, disease, pollution, and reduction of food supply, because anything that affects the habitat or even one bat will spread to the entire colony (Weiderholt, Lopez-Hoffman, …& Semmens, 2013). To date, the harvesting of guano has disturbed many bat colonies to the point of them abandoning the roost. Conservation efforts are working to protect the major roosts around the country from disturbances and vandalism. Texas is one of the main states that benefits from the ES that bats provides because it holds the top four highest scoring roosts that preserve the diversity of ES and provide significant financial gain to the surrounding urban communities (Wiederholt, et al., 2014). Despite their significant contribution to society the bats in Texas have had to overcome considerable challenges and will continue to push through more.

II. LITERATURE REVIEW:
Managing LID, ER and ES requires not only the understanding of the creatures that will be impacted by these processes, but also how they fit into the bigger picture. In order to discover much of this data, multiple studies were reviewed to compare the various data of other scientists. The following literature review will outline the different types of studies evaluated in this paper: there will be a review on the importance of biodiversity, the struggles of one
endangered species, how urban ecology is beneficial to migrating pollinators, and how vital ecosystems can support life within highly urbanized landscapes. Overall, there was a total of 30 articles reviewed specific for each species mentioned above; the following few where chosen specifically because they tied into either ER, or LID by either mentioning landscape restoration, or increasing biodiversity through native vegetation. Each of these articles will help understand the unique challenges each of these species face within a metropolitan area and help realize how simple steps to improve municipal landscapes within all areas of a city can make significant differences in survival of wildlife. The rest of the articles are listed in Appendix A, B, and C (See Appendices page 68).


This first article shows how biodiversity is a vital factor affecting extinction and climate change. In their article “Operationalizing biodiversity for conservation planning”, Sarkar & Margules (2002) argue that if biodiversity could be defined quantitatively, then it can be utilized as a primary factor in conservation planning. The authors begin with a historical review of how biodiversity has been viewed by scientists and managers. Viewing biodiversity historically is important since many development managers view conservation planning through history in order to achieve the same results or something better. After its coining in 1996, the term biodiversity has been utilized decisively in scientific journals and textbooks and has become a key goal in environmental health (Sarkar & Margules, 2002). The authors further review the difference of biological diversity, integrity and stability, explaining that each have a
relationship’ with the others. Sarkar & Margules (2002) explain that understanding the relationship of each species including the spatial (ecosystems) and taxonomic (genetic) ‘hierarchical’ bonds associated with each species is imperative to creating an effective conservation plan. This relationship can be extended to include ecosystem restoration and LID planning, since each of these is part of the hierarchical bonds mentioned in this article.

Biodiversity on its own is not an easy concept to understand. By the authors defining it in specific terms, it brings a whole new light to how biodiversity is viewed and allows it to become scientifically attainable. The authors then go into a few biological examples of this concept including migratory monarchs and African wildebeests, however they also stress that it is not necessarily the species that live on the land that make up biodiversity but the place that is the key. Without a place for biodiversity to exist, there cannot be any biodiversity. This is why conservation planning is so important, because it will preserve the areas, the landscapes, and the aquatic environments that breed biodiversity.

At this point in the article it explains the traditional methods in determining or prioritizing how to protect diverse places. Sarkar & Margules (2002) explain why it is a mistake to protect a place based solely on richness to humanity. If conservation planning only preserved those areas that are rich in resources, then only similar places are protected and diversity will not be obtained. Furthermore, richness by definition is not diversity, which means ‘different’ or ‘not the same’ (Sarkar & Margules, 2002). Biodiversity is the variance of individual and unique species from multiple places. The article takes the definition of biodiversity one step further by including the basis for a quantifiable algorithm that will prioritize landscapes for conservation planning by incorporating true and estimator surrogates that involve: character diversity, species diversity, landscape pattern, species richness, environmental parameter composition, vegetation
type, species composition, and genus/taxon composition (Sarkar & Margules, 2002). Though the article never actually tests the algorithm, it is a scientifically viable index in which to base biodiversity for managers.

As the authors went through their explanation of biodiversity, their arguments were sound and logical. The one thing that stood out most was the declaration that biodiversity needs to start with a place. Without a landscape in which to have life, then there can be no life. Biodiversity relies on a ‘place’ in which to exist. This is an important key concept, because as conservation managers plan out areas for restoration or preservation, they can see that all areas have the potential to accommodate biodiversity. One of the benefits of LID technology is that it can be established in practically any landscape, and one of the key components of an ecosystem restoration project is the location. If the landscapes are developed in ways that promote natural functions of the environment, then biodiversity can exist anywhere. In the following articles, it will show how urban ecology affects various migratory animals and ways to reap benefits from urban landscapes.


Managing the wild population of the whooping crane is a difficult task and has been ongoing since their near extinction in the early 1940’s. In their article, “Influence of whooping crane population dynamics on its recovery and management”, Butler, Harris & Strobel (2013) explain their methods for monitoring the whooping crane population and how it can be
determined to estimate possible declines in the future. There is only one wild whooper population in the nation and it migrates from Wood Buffalo National Park in Canada to Aransas National Wildlife Refuge off the Texan coast in the USA (Butler et al., 2013). According to the authors, the traditional method of management practices for this endangered species consisted of methods that were the result of reactions rather than long-term plans. These included a captive breeding program that consisted of removing one egg from each nesting pair of whoopers, habitat protection and restrictions on hunting. The article (Butler et al., 2013) follows the breeding program through 32 years, monitoring both negative and positive growth progression, flock influences from egg removal and reintroduction of juveniles, and the changes present after protection. Their methodology included mathematical equations to predict the possibility of extinction and dynamic patterns in population increases or decreases. This is a very logical and sound way to determine population changes in wildlife and allows for precise calculations that can be repeated.

After a small inclusionary description of the habitat the authors explain the autoregressive integrated moving average (ARIMA) model used in calculating the fluctuations within the whooping crane population and they found a very cyclic pattern similar to normal population variations (Butler et al., 2013). They utilized four other models to compare results of egg removal and juvenile reintroduction and brought in a simulation factor to predict future alterations in population density. The study showed a positive shift in population growth over the course of 73 years with various negative growths appearing approximately every 10 years (Butler et al., 2013). This is similar to normal growth patterns associated with any species where the negative factors are attributed to other environmental stresses such as habitat
restrictions, negative food supply, or ramifications from water quality issues, instead of from egg removal or other recovery efforts.

Butler et al., (2013) explain that their methodology has several applications that can benefit management of the whooping crane; for instance, future land restoration goals can be based on future predictions of the whooper population and proper planning can be implemented at the most opportune time. Additionally, managers can predict normal population declines and be prepared if and when more extreme losses occur. Another advantage of simulating future population levels allows conservation planners to anticipate need and make necessary changes or restoration requirements as needed. Restoring natural areas take time in order for normal vegetative growth to occur, managers will now be able to create needed plans for restoring landscapes that can benefit the whooping crane recovery efforts. However, environmental stresses such as disease, natural disasters, and pollution contamination are more difficult to predict and were not included in the author’s simulations. Though these are more burdensome to predict, it is still a major part of population dynamics and could have an effect on future population density. The authors realize this fault in their study and state in a disclosure that if this does occur that management will need to reevaluate the population at the time of the stressor.

This article is very well written and based on scientific facts and sound mathematical calculations. It covers a whole range of factors that affect the whooping crane population and allows for the authors to argue their point that the whoopers can and will recover from near extinction with proper management and environmental planning. It also specifically mentions that eco-restoration of landscapes can be tied to the projected recovery target numbers (Butler et al., 2013). This information can be processed to champion for the restoration of ecosystems and
usage of LID techniques in residential areas. Much of the uncertainty surrounding the future population goals of the whooper is based around unknown environmental stressors. If managers can minimize those unknown factors by planning to prevent them through ecosystem restoration then the future population of the whooping crane will have a much better chance of recovery.

In the article “Enhancing monarch butterfly reproduction by mowing fields of common milkweed” (Fischer, Williams, ...& Palmiotto, 2015), the authors show the importance of milkweed to the monarch population and how to manage and increase milkweed in order to expand on monarch reproduction. Due to loss of habitat and food supply (mainly milkweed), the monarch butterfly is diminishing in numbers and are unable to complete their migration route creating an “endangered biological phenomenon”, meaning that the migration of the monarch is in danger of becoming extinct (Fisher et al., 2015). This is important to mention because the monarch migration is a beautifully, unique event that is beyond any other migrating species, in that it takes four generations to migrate North and only one generation to migrate South.

The authors begin by describing their study area in the New York region; they utilized two fields of milkweed to mow down at various intervals throughout the monarch migration season and to monitor the plants for overall plant health, number of monarch eggs and monarch larvae. Fisher et al. (2015), uses three different methodologies to analyze their data which included ANOVA, Kruskal-Wallis, and SPSS; with these analogies, they found that the earlier
cut of milkweed was able to respond and grow to control heights much easier than the second cut of milkweed made later in the season. They found that while the control plants were withering and dying, many of the cut plants were still in full bloom at the end of the study period. The authors found similar results with the monarch egg density by the end of the study. Fisher et al., (2015) showed that monarchs utilized the cut milkweed much more than the control milkweed; by the end of the season there was 10 times more monarch eggs on the later cut of milkweed than even the earlier cut indicating that monarch’s seek out healthier, younger plants. It is vital to realize that the longer the growing season of the milkweed concludes a similar increase in egg laying in monarchs.

Fisher et al., (2015) make a point to stress that not all milkweed plants will respond such as these found in New York; other species found throughout North America may not regrow at the same rate or even at all with controlled cuts or burning at the same time periods. Each milkweed species needs its own scheduled cutting period, which will need to be discovered by managers. Furthermore, the authors explain that additional milkweed habitat is already present in all areas of the monarch migratory path in the form of highway roadsides, medians, unused farms and fields which could result in an extra 40 million increase in monarch population (Fisher et al., 2015). It can be concluded that by utilizing rain gardens as a LID developmental method in residential areas for potential milkweed habitat, it can also increase population sizes.

The author’s arguments are logically found through proven scientific methods and have accurate conclusions based on facts discovered in the study. The authors see the potential in exploring other areas for monarch breeding, seeing habitat in places that are not typically thought of as habitat area like roads and medians. This is crucial because many of these same areas can be utilized by other species as potential habitat. However, there is the extra danger of vehicle
damage and wildlife deaths, which are not mentioned in Fisher et al. study. This thesis wants to focus on safer regions to create habitat relying on non-traditional areas such as residential gardens, parks, and green spaces that can be modified, restored and used by wildlife to connect fragmented urban landscapes while at the same time increasing beauty and water quality for the human population. This article shows how easy it is to create extra habitat with proper management of the native vegetation and how it can benefit a migration route that is in peril. It is important to understand that if natural spaces are created then wildlife will utilize them to the best of their abilities.


In this article “Use of spatial features by foraging insectivorous bats in a large urban landscape”, the authors Avila-Flores & Fenton (2005), utilize scientific techniques to measure how various bat species hunt in the busy city of Mexico City, Mexico. The authors begin their study by describing the fragmentation of urban landscapes and how it negatively affects biodiversity and species richness. This article links to the first article in this literature review in that it focuses on the variances in species in a certain area, and the importance of allowing for biodiversity to thrive. The research set out to find why some species of bats have a higher success rate in hunting and roosting than others do in an urban setting, but ended up showing how much bats create a service for urban areas by doing exactly what they need to instinctually.
For their control they observed 12 natural sites in various areas outside of Mexico City, while the test site covered four sites of three (12 total) different urban habitat which included: large parks, small parks, artificially lighted open areas, and highly populated sites (Avila-Flores & Fenton, 2005). The four various urban spaces observed in this study is vital in showing how bats help control insects even in areas that are not naturally similar to their regular habitat. The author’s monitoring methods utilized “acoustic sampling” and BatPro Soundware to analyze ANOVA variations which determined bat activity; the deviations detected in the sounds showed type of species and whether the bat was eating (Anila-Flores & Fenton, 2005). Each sound made by a certain species had a different sound range and pitch that indicates its activity at the time. Additionally, the authors indicated insect population in an area through “photographic trapping” where a ‘blacklight’ trap was placed and a camera took periodic flash pictures in order to capture and count the number of insects. The methodology utilized in this study is unique due to the difficulty in observing insects in a nighttime setting.

Anila-Flores & Fenton (2005) identified a total of 7 bat species (through these methods listed above) within Mexico City and in the more naturally forested control space; however, large parks had nearly one and a half times less groups of bat species than the forested control area and with large parks showing the highest average of insects than even the control group. These results are interesting in that one would think that the control group would have more bat species as shown by the results, however that would also lead thoughts to believe these same natural areas would have more bats, even though there is not. Consequently, the total amount of bats foraging was positively related to the number of insects present in the study site (Anila-Flores & Fenton, 2005), so even though there were more taxon of bats present in the natural control area, the large parks had a greater number of certain bat species present at any
given time. This study suggests that certain taxon of animals avoid areas of high urbanization thereby limiting the biodiversity in the urban area. The authors conclude that as urbanization increases then the number of bat diversity decreases unless there is sufficient habitat present to support various species: Anila-Flores & Fenton (2005) recommend green, well vegetated areas in order to enhance insect populations around the city and habitats such as bridges and crevices along buildings to increase bat habitat and activity within an urban area.

The authors used sound scientific methods to gather evidence and come to conclusions on all their data utilizing the same methods. Avila-Flores & Fenton (2005) evaluate their results and conclude that many of the species that were not present in the urban spaces because of limitations in flight abilities or limitations to echolocation capacity. This is a logical conclusion for some variances in data gathered, since not all bat species have the same abilities. If the animal moves too slowly, or has limited echolocation, then the human population has a chance to capture, interrupt, or injure the bat. As mentioned above, the authors recommend an increase of green, well-vegetated areas. This data relates to this paper because as more LID methods are used such as bioswales, or rain gardens in local urban areas than it increases biodiversity and species richness for all wildlife including bats. Additionally, bats forage and eat insects, which is a huge problem in many urban green spaces. As more habitats are made available for the bats to forage, as education about bats is increased, than awareness of the importance of bats and biodiversity to society will increase.

There is an immense pattern that is interlaced within human society and wildlife. The literature reviewed here outlines the distinct types of influences that can be found within an ecosystem and how they interact with each other. The reviews observed above are just a few examples of how wildlife population numbers rely on key habitat located within an urban
The article above mentions that the fluctuations within the whooper population can be attributed to mainly water quality issues, which can be fixed through proper planning and the utilization of ecosystem restoration methods along the watershed, because all urban, suburban, and rural areas along the San Antonio River watershed affect the whooping crane. Bats contribute billions of dollar’s worth of pest and pollination services to the communities in which they reside. If there were more natural rain gardens or bioswales it would produce foraging habitat for the bats in the local area. Monarchs are a dwindling environmental event. The loss of so much suitable habitat for milkweed has created a crisis in which the monarch is having difficulty recovering from. The use of LID methods along roads, medians, green spaces, and residential yards will allow appropriate habitat in which the monarch can breed and gain energy for their long flight.

III. THEORETICAL FRAMEWORK/APPROACH

The 30 peer-reviewed articles reviewed for the literature review were also evaluated to determine how many of those studies recommended LID or ecosystem restoration as a possible solution in their research. Much of the urban developmental world argue against LID and ER for numerous reasons such as cost involved in initial setup and maintenance, and no positive financial outcomes (Groot et al., 2013). This study will attempt to see if current scientific data for LID and ER is sufficient to promote these techniques as a standard method of development or if there needs to be more studies done in order to prove the ecological, economical and physical worth of LID and ER. Each article was reviewed and summarized on a table for each species to see if each type of developmental technique was mentioned as a recommendation (Appendix A, B, & C). The U. S. Fish and Wildlife Habitat Sustainability Index (HSI) expanded upon data
extrapolated from the literature reviewed and a modified environmental analysis was
developed.

An HSI model evaluates the basic life facts of a species, utilizes the total area of coverage
utilized by the species, and the magnitude of the habitat’s ability to support that species, where
optimum habitat is equal to 1.0 and where 0.0 is considered inhabitable (USFWS, 1981).

\[ \text{HSI} = \frac{\text{Study Area Habitat}}{\text{Optimum Habitat}} \quad \text{or} \quad \text{HSI} = \frac{\text{Existing Model Output For Area Of Interest}}{\text{Defined Standard of Comparison}} \]

HSI is not a ‘restrictive’ equation (USFWS, 1981) and can be utilized for multiple aspects to
show the linear relationship between the amount of dual-functioning habitat and migratory
species population levels in the region; even basing the suitability index model on general
statements in literature is feasible for this model. According to U. S. Fish and Wildlife Service
(USFWS, 1981), the diversity of the model allows for general descriptions of the Defined
Standard of Comparison such as ‘excellent’, ‘good’, ‘average’, and ‘below average’ to be
converted to specific numbers as seen below (See Table 1: Defined Standard of Comparison).
It can also utilize a combination set of statements that uses averages or generalized information on
the habitat and convert it into graphical form in order to depict the HSI of the species. This
paper will apply a form of this part of the HSI model in general descriptions.

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<th>HSI Value</th>
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<td>Excellent</td>
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<td>1.00</td>
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</tr>
<tr>
<td>Below average</td>
<td>1</td>
<td>0.25</td>
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(USFWS, 1981)

The first phase of the model used in this research involves creating a tree diagram instead
of the mathematical equation listed above, and then utilizing that generalized data into a
graphical representation of the HSI. For example, the whooping crane tree diagram includes two types of habitat where area requirements are specified: nesting and wintering, data collected from literature indicates optimum habitat needed for the species and is written out in the diagram (Refer back to Figure 1: Whooping Crane Habitat Tree Chart page 22). The versatility of this model allows for general descriptions of the habitat to be documented in a graph form to represent the HSI for each species (USFWS, 1981).

In this model, defining the variables includes deriving optimum habitat capacity for three migratory species; the MFB, the whooping crane and the monarch butterfly within the boundaries of Texas from the literature reviewed earlier. Each of these species will have a graph or two associated with the amount or type of optimal habitat required for survival. Two of the species, the monarch and MFB have general descriptive graphs because it is unfeasible to verify the exact amount of space required for each animal due to the small size of the creature and population numbers. As a result, graphs were designed through generalized statements gathered from the data in the literature reviewed. In order to depict the HSI the following table was used as a reference to create the graph (See Table 2: Defined Standard of Comparison for the Monarch and MFB), this table will be used instead of the Defined Standard of Comparison and opposed to measured numbered data on the “standard of comparison” and the “existing model output for the area of interest” (USFWS, 1981). The use of tables shows how the numerical rank is derived and converted into the model. The HSI graphs are a derivative for existing land use according to type or size that was determined for each species, and will be explained using word descriptions from the graph being represented.
IV. RESEARCH DESIGN/METHODOLOGY:
Research is conducted through the evaluation of numerous peer reviewed journal articles, state and federal websites, conservation websites, and library databases including ProQuest, and Jstor. These evaluations of the literature are for each species designated in this paper and for LID, ER and ES as mentioned in this paper. Searches were focused by utilizing keywords: whooping crane, Mexican free-tailed bat, monarch butterfly, urban, development, ecosystem, restoration, services, water quality, migratory, species, habitat, critical, LID, landscape, economic value, pollinators, flyways, GIS, canopy cover, population and Texas.

The evaluation of the literature concentrated on articles and studies that mostly involved the human impact on migratory species in general, and ways to develop landscapes more sustainably. The literature was charted according to reference, dates of study, peer reviewed status, sample location on the central flyway, number of samples indicated, LID or ER mentioned in study, demographics of location, existing habitat of study, type of study, method of study, results of study and recommendations of study. A detailed literature review of four articles was accomplished by reviewing an article on biodiversity, one on whooping cranes, one monarch butterflies and one on Mexican free-tailed bats. Comparisons were made between the existing habitat and potential habitat of LID and ER. Patterns were observed in more specific areas such as if LID or ER was indicated in the study, and the existing habitat already present in

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the study area. These patterns were regarded in more detail through the HSI analysis of this report.

Issues involved in this type of study are the loss of actual data. Most data accumulated is done through other sources. It is possible any error margins associated with those resources are also indicated in this research. Furthermore, time constraints associated with data collected was limited. A study such as this would need more time than just the 16 weeks allowed compiling and evaluating the data. Additionally, the number of species chosen for this project was a bit ambitious and could have also been cut down to maybe one species in order to utilize time more efficiently. More time and less species would provide opportunity for more detailed research to be completed in addition to possible actual measurements of various local landscapes. Furthermore, there is a learning curve involved with the use of the HSI model analysis. However, the literature findings and logical correlations found between LID, ER, wildlife and the human race were found to be proven on a daily basis through the literature where these types of strategies are utilized as part of a landscape development plan. The initial results of any successful ER or LID project shows how wildlife and migratory animals have established themselves within the area regardless of the surrounding urban environment. More specific studies are needed in these areas to indicate the positive influence of these types of land development techniques.

V. FINDINGS/RESULTS/DISCUSSION
This paper attempted to show how usable habitat in Texas for the following migratory species, the whooping crane, the Mexican free-tailed bat and the monarch butterfly would increase within urban communities through the utilization of LID and ER land strategies. Additionally, this paper endeavored to show the importance of migratory ES that
connect the natural world to the human population. Working through the HSI model showed the various ways in which literature data could be viewed in the scientific world. Out of the initial 30 articles reviewed for this paper, only 3 out of 10 from the whooping crane articles, 3 out of 10 for the monarchs and 2 out of 10 for the MFB indicated LID or ER as a solution to recommend for improved habitat quality (See Figure 4: Articles Reviewed). This amounts to about 27% out of the total articles that show a correlation between habitat improvement and LID or ER. This number could be low for various reasons: LID and ER is not as prevalent as a solution as it needs to be, it is not well known enough to be used or thought of to be sufficient for improving wildlife habitat, or not enough articles were reviewed to gather a reasonably complete study sample. These results were surprising considering the benefits derived from utilizing LID and ER strategies in land management.

Moving on to the HSI model, much data was garnered regarding habitat requirements for the various focus species. Findings indicate that each one of these species can benefit from the widespread utilization of LID or ER techniques. The whooping crane requires specific land requirements and good water quality for both nesting and wintering grounds. Both its food supply and health of its young depend on good quality water at is migrating sites. Nesting areas
for the whooping crane pair is so diverse it is difficult to have a sufficient HSI for a nesting bird (See Graph 1: HSI for Whooping Crane Nesting Sites). Nests can average between 1.3 to 47.1 km² of land (Travsky & Beauvais, 2004), which can be nearly four times that of the wintering grounds required for the crane. The use of strategic ER plans along the nesting sites of the whooping crane such as those implemented along the Texas coast at Lavaca Bay (Cathey, 2007), could be the only way to establish more space for the whooper as its population numbers increase. According to Cathey, (2007), restoration efforts at Lavaca Bay established nearly 730 acres of wetlands and 70 acres of marshland that will become part of the ANWR territories. This land can grow and improve as the whooping crane population increases, and contributes to the amount of space required per wintering family. According to the graph (See Graph 2: HSI for Whooping Crane Wintering Territories Per Pair/Family), the HSI for 117 ha is equal to 1.0 for a whooping crane wintering group; so ideal habitat space per group is 117 ha or about 289 acres. However, if the one ER project already established in Lavaca Bay only produces approximately 800 acres (730 plus 30) of habitable land, that converts to approximately 324 ha and will only result in the landscape being able to support a maximum of maybe 3 whooper pairs/families, which is a minimum of 6 more birds. Though it seems to be an insignificant amount, it still...
proves that ER can produce habitat for the migrating whooping crane. If other areas along the Texan coast incorporate ER into restoration efforts, it could produce additional usable habitat for the whooper and other migratory species that utilize coastal landscapes.

**Graph 2: HSI for Whooping Crane Wintering Territories Per Pair/Family**

Wintering requirements for whooping crane in hectares (ha), one territory averages 117 ha. Data collected from (Travsky & Beauvais, 2004).

The monarch and the MFB both require specific habitat, but not necessarily habitat that can be measured by conventional means. Due to the nature of the species, it is not possible to determine the exact amount of space required for one monarch or one MFB, because each of these species lives in massive groups that usually travel together and utilize multiple aspects of the same habitat. In other words, exact distance is not a factor as opposed to type of land and quantity available of each type of landscape feature. For this reason, the HSI was modified to accommodate general statements instead of the defined standard of comparison. According to the U. S. Fish and Wildlife Service (1981), studies can base a ‘suitability index’ graph on general statements that measure abundance, where the HSI of 1.0 is assigned to the “maximum observed abundance” and other variables are designated accordingly. This study developed a chart to indicate which numbers are considered ‘maximum observed abundance’ for the MFB and the monarch and will be referred to as the ‘numerical rank’ (Refer back to Table 2: page 39).
graphs developed for each species is derived from literature data regarding overall habitat
requirements for each species in Texas.

According to citizen science reports in Davis, Nibbelink, & Howard (2012), monarchs
seen throughout their migratory region were observed for what type of landscape feature they
roosted on the most. This data was categorized by scientist designated flyway zone regions, in
which Texas included zones 3, 4, and 5 (Refer back to Figure 3, Monarch Habitat Tree Chart
page 25). The average of those three zones was calculated to determine the numerical rank of
each landscape feature (See Table 3: Average Number of Monarchs Per Type of Land Cover).
The data shows that cropland by far exceeded all other landscape features in regards to monarch
roosting areas during migratory periods. This data was then converted into graph form to
visualize the HSI of each landscape feature depicting cropland equal to 1.0 HSI or having the
‘maximum observed abundance’ (See Graph 3: HSI For Monarch Migration Habitat).

<table>
<thead>
<tr>
<th>Type of land cover</th>
<th>Flyway Region</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous Forest</td>
<td>5.9</td>
<td>4.3</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>18.1</td>
<td>17.5</td>
</tr>
<tr>
<td>Cropland</td>
<td>40.7</td>
<td>47.5</td>
</tr>
<tr>
<td>Grassland</td>
<td>15.1</td>
<td>17.9</td>
</tr>
<tr>
<td>Urban</td>
<td>7.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Wetland</td>
<td>5.8</td>
<td>5.5</td>
</tr>
<tr>
<td>Open Water</td>
<td>3.9</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Data Collected from (Davis, Nibbelink, & Howard, 2012)
Cropland is the ideal habitat for the monarch butterfly during migration with a HSI of 1.0, however cropland is only idyllic due to the historical amount of milkweed that was present on the land. In the past milkweed was commonplace throughout the Midwest. Currently cropland is being affected by the genetically altered crops utilized by the agricultural industry, which decreases the amount of milkweed in the fields (Davis et al., 2012). Additionally, cropland is being fragmented as urban communities spread out into agricultural areas. As milkweed is decreased so is the monarch population since they depend almost solely on milkweed to reproduce. A plan to decrease the amount of future impervious surfaces within the state should become a priority in order to maintain prime milkweed habitat. By growing milkweed in other areas, such as urban landscapes, rain gardens, and roadway medians, it can increase the HSI of various landscape cover and in turn increase the monarch population. As mentioned before, LID strategies along residential and business landscapes can be utilized as prime milkweed potential since it involves growing native plants as part of the design. Even LID practices along farmland borders such as bioswales can be implemented as monarch or pollinator habitat.

Since calculating specific size of monarch habitat is not feasible, the average percentage of land used by migrating monarchs in the Texas flyway region gathered by citizen scientists was used to interpret the HSI. Data retrieved from (Davis, Nibbelink, & Howard, 2012).
The MFB is the one migratory species that seems to thrive in an urban environment. The species was observed in various roadways and urban landscape features within a Texan city, and the results show the multitude of spaces that a bat can occupy (See Table 4: Percent of Bats Observed in Urban Designations).

<table>
<thead>
<tr>
<th>Type of Road</th>
<th>Percent of Bats Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway</td>
<td>5.6</td>
</tr>
<tr>
<td>Major</td>
<td>19.9</td>
</tr>
<tr>
<td>Local</td>
<td>68.5</td>
</tr>
<tr>
<td>Private</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Land</th>
<th>Percent of Bats Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Med/High Density Residential</td>
<td>6</td>
</tr>
<tr>
<td>Commercial</td>
<td>8.8</td>
</tr>
<tr>
<td>Low Density Residential</td>
<td>48.1</td>
</tr>
<tr>
<td>Mixed Use</td>
<td>29.2</td>
</tr>
<tr>
<td>Public</td>
<td>6.5</td>
</tr>
<tr>
<td>Industrial</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Data Collected from (Li & Wilkins, 2014)

The tree chart indicates the typical habitat desires of the MFB indicating how easily a bat can adapt to any small space or crevice (Refer back to Figure 4: Mexican Free-Tailed Bat Habitat Tree Chart page 28). Each of these shows the vast capacity of the bat and its ability to maneuver and adapt within small areas. Many times the residents of these places do not even know that bats are present or near them. Since bats occupy urban areas for habitat it is important to distinguish the types of urban landscapes in addition to the types of roads associated with each
area. For this reason, two HSI graphs were created showing type of landscape and type of roadway. The first graph (See *Graph 4: HSI of Mexican Free-Tailed Bats Near Various Urban Landscapes*) shows low-density urban landscapes to have a HSI of 1.0 making it the ideal area for MFB’s to occupy. The second graph (See *Graph 5: HSI of Mexican Free-Tailed Bats Near Various Urban Roadways*) indicates that with a HSI of 1.0, local roadways were more popular with MFB’s.

**Graph 4: HSI of Mexican Free-Tailed Bats Near Various Urban Landscapes**

<table>
<thead>
<tr>
<th>Suitability Index</th>
<th>Med/High Density</th>
<th>Commercial</th>
<th>Low Density</th>
<th>Mixed Use</th>
<th>Public</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
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<td></td>
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<tr>
<td>0.8</td>
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<tr>
<td>0.6</td>
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<td>0.4</td>
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<td>0.2</td>
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</tbody>
</table>

Percent of bats observed near or in urban areas according to type of landscape/usage.  
Data Collected from (Li & Wilkins, 2014)

**Graph 5: HSI of Mexican Free-Tailed Bats Near Various Urban Roadways**

<table>
<thead>
<tr>
<th>Suitability Index</th>
<th>Highway</th>
<th>Major Roadway</th>
<th>Local Roadway</th>
<th>Private Roadway</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td></td>
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<tr>
<td>0.6</td>
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<td></td>
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<tr>
<td>0.4</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Percent of bats observed near or in urban areas according to type of roads nearby.  
Data Collected from (Li & Wilkins, 2014)
Ideally, low-density urban landscapes that are near local roadways are the best type of habitat for the MFB, however they can also roost in areas where the human population is more prevalent such as mixed use and major highways. This is because of the unique ability for the bat to manage into small crevices to roost, making large bridges and tall buildings also ideal for this animal. The key for the bats survival is food supply. Without sufficient natural landscapes, or native vegetation within the surrounding areas of the roost, then the bat could not live in that area. However, some bats such as the MFB are able to forage great distances sometimes traveling about a 50 km diameter range, and while foraging they can eat on average 11 types of insects providing pest control to many agricultural areas (McWilliams, 2005). The loss of native lands to impervious surfaces has caused the bat to risk foraging at street lamps, which puts them at risk to predation and injury by motorists (Li & Wilkins, 2014). However, the use of LID strategies throughout the urban landscapes will connect natural areas in such a way as to allow the bat to forage without disturbances or injury. Insects will exist in all natural areas that do not use pesticides, which have been linked to MFB population decline; by utilizing strategies that focus on protecting the landscape through native vegetation will also protect the MFB (Weiderholt et al., 2015).

Preliminary findings indicate that migratory species are on the decline throughout Texas due to increased human development, pollution, habitat loss and fragmentation (Reidy, Thompson & Peak, 2009). It was found that LID and ER techniques are not used as much as could be in order to enhance the livelihood of people and increase survivability of wildlife. The population is sprawling out and altering natural landscapes indefinitely, however if developers can establish habitat simultaneously as they are establishing urban communities then both life systems can be preserved for generations. The use of LID and ER land strategies during
development of urban areas can improve much of what is being lost during the increased use of impervious surfaces. By developing landscapes naturally, utilizing what nature provided, and combining it with modern technology many species can improve and flourish in an urban environment. Additionally, these methods will improve water quality and increase water quantity through accelerated infiltration into groundwater.

Whether it is a bird, butterfly or bat, factors such as habitat loss influence how a species will survive and for how long it can exist in the area. Both the MFB and the monarch require very specific food sources in order to survive, while the whooping crane’s needs are met more through how much space it has to nest and breed. Each of these animals have adapted in many ways to human development, and yet still maintain the vital ES they provide. Such services deliver to the human population opportunities, products and amenities. Migratory species such as these are especially prone to environmental changes because they require so many different landscapes along their paths towards their winter or summer grounds, yet they also are some of the most productive animals in the amount of ES that they provide. LID and ER are ideal ways to develop urban landscapes throughout these migratory pathways to keep uninhabited and natural areas in a more natural state allowing for utility by wildlife, increased ES through improved water quality and quantity, and a more visually appealing landscape. This study only scratched the surface of how vital LID and ER can be to the human population. More scientific evidence is needed to show how deep the connections LID and ER can have within the community and how it can affect the surrounding wildlife.

The studies that are presented today have only initiated the possibilities of these unique, and functional developmental methods and more research is indicated in order to create a more positive correlation between humans, LID, ER and wildlife. However, in order for more
research to occur, more projects that involve LID and ER need to be accomplished on a larger and smaller scale; this includes industrial, business, and residential projects. The unique characteristics of LID and ER are that much of what can be accomplished can be done so before and after land development has occurred; the results are easy to maintain and are visually appealing in addition to being biologically sustainable. The establishment of regulations to increase the use of these techniques or the creation of incentives to utilize sustainable land strategies are viable solutions to increase the likelihood of creating sustainable landscapes however, the need for these regulations will not be seriously considered until much further in the future. The logical conclusion is to create knowledge of land management practices through public education in order to encourage the creation of positive sustainable habitats that unique traveling species can utilize and local residents can benefit from and which will sustain all forms of life.
VI. REFERENCE LIST


http://www.netstate.com/states/symb/mammals/tx_mexican_free-tailed_bat.htm


Operation Migration, (2016). The whooping crane. Retrieved from  
http://www.operationmigration.org/the-whooping-crane.asp


http://www.sanantonioriver.org/proj_benefits/benefits.php


Texas Parks and Wildlife Department, (2007). Bat watching sites of Texas. TPWD Clearinghouse PWD BK W7000-1411(05/07). Retrieved from [https://tpwd.texas.gov/publications/pwdpubs/media/pwd_bk_w7000_1411.pdf](https://tpwd.texas.gov/publications/pwdpubs/media/pwd_bk_w7000_1411.pdf)


## VII. APPENDICES

For all appendices: PR=Peer reviewed; OBSV=Observatory; MFB=Mexican free-tailed bat; WC=Whooping crane. Appendix A.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Dates of Study</th>
<th>IS IT</th>
<th>PR</th>
<th>Sample Location on Central Flyway</th>
<th>Number of Sample Areas</th>
<th>LID or ER</th>
<th>Demographics of Location</th>
<th>Type of Study</th>
<th>Methods of Study</th>
<th>Results of Study</th>
<th>RECOMMENDATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novak et al. (2009)</td>
<td>2005, late May to late August</td>
<td>Yes</td>
<td>Yes</td>
<td>Mexico City, Mexico</td>
<td>24</td>
<td>Yes</td>
<td>Dense Urban</td>
<td>OBSV</td>
<td>Used light photographs and field observations to determine number of species present</td>
<td>Increased residence time required; proportion of total nights occupied by bats</td>
<td>Promote bird watching and interpretive programs in urban landscapes with more vegetation and bat habitat.</td>
</tr>
<tr>
<td>Oksendal &amp; Scher (1994)</td>
<td>1996-1998</td>
<td>Yes</td>
<td>Yes</td>
<td>South Texas</td>
<td>6</td>
<td>No</td>
<td>Mixed Urban-Suburban Rural</td>
<td>Censuses, Biological Surveys</td>
<td>Population densities of bats are significantly lower in urban areas than in rural areas.</td>
<td>More research is needed to determine the impact of urbanization on bat populations.</td>
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<tr>
<td>Geen &amp; Mack (2003)</td>
<td>April 2000 to March 2006</td>
<td>Yes</td>
<td>Yes</td>
<td>Redlands Valley</td>
<td>37</td>
<td>No</td>
<td>Mixed Urban-Suburban Rural</td>
<td>OBSV and Censuses</td>
<td>Visually identified species and counted</td>
<td>Bats are more common in suburban areas than in rural areas.</td>
<td>More research is needed to determine the impact of urbanization on bat populations.</td>
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<td>Bailey et al. (2001)</td>
<td>1990-2000</td>
<td>Yes</td>
<td>Yes</td>
<td>Southeast U.S.</td>
<td>8</td>
<td>No</td>
<td>Mixed Urban-Suburban Rural</td>
<td>OBSV and Censuses</td>
<td>Visually identified species and counted</td>
<td>Bats are more common in suburban areas than in rural areas.</td>
<td>More research is needed to determine the impact of urbanization on bat populations.</td>
</tr>
<tr>
<td>Rosier et al. (2015)</td>
<td>N/A</td>
<td>Yes</td>
<td>Yes</td>
<td>North America</td>
<td>N/A</td>
<td>No</td>
<td>Mixed Urban-Suburban Rural</td>
<td>Case Studies</td>
<td>Visually identified species and counted</td>
<td>Bats are more common in suburban areas than in rural areas.</td>
<td>More research is needed to determine the impact of urbanization on bat populations.</td>
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<td>Matthews et al. (2010)</td>
<td>May 2000 to September 2000</td>
<td>Yes</td>
<td>Yes</td>
<td>Texas</td>
<td>113</td>
<td>No</td>
<td>National Park</td>
<td>Censuses</td>
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<td>More research is needed to determine the impact of urbanization on bat populations.</td>
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<td>Morley-Backen (2004)</td>
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<td>Yes</td>
<td>Yes</td>
<td>Southeast U.S.</td>
<td>1225</td>
<td>Yes</td>
<td>Rural Agricultural</td>
<td>Censuses</td>
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<td>Retallack et al. (2012)</td>
<td>2000</td>
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<td>Yes</td>
<td>Mexico and Southeast U.S.</td>
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<td>No</td>
<td>Mixed Urban-Suburban Rural</td>
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<td>Visually identified species and counted</td>
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<td>More research is needed to determine the impact of urbanization on bat populations.</td>
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<tr>
<td>Wiener et al. (2009)</td>
<td>Two Years, 2009-2011</td>
<td>Yes</td>
<td>Yes</td>
<td>Texas</td>
<td>6</td>
<td>No</td>
<td>Mixed Urban-Suburban Rural</td>
<td>OBSV</td>
<td>Visually identified species and counted</td>
<td>Bats are more common in suburban areas than in rural areas.</td>
<td>More research is needed to determine the impact of urbanization on bat populations.</td>
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<tr>
<td>Wadsworth et al. (2004)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Mexico and Southeast U.S.</td>
<td>25</td>
<td>Yes</td>
<td>Mixed Urban-Suburban Rural</td>
<td>Calculated</td>
<td>Visually identified species and counted</td>
<td>Bats are more common in suburban areas than in rural areas.</td>
<td>More research is needed to determine the impact of urbanization on bat populations.</td>
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</tbody>
</table>
## Appendix B.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Dates of Study</th>
<th>IS II PR</th>
<th>Sample Location on Central Flyway</th>
<th>Number of Sample Areas</th>
<th>UD or ER</th>
<th>Demographics of Location</th>
<th>Type of Study</th>
<th>Methods of Study</th>
<th>Results of Study</th>
<th>Recommendations</th>
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<tr>
<td><strong>MONARCHS</strong></td>
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<tr>
<td>Lepak et al. (2017)</td>
<td>2016, 2017, 2018</td>
<td>Yes</td>
<td>Mexico</td>
<td>N/A</td>
<td>No</td>
<td>Forest</td>
<td>OSRES and Collected Samples</td>
<td>Monarch numbers increased following experimental management of habitat.</td>
<td>Recommendations against logging and conservation of riparian zones.</td>
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<tr>
<td>Muhlack &amp; Camp (2012)</td>
<td>May to August</td>
<td>Yes</td>
<td>Canada</td>
<td>N/A</td>
<td>Laboratory</td>
<td>OSRES and Collected Samples</td>
<td>Monarch numbers increased following experimental management of habitat.</td>
<td>Recommendations against logging and conservation of riparian zones.</td>
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<tr>
<td>Middlebrooks &amp; Grant (2014)</td>
<td>15 years</td>
<td>Yes</td>
<td>Central U.S.</td>
<td>17,255</td>
<td>No</td>
<td>Savannah</td>
<td>Collected Samples</td>
<td>Monarch numbers increased following experimental management of habitat.</td>
<td>Recommendations against logging and conservation of riparian zones.</td>
<td></td>
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<tr>
<td>Moore &amp; Duhon (2014)</td>
<td>March to August</td>
<td>Yes</td>
<td>Oklahoma</td>
<td>6</td>
<td>Yes</td>
<td>Rural and Suburban</td>
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<td>Monarch numbers increased following experimental management of habitat.</td>
<td>Recommendations against logging and conservation of riparian zones.</td>
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<td>Ogawa et al. (2015)</td>
<td>March to August</td>
<td>Yes</td>
<td>Southern Ohio</td>
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<td>No</td>
<td>Mixed Urban, Suburban Rural</td>
<td>OSRES and Collected Samples</td>
<td>Monarch numbers increased following experimental management of habitat.</td>
<td>Recommendations against logging and conservation of riparian zones.</td>
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### Appendix C.

<table>
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<tr>
<th>Reference</th>
<th>Dates of Study</th>
<th>ISITPR</th>
<th>Sample Location on Central Flyway</th>
<th>Number of Sample Areas</th>
<th>UD CR</th>
<th>Demographics of Location</th>
<th>Type of Study</th>
<th>Methods of Study</th>
<th>Results of Study</th>
<th>Recommendations</th>
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<tr>
<td>Ibrahim A. &amp; Uranus, (2013)</td>
<td>1940s-1950</td>
<td>Yes</td>
<td>Minnesota</td>
<td>4</td>
<td>No</td>
<td>Mixed Upland/Smaller Bird</td>
<td>Collected Sample</td>
<td>Vegetation was collected and water samples collected in a suitable buffer and other water sources were noted.</td>
<td>Reduced vegetation and waterfowl numbers were noted in all study areas. Further research is needed to determine the actual number of trees and water sources.</td>
<td>In order to promote the recovery of suitable habitat for all species and waterfowl, we recommend the establishment of riparian zones to provide suitable habitat for all species.</td>
</tr>
<tr>
<td>Belding &amp; Tewksbury, (2013)</td>
<td>2000-2010</td>
<td>Yes</td>
<td>Wyoming</td>
<td>5</td>
<td>No</td>
<td>Mixed Upland/Smaller Bird</td>
<td>Collected Sample</td>
<td>Vegetation was collected and water samples collected in a suitable buffer and other water sources were noted.</td>
<td>Reduced vegetation and waterfowl numbers were noted in all study areas. Further research is needed to determine the actual number of trees and water sources.</td>
<td>In order to promote the recovery of suitable habitat for all species and waterfowl, we recommend the establishment of riparian zones to provide suitable habitat for all species.</td>
</tr>
<tr>
<td>Galley, (2013)</td>
<td>N/A</td>
<td>Yes</td>
<td>Wyoming</td>
<td>5</td>
<td>No</td>
<td>Mixed Upland/Smaller Bird</td>
<td>Collected Sample</td>
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<tr>
<td>Chenoweth et al., (2013)</td>
<td>1980-1990</td>
<td>Yes</td>
<td>Texas</td>
<td>3</td>
<td>No</td>
<td>Mixed Upland/Smaller Bird</td>
<td>Collected Sample</td>
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<tr>
<td>Kenkel &amp; Wohlschlegel, (2009)</td>
<td>1940-1950</td>
<td>Yes</td>
<td>Texas</td>
<td>6</td>
<td>Yes</td>
<td>Mixed Upland/Smaller Bird</td>
<td>Collected Sample</td>
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<tr>
<td>Keim &amp; Wohlschlegel, (2009)</td>
<td>Early June 1980</td>
<td>Yes</td>
<td>Wisconsin</td>
<td>6</td>
<td>No</td>
<td>Mixed Upland/Smaller Bird</td>
<td>Collected Sample</td>
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<tr>
<td>Hanmer, (1999)</td>
<td>Early June 1980</td>
<td>Yes</td>
<td>Canada</td>
<td>22</td>
<td>No</td>
<td>Mixed Upland/Smaller Bird</td>
<td>Collected Sample</td>
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<tr>
<td>Wohlschlegel et al., (2012)</td>
<td>1990-2010</td>
<td>Yes</td>
<td>Texas</td>
<td>5</td>
<td>No</td>
<td>Mixed Upland/Smaller Bird</td>
<td>Collected Sample</td>
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**TRAVELING LANDSCAPES**