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An Assessment of Viable Habitat for Blanding's Turtle (Emydodidea blandingii) in the State of Ohio Using GIS and Remote Sensing

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AN ASSESSMENT OF VIABLE HABITAT FOR BLANDING'S TURTLE (*EMYDODIDEA BLANDINGII*) IN THE STATE OF OHIO USING GIS AND REMOTE SENSING

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ABSTRACT

The Blanding's Turtle (*Emydoidea blandingii*) has received threatened status in the State of Ohio in 2010. The goal of this study is to provide information that can be used in conservation management to locate suitable habitat for conservation of the species as well as potential repatriation or translocation sites. Wetland Inventory and Land Use/Land Cover maps were combined with aerial photography to evaluate regions located in Ohio's Lake Erie Drainage Basin that would meet the essential requirements of the turtles life history by quantitative methods used in Geographic Information Systems (GIS) and Remote Sensing programs. This study identified suitable wetlands and vernal pools, lakes and ponds, and other areas with minimum canopy for nesting and movement. Throughout the region, the highest concentration of available habitat is found in Erie, Lucas, and Ottawa counties of the Blanding's turtle's historical range. This approach to creating Habitat Niche Models was validated by close correlation between the counties identified as having remaining appropriate habitat and the counties from the historical populations in which Blanding's turtles still remain. The potential exists to restore these areas through various means: restoring wetlands, protecting areas near agriculture that are more suitable for nesting, constructing small tunnels under roads and fences, and installing road warning signs to allow for safer migration. With protection and restoration

of the habitat, the species may still have a chance to recover and become a stable population without the need for intense management.

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CHAPTER I

INTRODUCTION

Global Turtle Decline

The decline of turtle populations is caused by many of the same forces that threaten other aquatic species. Generally loss of habitat, habitat fragmentation, pollution, over exploitation, and introduction of invasive species place undue pressure on habitat around the globe (Gibbons et al. 2000). The fast decline of turtle species had been projected as early as 1997 (Gibbons 1997) and reportedly two thirds of the 260 existing species are either threatened or endangered (Bonin et al. 2006). Many of these species are being lost in the unsustainable harvest of turtles for traditional Chinese medicine and Chinese food markets (Turtle Conservation Fund 2002). In 2000, at the Society for the Study of Reptiles and Amphibians (SSAR) conference in Indianapolis, Indiana, the herpetology community learned of the impact the Asian markets were having on the Asian turtle population.

In 2001, in response to this Asian Turtle Crisis, the Turtle Survival Alliance (TSA) was created as partnership with International Union for Conservation of Nature (IUCN) for “sustainable captive management of freshwater turtles and tortoises.”

(www.turtlesurvival.org). Since that time, TSA has become an independent group of academics, hobbyists, and zoos committed to the survival of all turtle and tortoise species. As the group started an active role in the Asian Turtle Crisis, the unsustainable exploitation of native species of the United States to China became apparent. Today it is known that the populations of chelonians around the world are in severe decline, not due just to the unsustainable markets in Asia, but to a variety of threats specific to the species range (Gibbons et al. 2000).

North American Turtle Decline

There are 56 species of turtles native to North America. These 56 species make up 18-20% of the ~ 256 turtles globally and make it the 2nd most diverse area for chelonians in the world. Of these species in North America, 35 (63%) receive conservation status by the Endangered Species Act (ESA), Convention on International Trade of Endangered Species (*CITES*), or the International Union for the Conservation of Nature and Natural Resources (IUCN) (Ernst and Lovich 2009).

Pressures on turtle populations include habitat loss, increased predation, invasive species, over collection, recreational parks, habitat fragmentation, urbanization, and other human threats (Garber and Burger 1995, Mazza 2004, Ernst and Lovich 2009). These factors contribute to the low recruitment of organisms with a slow rate of maturation (Earnst and Barbour 1992), and their deleterious effects can be catastrophic to populations.

Examples of unsustainable exploitation of turtles as a food source can be traced back to the late 19th century with the Diamond Back Terrapin (*Malaclemys terrapin*) along the east coast of the United States. A single buyer of Alligator Snapping turtle

(*Macrochelys temminckii*) for commercial use purchased 17,000 kg over a two year period in the mid 1980's (Sloan and Lovich 1995).

Invasive plants and animals can compete for food sources, pioneer nesting grounds, and become additional predators to native turtles as well as their eggs. Turtle species can even be invasive to other turtle species. In 2003 a study was done of European Pond turtles (*Emys obicularis*), a close relative to the Blanding's turtle, cohabitating with the Pond Slider (*Trachemys scripta*), under controlled conditions. A control group of European Pond turtles were placed in an artificial pond with basking sites and the experimental group, consisting of both species, was placed in an identical artificial pond with identical basking sites. The results show that the European Pond turtles were out competed by the Pond sliders, they showed a loss in body mass, and they experienced a higher rate of mortality than the control group (Cadi and Joly 2003, Spinks et al. 2003).

Habitat degradation can come in many ways including drainage of bogs, swamps, marshes, clear cutting of forest, mining, and all forms of urban development. Buhlmann and Gibbons noted in their 1997 report that 35.5% of turtles in the southeastern United States are threatened because of damage of the river systems alone. Urban development creates a necessity for roads, which not only severely fragments habitat, but become a lethal factor in itself (Ashley and Robinson 1996: Bury an dLuckenbach 2002; Dodd et al 1989, Gibbs and Shriver 2002, Gibbs and Steen 2005; Steen and Gibbs 2004; Steen et al 2006; Von Seckendorff Hoff and Marlow 2002). Roads fragmenting habitat become a hazard for nesting females, migrating males, and movement of hatchlings where they are often killed by passing traffic.

Conservation Status of the Blanding's Turtle

Emydoidea blandingii (Holbrook, 1838) is protected by statuette in several states, but no federal protection exists. The Blanding's turtle has a status of Lower Risk/Near Threatened as of the 2008 IUCN Red List (www.iucn-tftsg.org), and is not listed in Convention of International Trade in Endangered Species (*CITES*). According to NatureServe (www.natureserve.org), Blanding's turtle in the United States is listed as at risk in 15 of 16 states (Fig 1.1). It is "Extirpated" from Rhode Island and Pennsylvania, "Critically Imperiled" in Missouri, and South Dakota, "Imperiled" in Massachusetts, Minnesota, New York, and "Vulnerable" in Illinois, Iowa, Michigan, New Hampshire, and Wisconsin. It is considered "Secure" only in Nebraska. In Canada, it is considered "Critically Imperiled" in Nova Scotia, Ontario, and Quebec (Congdon et al 2008). The State of Ohio had elevated the Blanding's turtle from a Species of Concern to Threatened in October of 2010.

The first report on the reptiles of Ohio was done by Jared Potter Kirtland, M.D. in 1838 (ODNR, 2009). A century would pass until Roger Conant (1938) would flesh out the details of herpetology in the state of Ohio. In the first third of the 20th century, *Emydoidea blandingii* was reported by Conant (1938) as abundant in Ohio (Fig. 1.2) occurring in the marshes along Lake Erie and especially abundant in the wetlands between Toledo and Sandusky.

The Blanding's turtle was named after the 19th century naturalist William Blanding who first described this species in Pennsylvania where the species has now been extirpated (www.dcnr.state.pa.us). Blanding's turtle belongs to the genera *Emydoidea*. Feldman and Parham had suggested in 2002 that the Blanding's turtle is more akin to the genus *Emys*. This change to *Emys*, although used by some authors, has not been officially accepted by the IUCN's Tortoise and Freshwater Turtle Specialist Group (TFTSG) and will therefore not be referred to as such in this study.

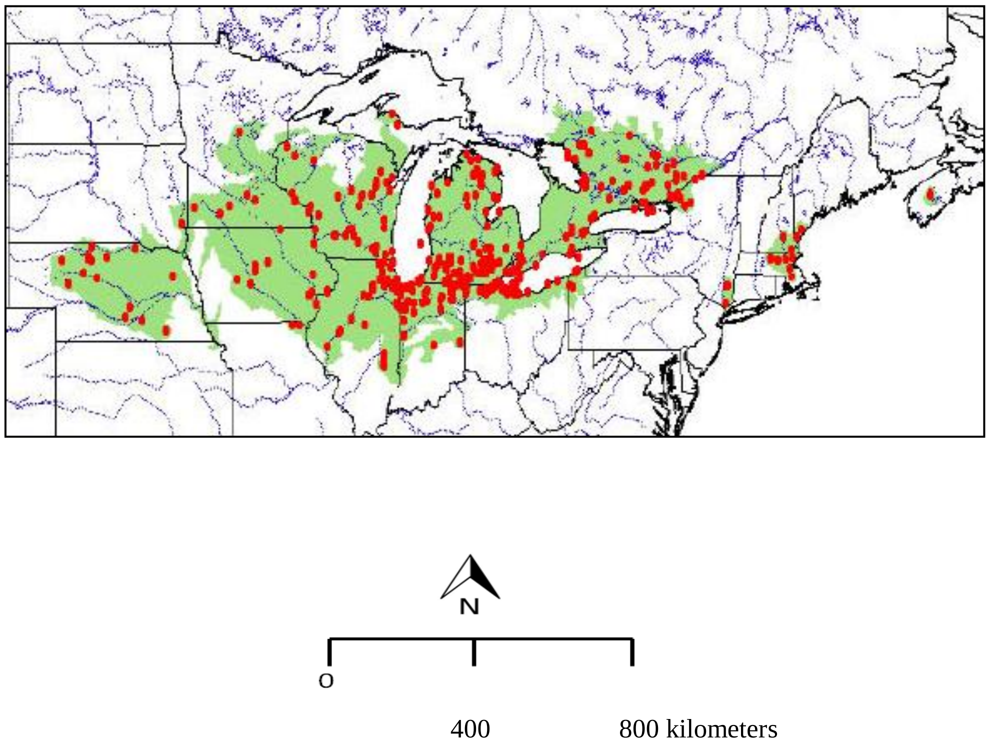

Figure 1.1: Historical range map of *Emydoidea blandingii*. Red points are records based on published records. Green shading is projected distribution. Modified from IUCN/SSC Tortoise and Freshwater Turtle Specialist Group (www.iucn-tftsg.org)

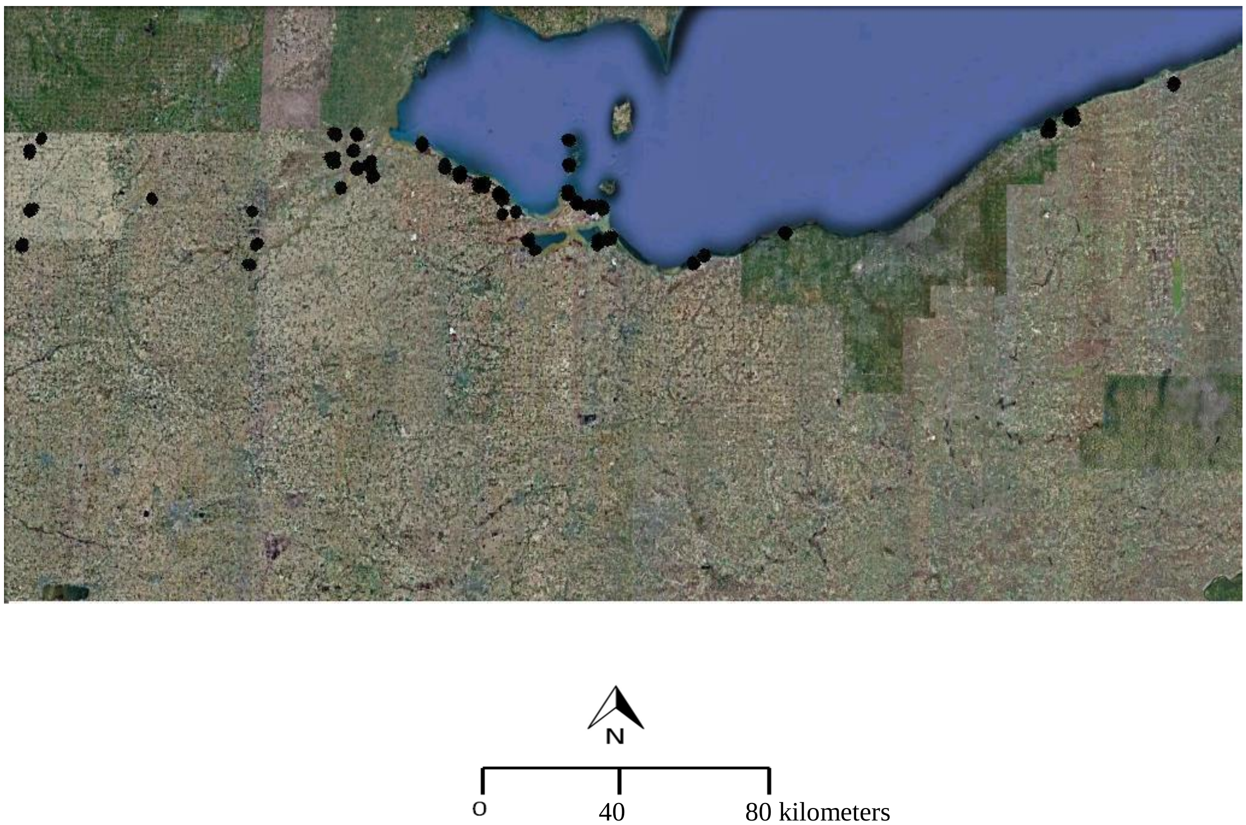

Figure 1.2: A satellite image of Northern Ohio. The marked areas are records of *Emydoidea blandingii* provided by Roger Conants surveys of Reptiles in Ohio; 1938. Image modified

Natural History

Emydoidea blandingii is a medium-sized (to 26 cm) turtle with an elongated, smooth carapace that is neither keeled nor serrated. As described by Ernst and Barbour (1992) and Ernst and Lovich (2009) the vertebrals are broader than long, and the 1st vertebral touches four marginals and the cervical. Neurals are six sided and shortest anteriorly. The carapace is blue black, with each pleural and vertebral having tan to yellow irregularly shaped spots or slightly radiating lines, and the marginals are heavily spotted. The plastron is yellow with large, dark symmetrically arranged blotches, which may be so large as to hide most of the yellow pigment. The chin and throat are bright yellow. The carapace is domed and elongate and the plastron is hinged at the pectoral-abdominal seam. The vent is located posterior to the margin of the carapace and the plastron is slightly concave in males (Congdon et. al 2008). The plastron can completely close at five years of age or 103 mm carapace length (Pappas et al. 2000). In adults, there is no apparent sexual size dimorphism, but intersexual shape differences may result from differences in morphology of the plastron (Congdon and van Loben Sels 1991; Pappas et al. 2000). Blanding's turtle is one of the longest-lived emydid turtles with individuals reaching ages greater than 75 years (Congdon et. al. 2001). This animal is easily identified in the field by its long yellow throat and high domed carapace and no turtle found in Blanding's turtle habitat looks similar. *Emydoidea blandingii* is not divided into subspecies and the range does not overlap with the Wood turtle (*Glyptemys insculpta*), a species that has recently been discovered to have the ability to hybridize with the Blanding's turtle in captivity (Harding 2009).

Diet

Emydoidea blandingii is a carnivore with a preferred diet of crayfish and snails (Spetz 2008), but is known to consume earthworms, leeches, slugs, bivalves, millipedes, small crustaceans, spiders, insects (including beetles, flies, damselflies, dragonflies, mayflies, orthopterans, soldier flies, and true bugs), fish, and reportedly plant material, which may be incidental to the carnivorous diet (Ernst and Lovich 2009). *Emydodiea blandingii* uses a pharyngeal feeding mechanism that utilizes the high density and viscosity of water. Rapid expansion of the chamber by the hyoid apparatus, coupled with a fast inertial feeding thrust of the head, generates negative pressure that quickly draws water and prey into the mouth in a process known as the suck and gulp method (Ernst and Lovich 2009, Harding 2009).

This species of turtle will also use their long neck to strike items offered on land (Harding 2009). On more than one occasion, *Emydoidea blandingii* has been observed striking at flies while basking on a log as well as dragging duck carcasses into the water to consume (personal observation). A recent study in Ohio has shown *Emydoidea blandingii* to feed on a variety of prey items with a large component being gastropods. During the summer months, crayfish numbers increase with their stage of the reproductive cycle. By the use of stomach washing, it has been determined the Blanding's turtle ingest a higher proportion of crayfish to gastropods during this time of the year (Spetz 2008).

Habitat Use

In general, *Emydoidea blandingii* lives in productive, eutrophic habitats of clean shallow water, glacial lakes, alkaline to acidic pH, a soft but firm organic bottom, and abundant aquatic vegetation (Hearwig and Kiviat 2007, Kiviat 1993, Earnst and Lovich 2009). The core habitat of Blanding's turtles has an aquatic component that consists of a permanent wetland and a suite of other usually smaller and more temporary wetlands, such as vernal pools, that are used by adults and hatchlings as temporary refugia and seasonal feeding grounds. Blanding's turtle habitat also has a large terrestrial component that consists of nesting areas and corridors for movement to select habitat sites. Throughout its range the *Emydoidea* is found in glacial lakes (Buhlmann 2009), ponds, bogs, swamps, marshes, fens, creeks, wet prairies, and sloughs (Ernst and Lovich 2009). *Emydoidea. blandingii* need elevated nesting grounds with well drained soils, absent or open vegetation for nesting grounds, as well as migration corridors (Kiviat 1997, Congdon and Keinath 2006).

The state of Ohio is home to 11 species of chelonians. One terrestrial, *Terrapene* c. carolina, 6 aquatic, *Sternotherus odoratus, Chelydra serpentina, Graptemys geographica*, *Graptemys ouachitenisis*, *Apalone s. spinifera*, *Apalone mutica mutica* and 4 semi-aquatic, *Chrysemys picta marginata, Clemmys guttata*, and *Trachemys scripta elegans*, *Emydoidea blandingii*. Terrestrial and aquatic species require relatively few habitat complexes to survive while the semi-aquatic species need multiple components to there core habitat. The Blanding's turtle has the largest terrestrial component to the core habitat and both sexes use terrestrial corridors for movements among wetlands and for nesting migrations (Congdon and Keinath 2006). The complex and diverse habitat of *Emydoidea* may be one reason their population numbers are declining while the other eight species of turtle found in Ohio, with the exception of *Clemmys guttata,* require fewer habitat permutations and appear to be stable.

Wisconsin *Emydoidea* seem to spend more of their time in marshes rather than ponds compared to other populations, but the marshes are used less than expected based on habitat availability, as are terrestrial habitats. Ponds with sand bottoms and no aquatic vegetation are rarely used. Wetlands covered by cattail (*Typha* sp.) mats are not used, but areas cleared of cattails by muskrats (*Ondatra zibethicus*) are entered by the turtles, possibly for foraging (Ross and Anderson 1990, Rowe and Moll 1991).

Reproduction

Courtship and mating have been observed in every month from March to November but are most common from March to July (Conant 1951, Graham and Doyle 1979, Vogt 1981). Although they may mate during these months, females have the ability to store viable sperm (Harding and Davis 1999) perhaps as long as five years after mating. Therefore, females of this species can produce a clutch of eggs during the nesting season consisting of multiple sires of any males the animal had copulated with over the past five years. However, the percentage of eggs sired during a given year diminishes with an increase in time from the initial reproductive event (Harding and Davis 1999).

Nesting season lasts from late May to early July, depending on geographic location and weather conditions. Nesting usually begins in the early evening and is completed after dark (Congdon et al. 2000). The nests are flask shaped and consist of one clutch per year (Pappas et al. 2000). Not all sexually mature females nest in a given year.

Size and age at attainment of sexual maturity vary among populations and individuals. Data collected during a 24-year study of *Emydoidea* in Michigan (Congdon and van Loben Sels 1993) provide critical long-term information on maturation. The youngest female found in her first reproductive season was 14 years old while females often mature 5 or more years later. No relationship was detected between body size and age at first oviposition.

Emydoidea exhibits Temperature Dependant Sex Determination or TSD (Ernst and Lovich 2009). *Emydoidea blandingii* eggs incubated at 22.5-26.5°C produce 97-100% males, while eggs incubated at 30-31°C produce only females (Ewert and Nelson 1991, Gutzke and Packard 1987). Most hatchlings emerge in September after a 65—80 day incubation period; however, some may over-winter in the nest and emerge the following spring (Ernst and Barbour 1992).

The importance of TSD as a conservation issue comes into play via habitat choice of the species. If the nesting areas chosen by females are too cool or too warm, the long term effects to a population could be catastrophic. For example, a Blanding's turtle population in Ottawa County Ohio has been encroached by agriculture (Spetz personal comm.). The female Blanding's turtles will lay their eggs in corn fields. The corn will grow after nesting season and cover the nests in shadow during the gestation period. The result is cooler nests that may skew the sex ratio of the population toward males. If the temperature is too cool during gestation, the hatchlings may either hatch deformed or will die during the incubation period (Ewert and Nelson 1991, Gutzke and Packard 1987).

The Blanding's Turtle Decline

Congdon et al. (1993) demonstrated that Blanding's turtle populations are sensitive to change both at juvenile and adults stages, while changes in age at sexual maturity, nest survival, and/or fecundity had lesser effects on population stability. Nest predation rates are highly variable among turtle populations in Michigan and averaged 74%. Most nest predation is caused by raccoons and foxes and occurs within three days of nest construction. Minor nest predators in Michigan include skunks, opossums, and unknown burrowing mammals. Many nests are constructed in areas with disturbed soils, such as gardens, driveways, dirt roads, roadsides, railroad embankments, fire lanes, and agriculture fields. Some nests in disturbed areas are at risk of being destroyed by garden tools, farm machinery, road graders and other motor vehicles (Congdon et al 2008).

Emydoidea are frequently killed on roads by vehicles while migrating or emerging from hibernacula, but hatchlings are also at risk when emerging from nests (Ashley and Robinson 1996, Gibbs and Shriver 2002, Harding 1990, Kofron and Schrieber 1985, Standing et al 1999). Females may be more vulnerable to road mortality than males due to distance traveled during nesting movements (Steen et al 2006).

Blanding's turtles occasionally appear in the commercial pet trade, but as of 2000, the level of exploitation appears to be low, with no indication of large-scale sales in domestic or foreign markets (Levell 2000). Occasionally *Emydoidea* can be found on the black market pet trade. In 2003, 13 Blanding's turtles were confiscated in a sting operation at a Reptile Swap in Columbus, Ohio. The animals were released to the Cleveland Metroparks Zoo to be part of their repatriation program.

Effective conservation of Blanding's turtles requires that rural habitat complexes be conserved in large working landscapes of 5-10 km^2 that include parks, farms, and partially developed parcels. A buffer zone of 1000 m around wetland habitats will be necessary to design an effective preserve (Kiviat 1997).

Goals

For this study I will look at available habitat in northern Ohio and determine what habitats are viable for this species. Open water, wetlands, and emergent woody vegetation from shallow water will be the defining complexes to be used. These categories were chosen as they are the closest match of the habitat requirements based on the literature (Hearwig and Kiviat 2007, Kiviat 1993, Kiviat 1997, Congdon et al 2008) or offered in the Wetland Inventories and Land Use/Land Cover maps utilized in this study. The goal will be to analyze northern Ohio for appropriate habitat types with the least amount of fragmentation and with sufficient corridors to connect them.

Habitat deemed acceptable will be narrowed down from the entire area of northern Ohio to smaller clusters that meet the species requirements. These areas with dense appropriate habitat types would then warrant further investigation and surveys. A field visit would then validate the results of this study. An assessment of the habitat suitability at the desired location will determine if an area has the ability to support the species, and if so, does it have an effective corridor that can link other suitable habitats in the region. If areas can be located that meet these requirements and have the potential to be protected, *Emydoidea blandingii* may have an area in which to populate without artificially supplying offspring to maintain a population of animals. To contrast the assessment of habitat, a long-term repatriation project in the Cuyahoga River watershed is described first, and assessed within the broad scale study of habitat.

CHAPTER II

BLANDING'S TURTLE REPATRIATION PROJECT

Introduction

In 1999 a female Blanding's turtle was found nesting at the Ohio & Erie Cananl Reservation (OEC) Nature Center in Cleveland, Ohio. The discovery of this one animal outside of its normal range prompted the Metroparks to survey the area for a Blanding's turtle population by hoop net traps. They captured an additional three males. This small wetland area was chosen to see if a small population of the species could survive.

Cleveland Metroparks, along with the Cleveland Metroparks Zoo, developed a repatriation program for *Emydoidea blandingii* in the OEC. The repatriation program consisted of capturing adult females from both OEC and Winous Point Marsh, Ottawa County, Ohio during the nesting season to harvest the eggs. The eggs were kept in an incubator at the Cleveland Metroparks Zoo until hatching and raised for a minimum of two years before release. The released animals were split between OEC and Winous Point Marsh. The animals were marked for identification by notching the margianls with a file and fitted with VHF transmitters. I, as well as Cleveland Metroparks staff, located the animals weekly and assessed the habitat preferences of the animals.

Repatriation Methods

In early June 2000, the female Blanding's turtle from the OEC was collected and taken to the Cleveland Metroparks Zoos veterinary hospital. The female had radiographs taken to determine if the animal had eggs and if so, how many. She was gravid and Oxytocin, a hormone that induces labor, was administered by veterinary staff. She was placed in a Rubbermaid bin, half full of water, with a rubber coated wire frame false bottom. The false bottom allowed the animal to expel the eggs without crushing them while the water created enough resistance that the eggs did not break as they dropped. The animal was monitored and the eggs were retrieved as they were passed.

I placed the clutch of eggs in a small Rubbermaid box (24 x 12 x 4) half filled with vermiculite. Water was added to the vermiculite in a 1:1 ratio by weight to keep the environment humid enough to mimic a natural nest. I placed the box in an incubator at 28°C, a temperature chosen as the midpoint of the incubation temperature range to yield a mix of both sexes (http://lllreptile.com). The clutches hatched in 56 ± 5 days and the hatchlings were then kept in a container remaining in the incubator filled with a ~2cm of warm water for three to four days in which time the remaining yolk sac was absorbed. The hatchlings were examined by the veterinary staff and transferred to an enclosed greenhouse on zoo grounds, where zoo Aquatics' Department staff provided daily care. The turtles were housed separately from other park animals to minimize the possibility of disease and parasite transfer. Each clutch of hatchlings was kept in a galvanized watering trough filled with ~5cm of water, plastic plants for hiding areas, and rocks on which to bask. Each trough was on a 12 hour light cycle using full spectrum florescent lamps (Mitrus 2005).

The two-year-old animals to be released at the OEC were split into two groups for a hard and a soft release (Clarke et al. 2003, Bright and Morris 1991). The hard release group was released in open habitat without any acclimation. The soft release group animals were placed in a fenced portion of the wetland for acclimation. Crayfish were released in the cage to give the turtles an opportunity to locate prey items. These animals were released from the cage after one week. The first six head start animals were hard released in 2002 and were fitted with small transmitters so they could be tracked several times a week by Metroparks employees, volunteers, and me. When an animal was found, a GPS location, a description of the area (e.g., under log, resting on vegetation mat, in cattail stand, buried in mud, etc.) the vegetation type, time of day and water temperature were recorded along with the animal's mass.

In 2003, Cleveland Metroparks staff determined that the repatriation program would need additional females to supplement the population at the OEC. With the approval of the Ohio Department of Natural Resources (ODNR), the first eggs were collected from Sheldon Marsh State Nature Preserve and these hatchlings were placed in the repatriation program. Later in 2003, 18 adult Blanding's turtles (5 males and 13 females) were confiscated in a sting operation at a reptile expo in Columbus, Ohio. ODNR loaned these animals to the Cleveland Metroparks Zoo as breeding animals to be used in the repatriation research program. Subsequently, 2 males and 1 female died in captivity leaving 3 males and 12 females in the program.

An additional 34 first generation (F1) offspring from the program were released in 2005. Of these, 20 animals were released in OEC and 15 animals in Sheldon Marsh. The animals in O & E Canal were split into two groups of 10 for the hard and soft releases and monitored via telemetry.

In 2008, the repatriation project was reevaluated and the Cleveland Metroparks Zoos involvement in the program came to an end. The remaining 41 turtles were released with 24 at OEC and 17 at Winous Point Marsh. With the end of the project coming in the 7th of the 10 year goal, volunteers remained active with the trapping of the released animals and their subsequent telemetry through 2010.

Repatriation Results

Of the 31 Blanding's turtles released as juveniles in the period of 2002-2008 at OEC, 6 were confirmed dead. Two deceased animals were found two weeks post release and the additional 4 within three months of the release date. Fifteen of the 31 released animals were documented on site between 2007 and 2008 resulting in a minimum survival rate of 48%. Data is insufficient to speculate on the different benefits of a hard or soft release.

The mean water depth of the juveniles captured at OEC was significantly different than the mean depth of adults captured at Winous Point Marsh during the active season (April-September). The juveniles were found at a mean depth of 19 cm while the adults' depth was a mean of 44 cm. Additionally it was noted that both the adults and juveniles were found in significantly deeper water during the inactive season (October-March) with a mean of 18 cm and 30 cm, respectively with $p<0.001$ (Spetz personal comm.). The movement of these Blanding's turtles was similar to other populations found throughout the species range (Evermann and Clark 1916, Gibbons 1968, Vogt 1981, Kofron and Schreiber 1985, Rowe 1987, Ross and Anderson 1990, Rowe and Moll 1991, Pappas et al 2000, Piepgras and Lang 2000, and Banning 2006).

Repatriation Discussion

The telemetry and recapture results suggest that the head-start juvenile Blanding's turtles prefer habitat consisting of marsh land with emergent vegetation (Spetz 2008). The adult females needed nest sites with an open canopy for proper incubation temperatures, and the movement corridors used by adults to safely migrate between sites confirmed the habitat requirements listed in the literature. If indeed the released animals become reproductive and contribute a second generation into the population, the argument for additional repatriation programs may be bolstered.

A study done on spatial ecology and habitat of Blanding's turtles in Indiana found similar results to those in Cleveland Metroparks (Kingsbury 2010). A strong relationship was found between size and water depth preferred. Animals in the 5 cm plastron length used water averaging 10-20 cm in depth in areas dominated by sedges and shrubs while animals' 10-15 cm plastron length category used water with a mean of 40 cm depth. Adults used a variety of vegetative types including lilies, floating vegetation as well as vegetation used by all age groups. The vegetation preference of the OEC turtles and the Winous Point adults also showed a strong preference toward emergent vegetation (Spetz personal comm.).

These studies mirror habitat usage described by the literature (Hearwig and Kiviat 2007, Kiviat 1993) but added to these studies is that the habitat varied in use based on size and age class of the animals. The Ohio populations of Blanding's turtles are typical in size to those found across the species range (Rowe 1987, Rowe 1992, Joyal et al 2000, Banning 2006, and Congdon and Keinath 2006). To conserve populations of these turtles, different variable habitats need protection. To prepare for future releases, an assessment of usable habitat in the region is required, and the goal of this study is to locate, via satellite and aerial imagery, these habitats within close proximity to each other that will support the Blanding’s turtles’ complex life cycle.

CHAPTER III

HABITAT NICHE MODELING

Introduction

Northern Ohio's wetlands have been severely fragmented by urban expansion and agriculture. The once Great Black Swamp of northwestern Ohio has decreased in size from 4,000 km^2 to just 100 km^2 and much of these remaining wetlands are encompassed and managed behind dikes (Herdendorf, 1992). In Ohio, Blanding's turtle habitat destruction has resulted in species being extirpated from six counties in its former range while other populations have been severely fragmented. The loss of suitable habitat and the over-collecting of the species has eliminated it in many areas and significantly reduced numbers in the remaining populations around the Great Lakes. Because of its decline nationally and locally, a habitat assessment would help to determine how these animals can be managed and to ensure not only the survival of self-sustaining populations, but to protect enough habitat for sustaining genetic variability over time. This study aims to create a Habitat Niche Model using GIS and Remote Sensing of Blanding's turtle habitat for conservation and recovery in Ohio.

To define the assessment range, I first produced maps of the distribution of Blanding's turtle, which were overlaid on a Physiographic Regions of Ohio map. The documented localities published in 1938 (Fig. 3.1) and the localities from 1952 to the present provided by Ohio Department of Natural Resources (Fig. 3.2) show clearly that the Ohio population of *Emydoidea* reside in the Maumee Lake Plains and the Erie Lake Plain with one exception documented of an individual in Wayne County, which resides in the Killbuck-Glaciated Pittsburgh Plateau. The record of the animal found in Wayne County is most likely either a misidentification or a released animal, but it is considered a record nonetheless.

In an effort to be thorough, 20 of the northern Ohio counties were examined for the project and modeled using the GIS software Erdas Imagine. To produce maps that predict possible viable habitat for *Emydoidea blandingii*, information was gathered from the State of Ohio and information from Cleveland State University Biology, Geology, and Environmental Science Department that included aerial photographs, wetland Inventories and Land Use/Land Cover information. I chose key habitats necessary for a viable population based on a literature review (Table 3.1). (Hearwig and Kiviat 2007, Kiviat 1993, Kiviat 1997, Congdon et al 2008) and used this list to compare habitat types characterized the Wetlands Inventory, which is a comprehensive map of a given county detailing the size, shape, and location of each wetland. Each wetland was then classified into one of seven categories (Table 3.2). Land Use/Land Cover maps were similar to the Wetland Inventories in that they also categorized natural and manmade structures into seven categories (Table 3.3).

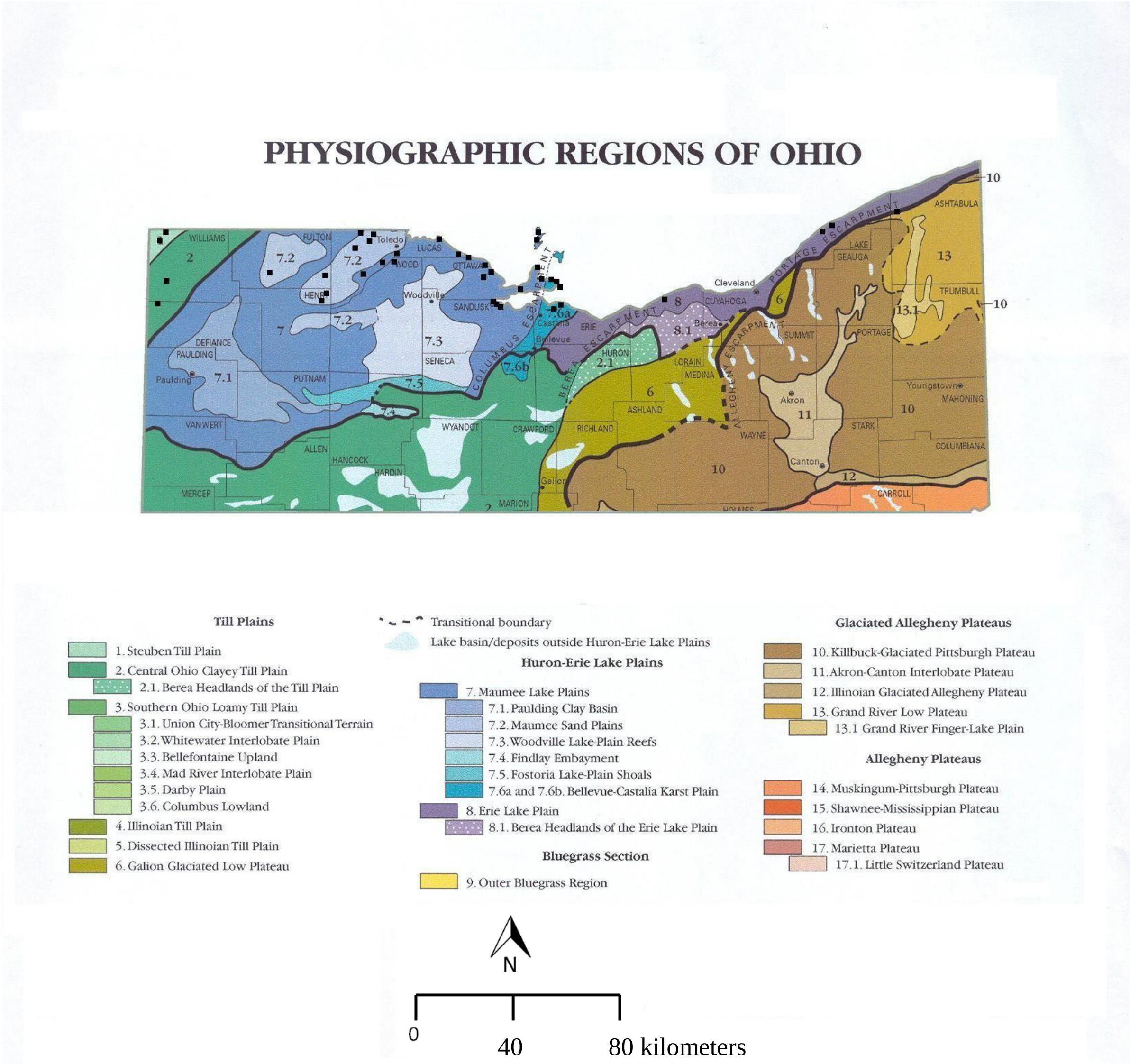

Figure 3.1: Physiographic map (Drochman 1998) with the locality data provided by Conant; 1938. Conant found populations in the Steuben Till Plain (1), Central Ohio Clayey Till Plain (2), Maumee Lake Plains (7), Maumee San Plains (7.2), Bellevue-Castalia Karst Plain (7.6a), and Erie Lake Plain (8). Note the species was not found in the Southern portion of the 2. Central Ohio clayey Till Plain. This may be because to the Northern portion was once part of the Great Black Marsh.

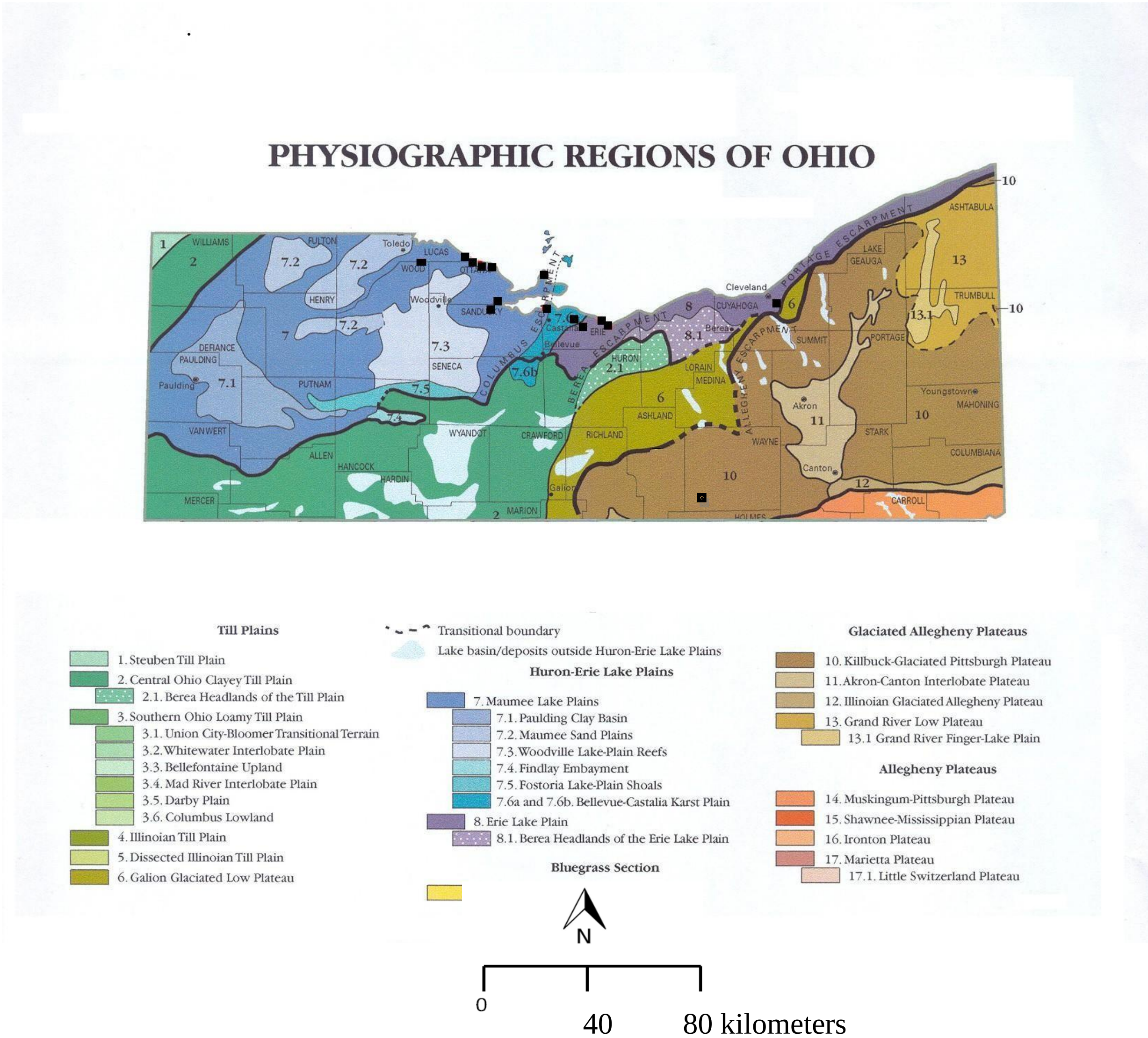

Figure 3.2: Physiographic map showing the locality data from 1952-present based on data provided by ODNR. The range has become depleted because of habitat loss and exploitation and remains only in Maumee Lake Plains (7), Bellevue-Castalia Karst Plain (7.6a), and Erie Lake Plain (8). One record cites an animal in Killbuck-Glaciated Pittsburgh Plateau (10). Considering the region this specimen was found, the distance from any other recorded population, and that no turtles have been sighted since, this animal most likely was either misidentified or a released pet.

Table 3.1: *Emydoidea blandingii* requirements based on literature

DESCRIPTION	WETLANDS INVENTORY CODES	LAND USE/LAND COVER CODES
Eutrophic-clean shallow water	35	5
Glacial lakes	35	5
Aquatic vegetation	36	6
Permanent wetlands	36,37	3,6
Temporary wetlands such as vernal pools	36	6
Large terrestrial component for nesting and movement corridors	N/A	3,6
Ponds	35	5
Swamps	36	6
Marshes	36	6
Fens	36,37	3,6
Creeks	35	5
Wet prairies	36,37	3,6
Sloughs	36	6
Bogs	36,37	3,6
Elevated nesting grounds with well drained soils	N/A	3
Absent or open tree canopy for nesting grounds and migration corridors	N/A	3

(Hearwig and Kiviat 2007, Kiviat 1993, Kiviat 1997, Congdon et al 2008)

Table 3.2: Wetlands Inventory Grid Codes and Explanations

CODE	DESCRIPTION	DESIRABLE
1	Upland areas within the county	No
34	Woods on hydric soil	No
35	Open water (excludes Lake Erie)	Yes
36	Shallow marsh (emergent vegetation in water < 3 ft.)	Yes
37	Shrub/scrub wetland (emergent woody veg. in water < 3 ft.)	Yes
38	Wet meadow (grassy vegetation in water < 6 inches)	No
39	Farmed wetland (wet meadow in agricultural areas)	No

Table 3.3: Land Use/Land Cover Grid Codes and Explanations

CODE	**DESCRIPTION**	**DESIRABLES**
1	Urban areas	No
2	Agriculture with open urban areas	No
3	Shrub/scrub areas	Yes
4	Wooded areas	No
5	Open water	Yes
6	Nonforested wetlands	Yes
7	Barren	No

Niche Modeling Results

The aerial photographs for each county were entered into a mosaic function of Erdas Imagine, which allowed creation of a single image from all the individual county maps (Fig 3.3). This was then available as a single file rather than computing each variable on each county. Likewise, the Wetlands Inventories for each county and the Land Use/Land Cover data for each county (provided by the State of Ohio's Department of Natural Resources) were entered into the mosaic creator function (Fig. 3.4 and Fig 3.5 respectively) allowing me to work with three maps. Both maps yield a large amount of information. In Figure 3.4, the darkest areas along Lake Erie, of the Blanding's turtle former range, are found in Ottawa, Lucas, Erie, and Sandusky Counties. These areas of high concentration are where most of the remaining Ohio populations can be found. The habitats listed in the literature (Table 3.1) are more detailed than the options offered by the Wetlands Inventory, Land Use/Land Cover maps, and Grid Code data available. Mapping codes did not always correspond to desirability of habitat. Therefore, the usable habitat was matched from the literature to the closest possible counterpart for a given data set. The closest matches to "desirable" habitat for the Wetland Inventory are Grid Codes 35-Open water, 36-Shallow marsh (emergent vegetation in water < 3 ft.), and 37-Shrub/scrub wetland (emergent woody vet. in water < 3 ft.) as seen in Figure 3.4. Conversely the Grid Codes 1-Upland areas within the county, 34-Woods on hydric soil, 38-Wet meadow (grassy vegetation in water < 6 inches), and 39-Farmed wetland (wet meadow in agricultural areas), were used to specify "undesirable" habitat (Table 3.2). Land Use/Land Cover maps used were also less detailed than the literature resulting in the use of Grid Codes 3-Shrub/scrub areas, 5-Open water, and 6-Nonforested wetlands as

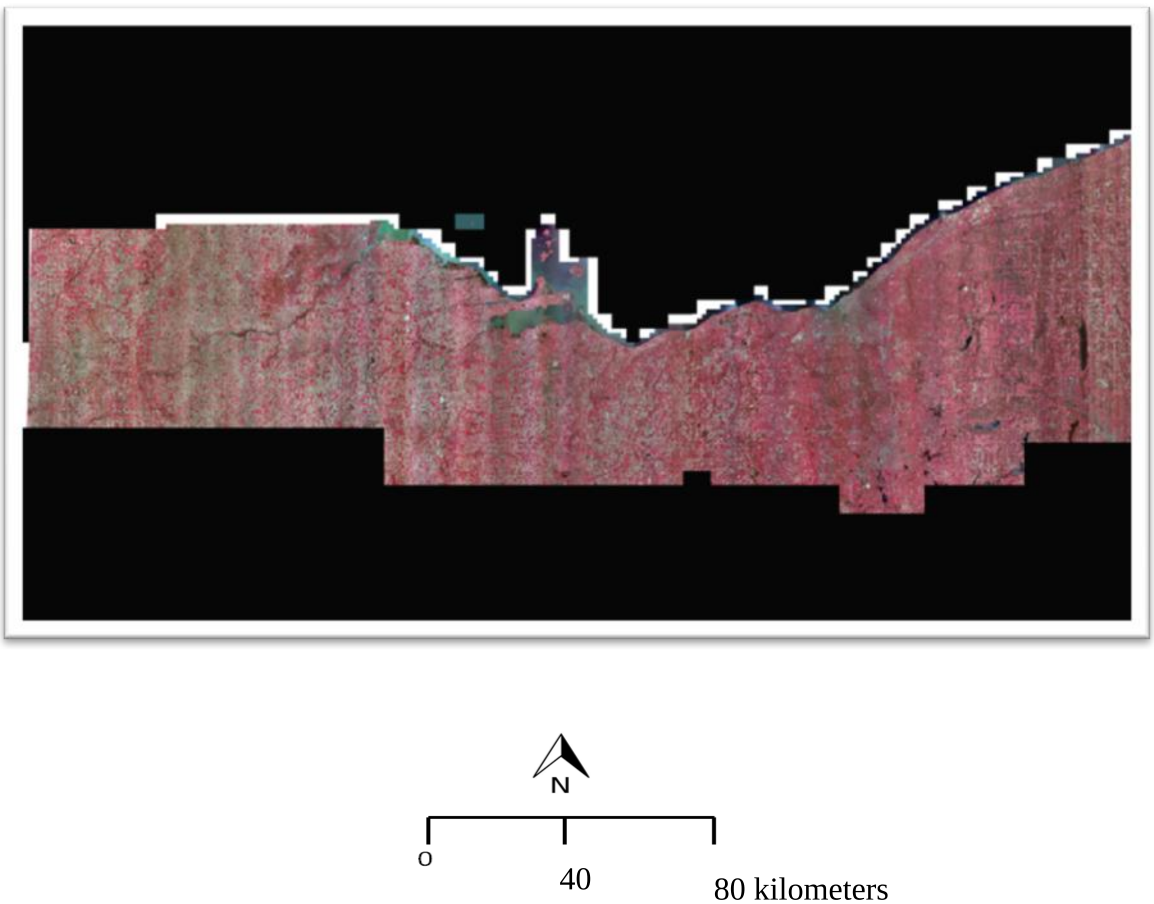

Figure 3.3: Mosaic of aerial photographs of the northern Ohio counties. This photograph is a composite of all counties and physiographic regions where *Emydoidea blandingii* historically resided. Photograph provided by Cleveland State University.

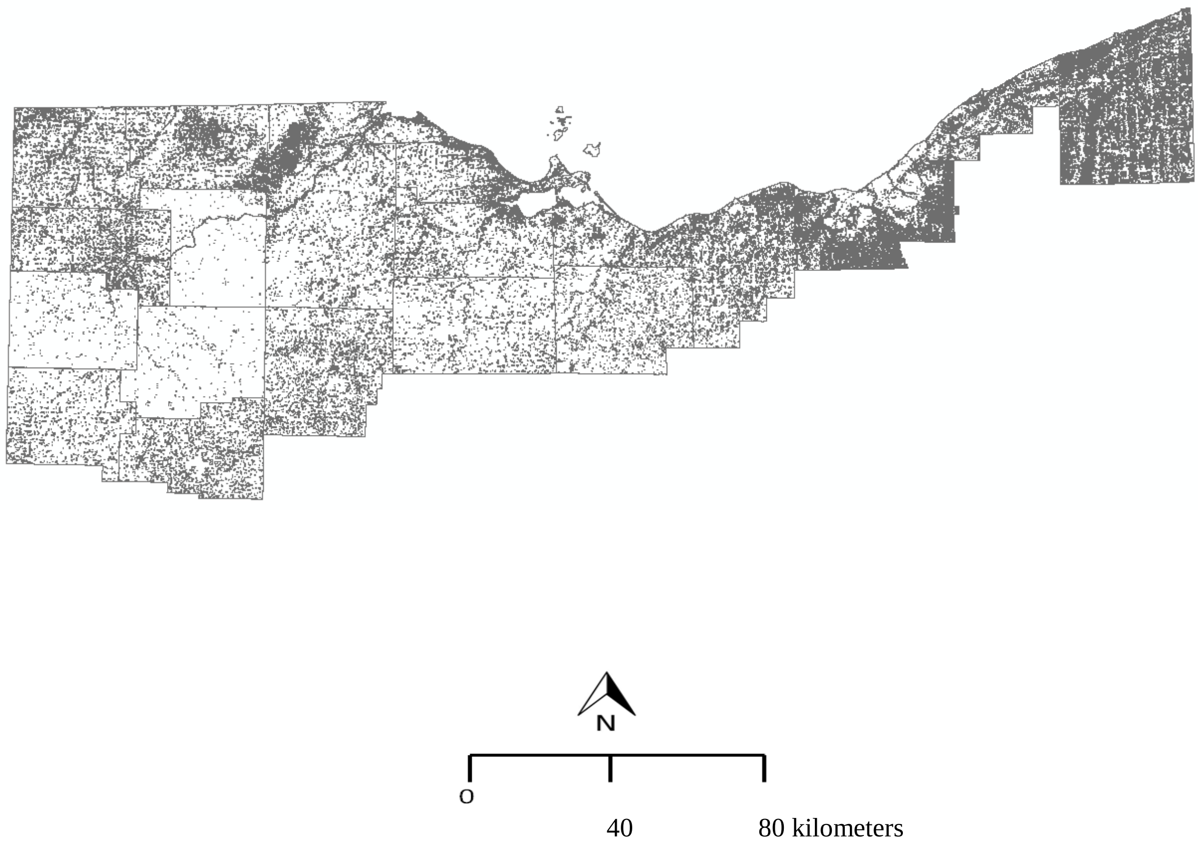

Figure 3.4: Current wetlands inventory of northern Ohio provided by ODNR. Each grey dot represents a specific grid code detailing each of the seven specific wetland types (see Table 2). The darkest areas represent the highest concentration of wetlands.

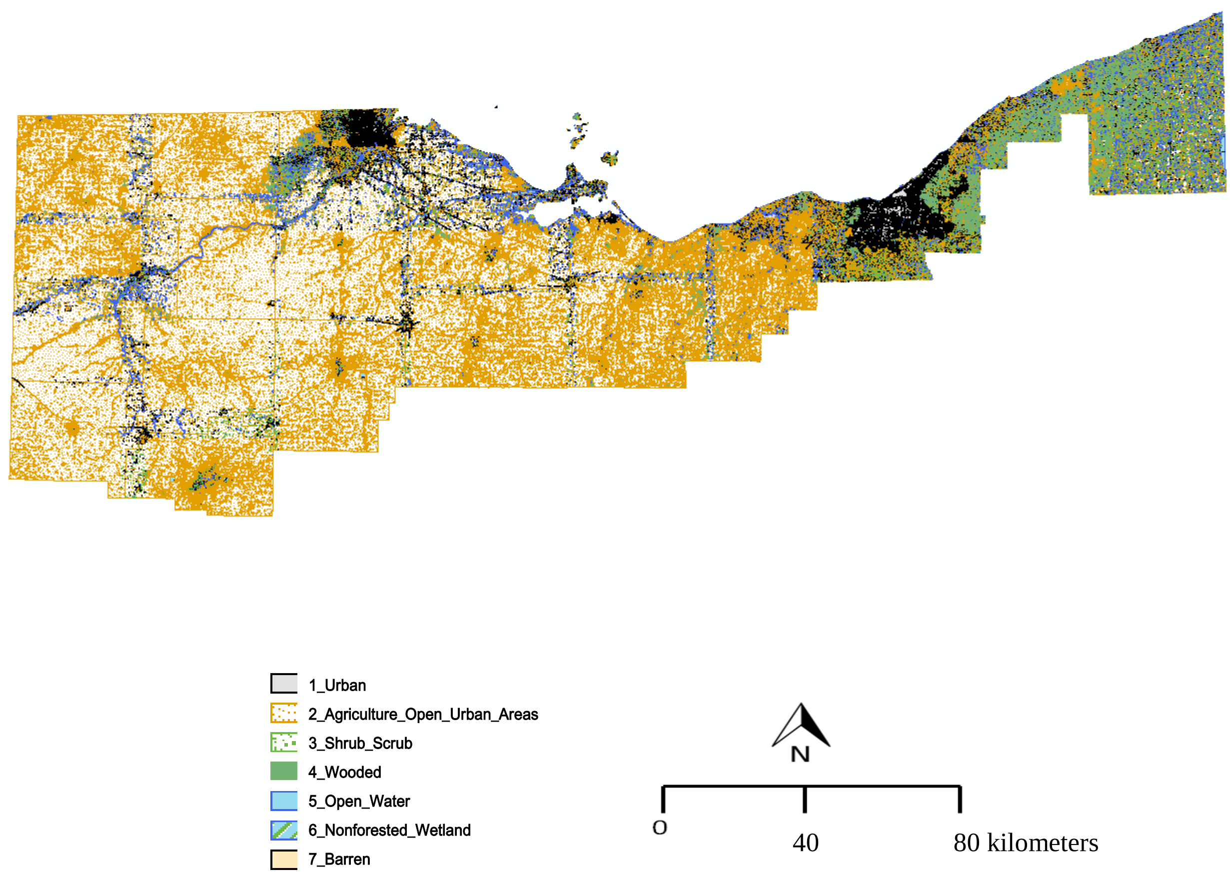

Figure 3.5: This composite of northern Ohio counties shows the distribution of seven land cover classifications across northern Ohio provided by ODNR. A high concentration of Open Water can be found in Ottawa, Lucas, and Erie, and Sandusky counties. Areas shaded black indicate urban and suburban land development.

"desirable" (Fig. 3.6) and Grid Codes 1-Urban areas, 2-Agriculture with open urban areas, 4-Wooded areas, and 7-Barren as "undesirable" (Table 3.3). Figure 7 gives an indication of where to look for viable habitat for these turtles by showing that most of the former range is now agriculture, which is unusable for this species.

The Grid Codes for the desired habitat in the Land Use/Land Cover map (Codes 3, 5, and 6) produced a model of all usable habitats by the Blanding's turtle (Fig. 3.6). This map indicates a multitude of viable habitats for *Emydoidea blandingii* in the region. Although this map shows areas of high concentrations of habitats to survey, it is not useful as a stand alone final habitat niche model. Buffer Zone maps of usable habitat of 2 miles around each Grid Code, detailed by this mosaic, indicated that the turtle population would have the potential to be found at any place in the species former range as well as the rest of Northern Ohio. A second approach is to use the Grid Codes for undesirable areas (Codes 1, 2, 4, and 7) in the Land Use/Land Cover map to eliminate areas where the turtles cannot live. When entered into the buffering function of Erdas program with the 75 foot buffer surrounding the undesired habitat, all that remains is the desired habitat. This creates a map that does not detail the usable habitat with the necessary 2 mile radius to be necessary for a population of Blanding's turtles to thrive (Fig. 3.7). The habitat niche model imposed a distance of 2 miles around desirable habitat to encompass distance traveled by females for nesting as well as distance for traveling males. A distance of 75 feet near unwanted habitat was also applied arbitrarily to reflect roads, fences, etc. that may in effect, create unusable area.

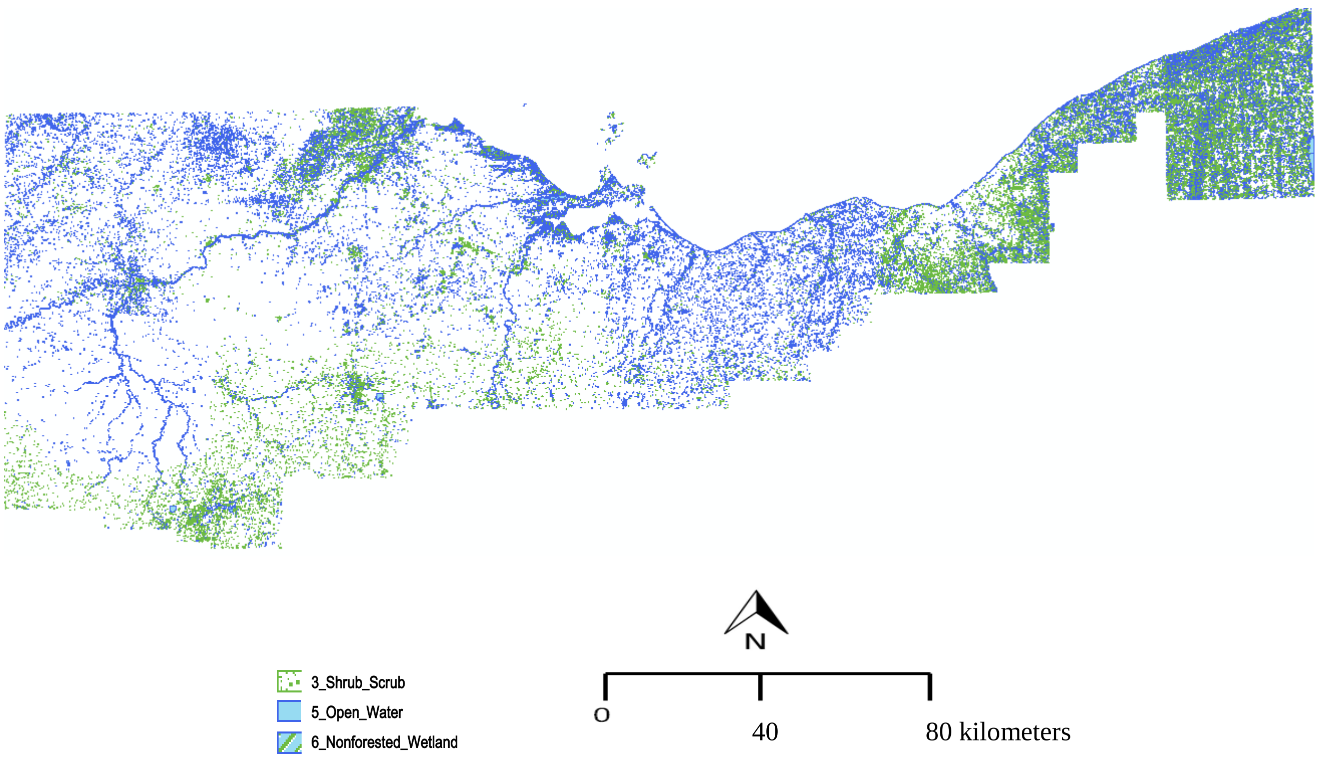

Figure 3.6: Land Use/Land Cover mosaic of northern Ohio displaying viable habitat for *Emydoidea blandingii*, 3. Shrub Scrub, 5. Open Water, and 6. Nonforested Wetlands. The areas with high concentration of these three habitat types may indicate areas a population would be likely to inhabit.

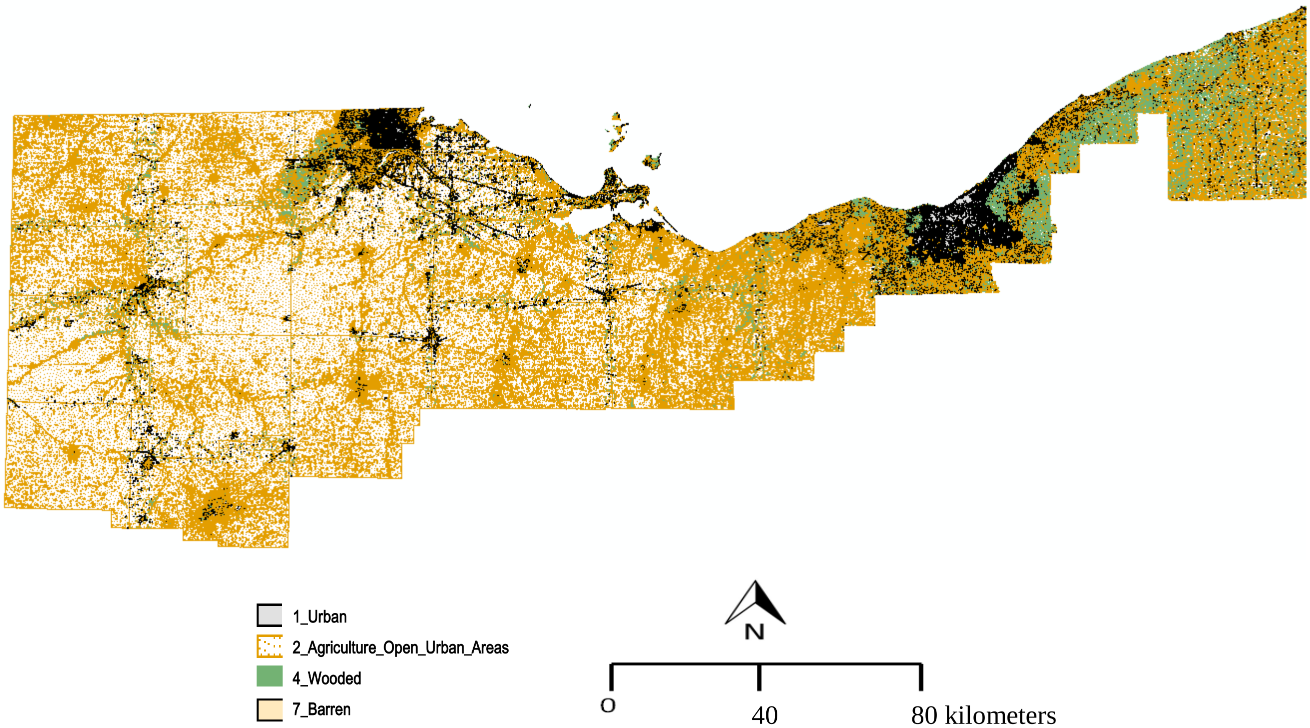

Figure 3.7: Land Use/Land Cover mosaic of northern Ohio displaying only the unusable *Emydoidea blandingii* habitat; 1. Urban, 2. Agriculture Open Urban Areas, 4. Wooded, and 7. Barren. The Land Use/Land Cover map is the best indicator of viable habitat by showing areas to eliminate where the species will not survive.

Preliminary models based on buffer zones larger than 1 mile around target areas predicted no usable habitat. If human impact was so detrimental to negate all areas within one mile of the environmental disturbance, there would be no intact habitat complexes left for this species in Ohio. Assigning Grid Codes with a buffer zone of 2 miles or 3,219 meters (141 pixels) around the areas of wanted habitat and 75 feet or 23 meters (3 pixels) around the areas of unwanted habitat produced these two images that were then combined for a single preliminary image. Using an attribute table created by Erdas, which detailed all pixels in the image, the opacity of individual pixels for undesirable habitat was changed along with the corresponding buffers to white, while all pixels for desirable habitat with the corresponding buffers were changed to transparent. This approach allowed the aerial photograph mosaic image layer (Fig. 3.8b) to be placed beneath the computer model (Fig 3.8a). This final image is a composite of figure the positive attributes of Figure 8 minus the negative attributes shown by Figure 3.7.

This habitat niche model (Fig. 3.8) predicted where appropriate habitat exists, along with habitat corridors that turtles may use to travel to more remote nesting grounds or safe migration routes. The output was magnified in Figure 3.9 to view areas where Blanding's turtles are known to currently inhabit in Cuyahoga, Ottawa, Lucas, and Erie counties. Pockets of appropriate habitat are heavily fragmented by unusable habitat. Few, if any, corridors remain to link areas. These turtles therefore must transverse numerous areas of unusable habitat for females to utilize nesting grounds, for the males to move to new areas to mate, and for sub-adults to move to the appropriate habitat for the next life history stage. The type of unusable habitat is not visible in these models,

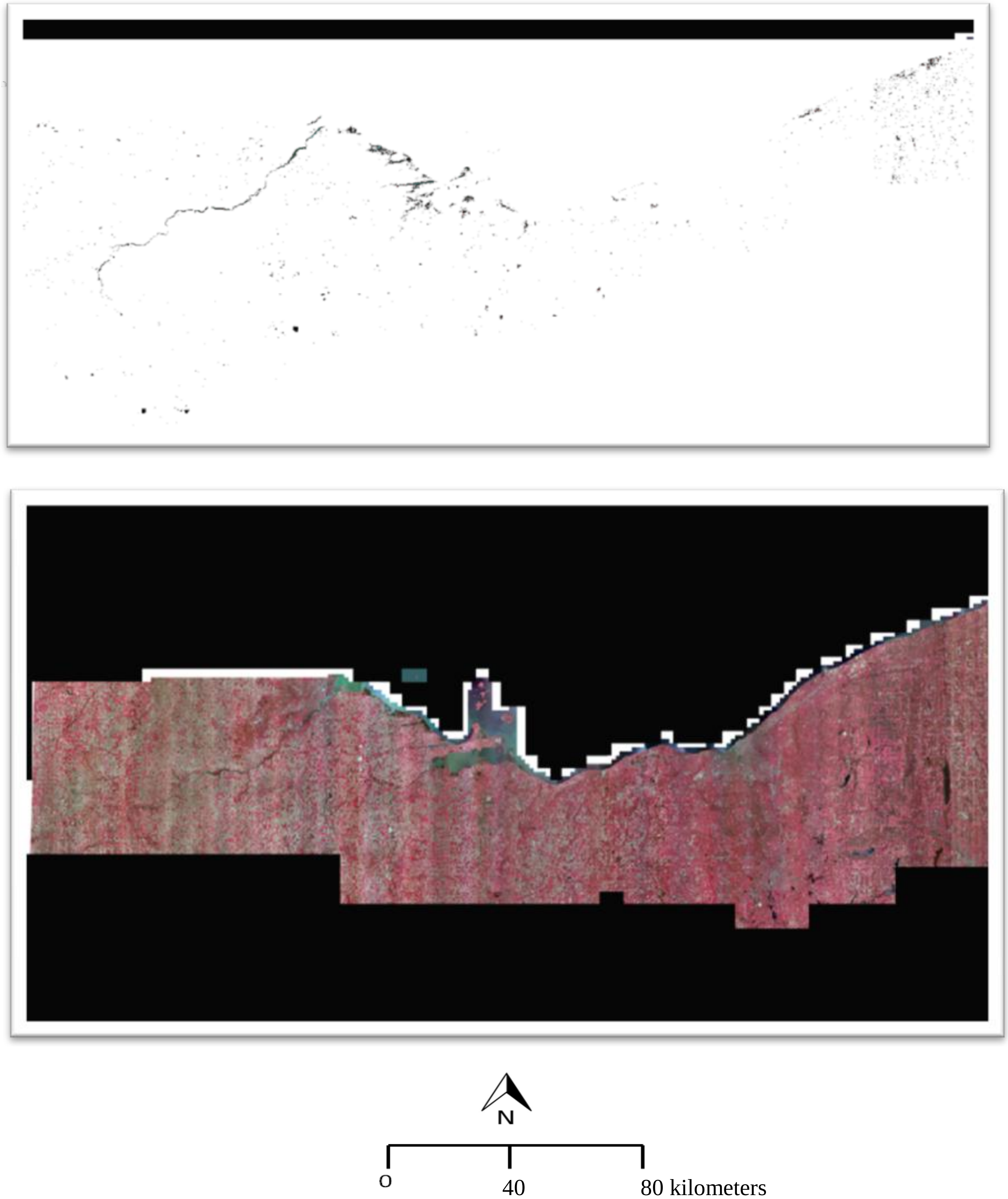

Figure 3.8a: Final Habitat Niche Model. The Land Use/Land Cover of usable habitat (Fig. 8) with a 2 mile buffer was combined with the unusable habitat (Fig. 9) to create a single image. This image eliminated all buffered areas of unusable habitat as well as usable habitat that did not meet the 2 mile requirement by covering the satellite image (Fig. 6) in white. Remaining is viable areas that may be able to sustain a population of *Emydoidea blandingii*.
Figure 3.8b: Aerial photograph of the region for reference.

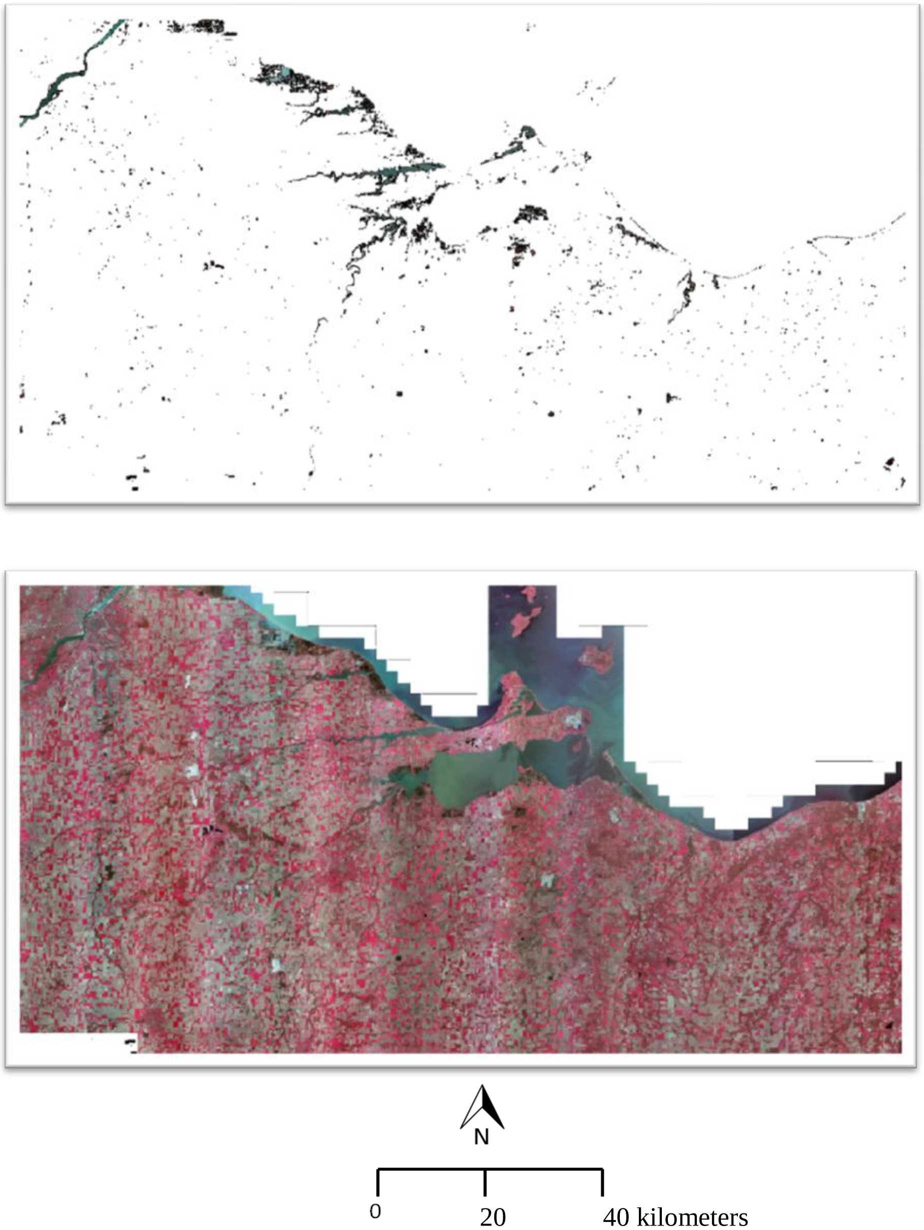

Figure 3.9a: Habitat Niche Model for Cuyahoga, Erie, Ottawa, and Lucas Counties. The areas of the highest concentration of viable habitat are also those possessing the remaining populations of *Emydoidea blandingii*.
Figure 3.9b: Aerial photograph of the region for reference.

Figure 3.10 shows the lack of available habitat in Cuyahoga County near the protected population in Cleveland Metroparks Ohio and Erie Canal Reservation (Circled in yellow). This area has no open corridors for movement, is surrounded by industry and has little to no room for expansion. The area in which turtles were found is therefore not large enough by the parameters chosen here for the habitat niche model to recognize any viable habitat.

Ottawa County (Fig. 3.11) appears to hold the most promise for Blanding's turtle restoration. The desirable areas found near the lake are the densest in the state and varying habitat types exist within close proximity of each other. This region has been historically, a location of multiple populations and may have the potential for reestablishment of additional populations. Lucas County (Fig. 3.12a) is adjacent to Ottawa along Lake Erie's western basin and also has some overlap of dense appropriate habitat sites. Lucas County also contains the upstream Lower Maumee River Basin, where tributaries may provide corridors to other suitable area.

To the east of Ottawa County lies Erie County including Lake Erie's Central Basin (Fig. 3.13a) is not as industrialized as Cuyahoga County, but habitat remains heavily fragmented. Habitat near the lake may be available and is worth closer observation. The potential Erie populations, from these models, would need some protected habitat and restoration if a population were to survive without the need for consistent intervention.

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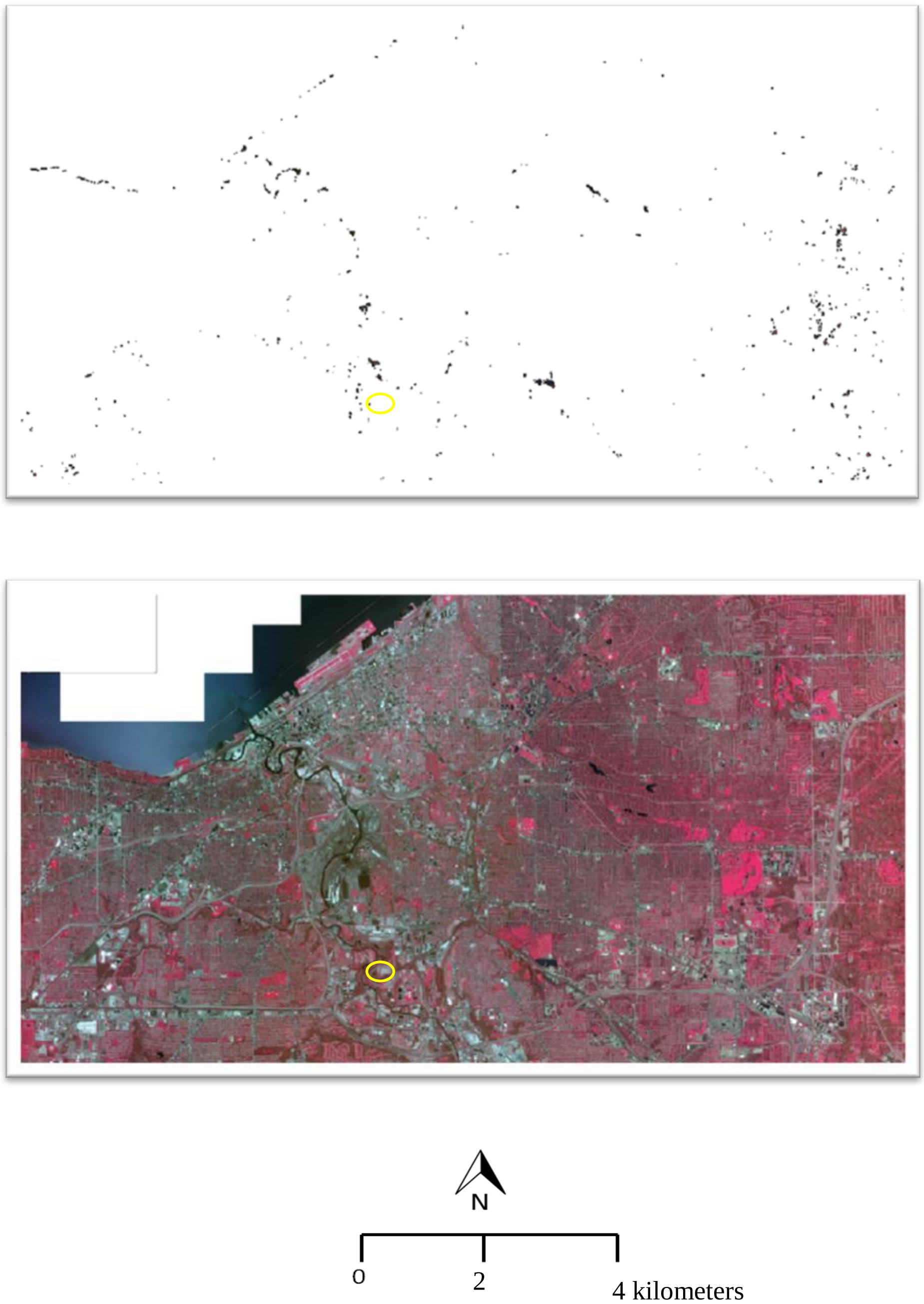

Figure 3.10a: Habitat Niche Model for Cuyahoga County. Visible areas indicate viable habitat. As you can see there are no areas with high concentration desirable habitat. The population in the Ohio and Erie Canal Reservation (circled in yellow) is surrounded by industry. This area, where four adult animals were found in 1999, may support a small population but will most

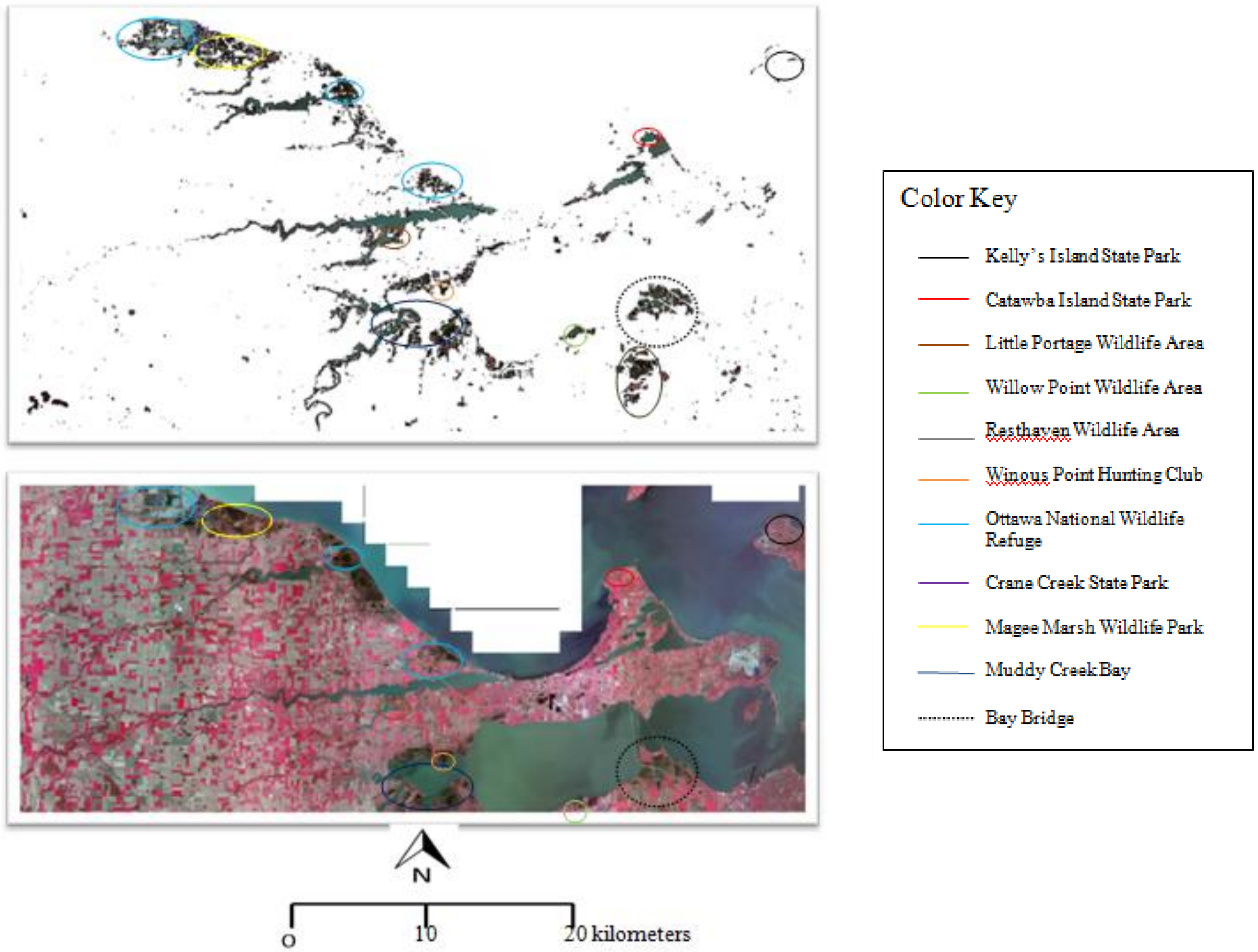

Figure 3.11a: Habitat Niche Model for Ottawa County. Visible areas indicate viable habitat. Ottawa County has the highest concentration of remaining habitat found in Northern Ohio and may also be the best area to look for additional undiscovered populations of *Emydoidea blandingii*, to establish protection for the current remaining populations, to develop possible repatriation sites. **Figure 3.11b:** Aerial photograph of the region for reference.

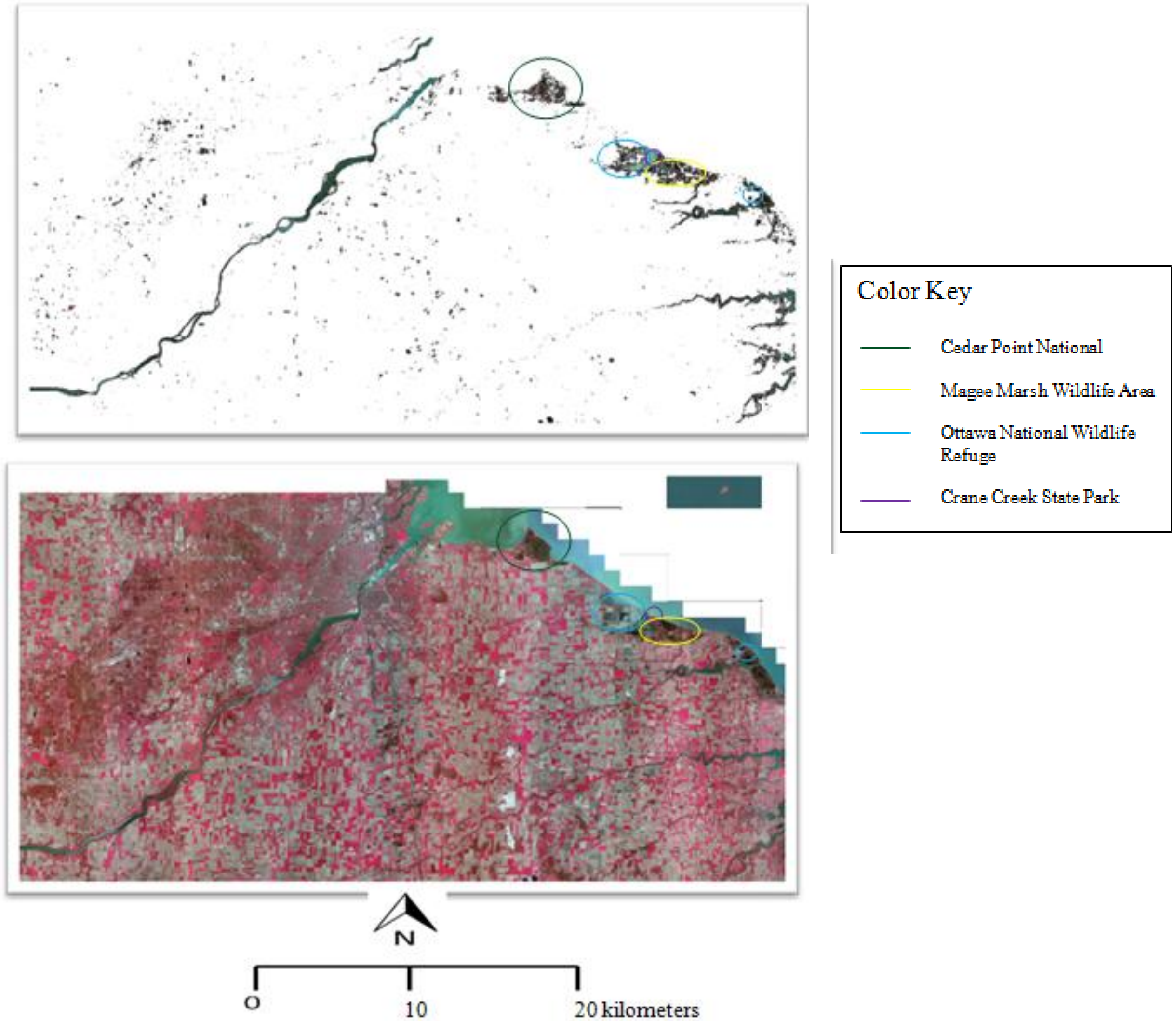

Figure 3.12a: Habitat Niche Model for Lucas County. Visible area indicate viable habitat. Some areas of high concentration of desirable habitat remain in Lucas County near its border with Ottawa County along Lake Erie. These areas may be potential sites for state protection.
Figure 3.12b: Aerial photograph of the region for reference.

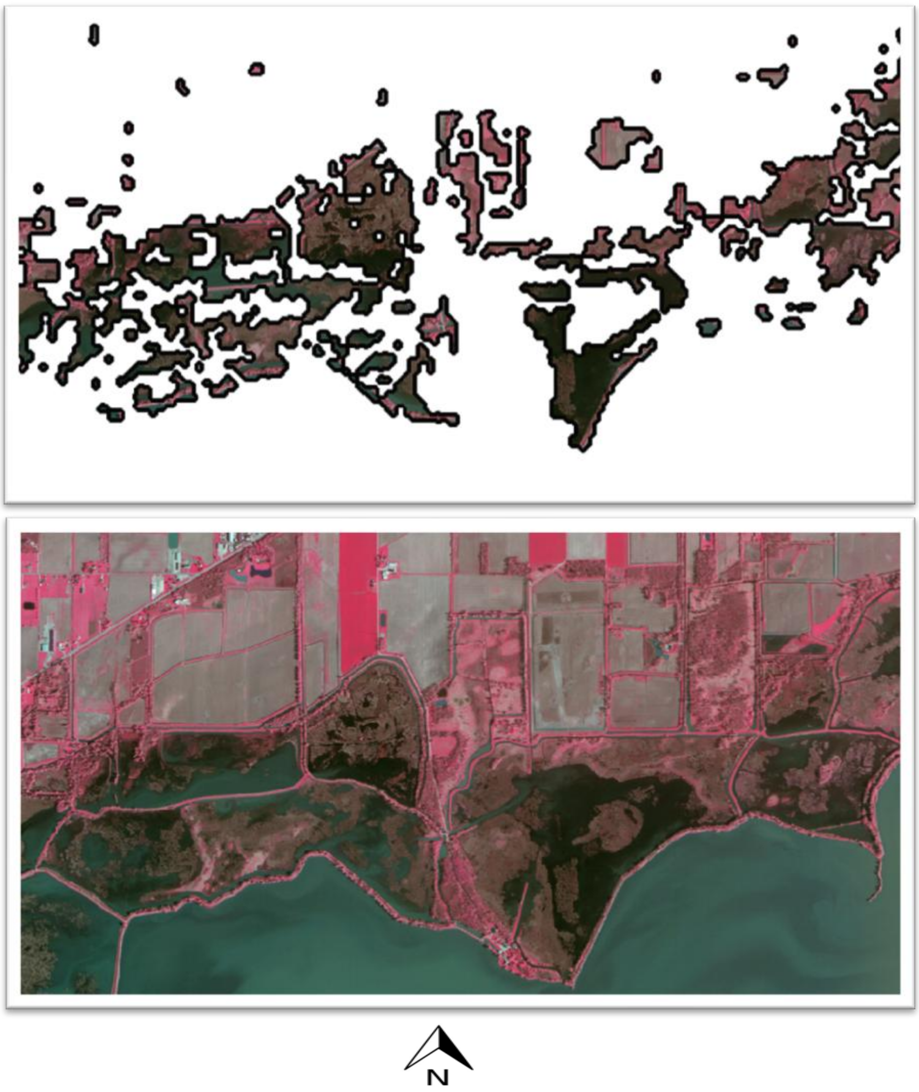

Figure 3.13a: Habitat Niche Model for Winous Point Hunting Club. The computer identified this area as having usable habitat for Blanding's turtles. Blanding's turtles do exist here in the marshland; however, the computer also identified areas within this marsh land as unusable habitat. This is an example of an area that needs ground truthing to identify why the model identified pixels as unusable within usable habitat.
Figure 3.13b: Aerial photograph of the region for reference.

Niche Modeling Discussion

The habitat niche model produced by the Erdas Imagine Program indicates remaining habitat that has the potential to be suitable for *Emydoidea blandingii*. Although the maps show areas that fit the criteria over the entire region, conservation and protection efforts should be focused on the counties in the former range of this species. The remaining populations of Blanding's turtles occur in Cuyahoga, Ottawa, Lucas, and Erie Counties and their presence reflects the number of habitat sites in close proximity.

In comparing species occurrence from 1953 to present to the habitat niche models of the Ottawa and Lucas Counties, the model accurately predicted where Blanding's turtles should be found. Most of the populations live in wildlife refuges indicated by the colored circles (Fig. 3.11a & 3.12a). Winous Point Mash is protected by the Winous Point Shooting Club as it resides on privately owned land (Fig. 3.13a). This population, however, lacks appropriate nesting grounds. The state records indicate that a population also may still exist near Muddy Creek Bay, an area that does not currently receive any form of protection by the state or county. This population will, without habitat reconstruction and protection, either need to be heavily managed, repatriated, or it faces almost certain extirpation.

The habitat prediction model indicates that the best chance for continued survival of Blanding's turtles in Ohio lies west of Sandusky along the coast of Lake Erie. Kiviiat suggested in 1997 that effective preserves for Blanding's turtles need large habitat complexes with 1000 meter buffer zones abound wetland areas. The areas located between the wildlife refuges along the Ottawa County coast of Lake Erie may still harbor additional or fragmented populations of Blanding's turtles.

A compilation project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group on the status of the Blanding's turtle (Congdon et al. 2008) suggested a number of proposals to ensure the survival of the species. Among these suggestions was an effort to reduce road mortality via habitat fragmentation. Signs could be placed to increase driver awareness at locations where high volumes of traffic from vehicles intersect turtle movement patterns. Fencing and safe crossing areas (e.g. culverts, tunnels, or bridges) can be implemented to existing areas or areas of new construction. Additionally, Congdon et al. (2008) suggest removing invasive species (both plant and animal) that impact nesting grounds and hatchling mortality, and creating monitored artificial nesting sites. If these suggestions could be implemented along with habitat preservation and restoration of known population sites as well as identifying additional areas for unknown populations or repatriation sites, Blanding's turtles continued survival in the State of Ohio may be possible.

A positive relationship has been demonstrated between areas of roadless habitat and the home range size of Blanding's turtles in Massachusetts (Grurovic and Sievert in 2005), and the authors suggest that large landscapes are needed to support even single animals let alone an entire breeding population. If this area of wetlands could be protected and the necessary measures (e.g. fencing, tunnels, road signs, etc,) instated to ensure safe migration corridors, these fragmented turtle populations could be linked, creating one large complex and ultimately an area suitable for a self sustaining population. Another area that appears to have a high concentration of wetlands that may support a population of Blanding's turtles is the surrounding area of the City of Bay

Bridge in Ottawa County. The wetland complex may, with protection and reconstruction be viable for population translocation.

Niche Modeling Conclusions

I would recommend a detailed survey of the regions identified. Areas shown in the niche model with high concentrations of appropriate habitat and corridors for the turtles to navigate should be field checked in an effort to locate additional Blanding's turtle populations. Previously unknown populations or possible sites for translocation and/or repatriation of the species are possible. Areas selected for conservation that are heavily fragmented by roads and industry should be looked at for mortality rate during the spring nesting season and be addressed with tunnels, gates, fences, or perhaps translocate the turtles westward where some viable habitat remains. The Cuyahoga County population discussed herein has been supplemented via Cleveland Metroparks repatriation project. Management interventions that focus on maintaining high adult survival and increasing juvenile recruitment can be the most beneficial to the survival of turtles in the region as suggested by Rubin in 2004 for his study population in suburban Chicago. Although there has been some success of animals surviving in the release area, it is visible in Figure 3.10 that this site is not viable for a long term, self sustaining population and the aforementioned conservation methods should be considered. I would suggest translocation of these animals to an uninhabited site or to bolster an existing population in a region with suitable habitat.

The decline of *Emydoidea blandingii* in the Great Lakes region warrants further attention and conservation measures to address the negative pressures on remaining populations. A future survey should evaluate habitat suitability and sustainability and contribute to the habitat maps that can facilitate the development of successful habitat management models. A quantitative assessment of the suitability of identified areas should include quantifications of aquatic foraging, dispersal, nesting habitat, hatchling habitat, over-wintering habitat, basking habitat, and the corridors to transverse these areas. The areas should be scored categorically to further identify areas with the best possible chance of protection, rehabilitation, minimization of current threats, and for the potential to enable populations of *Emydoidea blandingii* to persist.

Here, I explored the use of GIS software as a habitat niche locator and identified areas in which to focus further conservation efforts. In the future, more specific information may be added to the current offerings by the State of Ohio to refine parameters such as specific soil data, vegetation types found at the banks of lakes and rivers, water depth and depth of the lakes, rivers, or wetlands substrate. Additional information may lead to better prediction models.

The limitations of the current programs can be viewed in Figure 3.13. A closer view of the area shows the usable habitat surrounded by agriculture. However, within the usable habitat, the computer identified areas in the marsh as an unwanted type and placed a white pixel where the habitat should be usable. Ground truthing needs to be done in areas such as this to determine exactly what the algorhythm is identifying as unusable. For the purpose of this study, the program identified the areas of high concentration of Blanding's turtle habitat, and narrowed the search in the state to areas in which to concentrate further efforts.

The decline of populations globally is reaching 75% for turtles listed as threatened or endangered, making them the most imperiled vertebrates on the planet. Many of these animals are extirpated because of loss of nesting beaches, migration routes, forging areas, and habitat fragmentation.   Habitat niche modeling though GIS and remote sensing may allow researchers to identify these habitats for protection and implementation of conservation strategies to manage turtle populations. One of the key elements for protecting endangered turtles is to survey habitats to find unknown populations. With the tools outlined in this paper, a researcher can plot in known nesting sites of turtles and run the program to find similar nesting habitat. The results would significantly reduce time and resources by concentrating efforts in key habitat areas rather than systemic surveying.

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