Lipps Jr GJ. 2021. Reptile Conservation. Pages 889-920 in: Davis JG, Lipps Jr GJ, Wynn D, Armitage BJ, Matson TO, Pfingsten RA, and Caldwell C (editors). Reptiles of Ohio. Ohio Biological Survey Bulletin New Series, Columbus, Ohio.

Section X

Reptile Conservation

Gregory J. Lipps, Jr.

A Woodland Box Turtle crosses the road following a late May storm. Lucas County, Ohio. Greg Lipps, Jr. photo.

From the vantage point of younger reptile enthusiasts perusing the latest publications, it might seem that nearly all recent reptile research has a conservation and management focus, at least implicitly. Conversely, there is still a sizable number of “old timers” who haven’t realized that reptile conservation has gone mainstream, believing that wildlife agencies, organizations, and academics are still only interested in the “hook and bullet” species, failing to recognize the resources that are expended yearly on wildlife diversity (non-game species). It is true that management of game species is still much better funded than that of non-harvested wildlife, but that is mostly an artifact of how and when funding was established, more than lingering ignorance of biologists who fail to see value in species that do not provide food, fur, or sport.

While the dramatic decline in amphibian populations has been in the spotlight since the late 1980s (Lipps and Matson 2013), reptile conservation has lagged behind. It has only been recently that comprehensive volumes dedicated to the topic have appeared, most notably Klemens (2000), Mullin and Seigel (2009), McDiarmid (2012), and Dodd (2016), all essential resources for the reptile conservation practitioner. These works, and the research they draw upon, are invaluable considering that snakes, lizards, and turtles are likely just as imperiled as any vertebrate taxa (Gibbons et al. 2000). Given the amount of work that is required before the Global Reptile Assessment can be completed, a randomly selected, representative, and global sample of 1,500 reptiles (16% of all reptile species) was analyzed as a shortcut for identifying patterns of risk among reptiles (Böhm et al. 2013). This analysis revealed that nearly one in five species is threatened with extinction, with an equal proportion classified as data deficient. The predominant threats identified were human-induced habitat loss and harvesting.

The lack of reliable data concerning reptiles, including their current and previous distributions, changes in populations, and even basic life history information, pervades every discussion of reptile conservation. Many species are quite cryptic in their habits, making it difficult to confidently determine even where they occur. A survey that results in an observation of a species is easy to interpret: it occurs at the site. But what to make of the survey that fails to find even a single individual? Is it absent from the site (true negative), or does it occur there but went undetected (false negative) due to the environmental conditions, the species being inaccessible (e.g., underground), the techniques employed, the inexperience of the surveyors, and/or for some other, unknown, reason?

This issue of imperfect **detection** of reptiles has long been recognized, leading to common sense practices such as not attempting to estimate population sizes or even relative abundances based simply on raw counts. Accounting for the detection probability of reptiles has quickly become standard practice in most field research, reducing biases in estimates that are crucial for conservation, including occupancy, abundance, and survival (MacKenzie et al. 2006; Mazerolle et al. 2007).

The most frequently used method for gathering information on populations of reptile species that occur in Ohio is **capture-mark-recapture** (**CMR**), where captured individuals are marked and released and subsequent counts of the number of marked and unmarked animals are used to calculate population sizes and vital rates (Plummer and Ferner 2012; Rodda 2012). Even when using CMR, reptiles can often be frustratingly difficult to study, as detection probabilities may vary widely for reasons that are difficult to determine, even at a single site (Durso and Seigel 2015), and capture rates for some species are often too low to result in sensible analyses (Steen 2010). Moreover, “successful” CMR projects for reptiles commonly result in estimates of population sizes and vital rates that are so imprecise as to make it impossible to detect all but extreme changes in these values over time, frustrating efforts to monitor the status of populations. The use of integrated population models to combine the often sparse and fragmentary data associated with reptiles is one promising avenue for helping to overcome some of these issues (Zipkin and Saunders 2018; Crawford et al. 2020).

Despite all these limitations in our knowledge of the life history of species and in our ability to monitor populations, it is evident that the abundance of many reptile species has declined in Ohio and that ranges of some species have contracted. It is equally clear that these limitations should not be used to further a perception that we “must study something to death before making conclusions” (Seigel and Mullin 2009). As a crisis science, conservation biology requires action even when the data is less than ideal.

While the response to the well-publicized amphibian declines resulted in a coordinated response, including five amphibian conservation conferences in Ohio (1996, 1999, 2004, 2008, and 2012), it wasn’t until 2010 that a similar Ohio Reptile Research and Conservation Conference was organized, and repeated in 2014. In 2018, these were both replaced with an annual conference focused on both amphibians and reptiles launched under the umbrella of a newly formed Ohio chapter of **Partners in Amphibian and Reptile Conservation** (**PARC**). PARC was established in 1999 to address the widespread declines, extinctions, and range reductions of amphibians and reptiles in the United States. The founders of PARC envisioned a partnership of diverse parties, including government agencies, academic institutions, industry, businesses, and conservation-minded citizens working together with a shared goal of “keeping common species common.” The Midwest Regional Working Group of PARC was the first of five working groups established and from the beginning has included individuals from Ohio.

PARC has identified six threats to amphibian and reptile populations, and all are relevant to the conservation of Ohio’s reptiles. These threats include: (1) habitat loss, degradation, and fragmentation; (2) diseases; (3) pollution; (4) invasive species; (5) global climate change; and, (6) unsustainable use. As the amount of research published on each of these topics is vast and continues to grow, what follows are admittedly incomplete summaries, with emphasis on the Ohio landscapes and reptile communities.

For homeowners and land managers looking for more information and guidance on managing their property to benefit reptiles, a recommended resource is PARC’s *Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States* (Kingsbury and Gibson 2011) available for free at **mwparc.org**. The book provides practical recommendations written in easy to understand language for improving the compatibility of land management practices with the conservation of native amphibians and reptiles.

Habitat Loss—It is widely agreed that the destruction, degradation, and fragmentation of natural habitats is the greatest driver of the loss of biodiversity, both in Ohio and worldwide. By the early part of the twentieth century, Ohio’s landscape had been greatly altered from that which was found

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at the time of European settlement. Gone were the majority of the state's forests, prairies, and wetlands. In their place were agricultural fields, urban centers, and a vast network of roads, railroads, canals, and ditches. It's impossible to know exactly what effect these changes had on the reptile fauna, but judging from the effects of modern day changes in land-use and land-cover, it is likely that distributions were altered and the abundance of many species was greatly decreased.

In what is now Ohio's most forested region, the rush to mine and smelt iron ore in the nineteenth century took a heavy toll on forests. By 1869, Ohio had 45 charcoal blast furnaces, most located in Jackson, Vinton, Lawrence, and Scioto counties. The production of "pig iron" at these furnaces required over 300 acres of timber per furnace each year to produce charcoal. One reason for the demise of the furnaces at the end of the nineteenth century was the scarcity of timber, a remarkable feat considering the forest resources of the region. In the first decade of the twentieth century, forest cover had been reduced to 10% of the state, but since the 1940s it has steadily increased to where it now comprises 30% (Widmann et al. 2009; Albright 2018).

In the northwest portion of Ohio, settlers took to clearing and draining what was the largest wetland complex in the modern continental United States, the Great Black Swamp. Stretching from the western edge of Erie County, south to northern Darke County, and west to New Haven, Indiana, the swamp forest covered nearly 4,000 km^2, more than twice the size of the Florida Everglades.

The conversion of the Great Black Swamp was largely completed in the late nineteenth century, thanks in part to demand for timber by a growing country and the ease at which it could be transported by the newly constructed canals and railroads. Public ditch projects and more than 50 drain tile factories helped complete the conversion to the row crop dominated landscape found in northwest Ohio today (Figure X-1). The near complete loss of the Great Black Swamp helped put Ohio second only to California in the percentage of original wetlands lost, estimated at 90% from the 1780s to the 1980s (Dahl 1990).

Similarly, the prairies that dotted the western portion of the state were quickly put under plow, given the productivity of their soils. Comprising 2.5–4% of the state's original land cover, a greater proportion of prairies have been lost in Ohio than any other habitat type.

Similar landscape-scale changes to Ohio's rivers, creeks, springs, and marshes also occurred during settlement of the state and were detailed by

Figure X-1. Color infrared aerial image of a portion of central Paulding County, the only county that was entirely within the boundaries of the historic Great Black Swamp. Today, nearly the entire county is underlaid by a network of drainage tiles, that together with the drainage ditches they empty into, have allowed for row crops (predominantly corn and soybean) to become the dominant land-use. Areas inhabited by reptiles are severely limited in such areas, and mostly consist of species that are more generalists in their habitat requirements. From the Ohio Statewide Imagery Program.

Trautman (1981). During the period of 1801–1955 in Ohio there was widespread draining-ditching-tiling of the land, clearing of forests, impoundment of waterways for industrial and domestic uses and to prevent flooding, and a dramatic decrease in groundwater levels.

The increase in drainage and amount of impervious surfaces associated with developed areas, along with the drop in groundwater levels has had significant impacts on hydrologic regimes. Early accounts of Ohio indicate that springs were very numerous throughout the state and most flowed year-round. Large flooding events were mainly limited to times of winter thaw and spring rains. By 1950, "once universally abundant springs had become a rarity in many sections, or they flowed only during the wettest portions of the year" (Trautman 1981).

The severity and frequency of floods and droughts also increased after 1850 (Trautman 1981). The efforts of pioneering Ohioans to promptly move water off the land and into the nearest waterway were proving successful, causing many streams to become intermittent during summer droughts and raging torrents with falling rain or melting snow.

In 1940, the average drop in the groundwater table from 20 years previous was an astounding 6 m. Considering the number of Ohio reptile species that rely on groundwater for survival, these changes likely had dramatic impacts on populations. For example, many of the preceding species accounts document the importance of crayfish burrows, ant mounds, and small mammal burrows as over-wintering sites for Ohio's snakes and lizards, and quite often the burrows permit access to the groundwater to avoid desiccation and freezing (Carpenter 1953; Ravesi et al. 2015). Similarly, for Ohio's freshwater turtles, areas with groundwater influence can provide an important "Goldilocks zone," where water is shallow enough to allow for occasional aerial respirations, but—thanks to the groundwater—unlikely to freeze to the bottom.

In recent years, Ohio—like much of the Midwest—has come to be dominated by three broad terrestrial land-covers/land-uses: agriculture, forest, and urban. Using field notes of original surveys and other sources, Sears (1926) estimated that "natural treeless" areas originally covered at least 1,500 square miles (3,885 km^2) of Ohio. For many reptiles, physiological functions are optimized when body temperatures are greater than 25° C, and this often requires access to sunlight. Treeless areas can thus be a critical component of reptile habitat, even for species that are generally thought of as forest dwellers.

The widespread loss of natural herbaceous-dominated land-covers, including prairies, grass-lands, and similar "treeless" areas is reflected in temporal changes in the documented occurrences of five reptile species that are dependent on such habitats. If occurrences documented after 1989 accurately portray the current distribution of these species, then 128 Ohio townships have lost from one to three of the five herbaceous-obligate species that were found there on or before 1989 (Figure X-2A). In only 45 townships has there been an increase in the documented occurrences of these species, with 14 unchanged. These changes have largely occurred in glaciated western Ohio, where both grassland species and their habitats were most common.

Applying this same methodology for five forest-obligate reptile species tells a different story (Figure X-2B). For this group, documented species richness has declined in 163 townships, increased in 173 townships, and not changed in 56 townships. Changes in forest-obligate reptiles are also not randomly distributed, being most notable in the unglaciated southeast portion of the state. While some of these changes, particularly the increases in species richness, are undoubtedly due to increased sampling effort, many of the decreases are located near population centers where occurrences should be less likely to go unreported. Furthermore, there is no reason to suspect that forest reptile species occurrences are more likely to be documented, particularly given the resources

Figure X-2. [**opposite page**] Changes in documented species richness in Ohio townships after 1989 compared to before 1989 (inclusive) for selected species dependent on **A.** herbaceous and **B.** forested habitats. The total number of species documented on or before1989 was subtracted from the total number documented after 1989. Larger symbols correspond to a greater change of documented species richness, some of which may be due to changes in survey effort. The five herbaceous obligate species in **A** include: Spotted Turtle (*Clemmys guttata*), Kirtland's Snake (*Clonophis kirtlandii*), Smooth Greensnake (*Opheodrys vernalis*), Eastern Massasauga (*Sistrurus catenatus*), and Plains Gartersnake (*Thamnophis radix*). The five forest obligate species in **B** include: Woodland Box Turtle (*Terrapene carolina*), Eastern Copperhead (*Agkistrodon contortrix*), Timber Rattlesnake (*Crotalus horridus*), Ring-necked Snake (*Diadophis punctatus*), and Smooth Earthsnake (*Virginia valeriae*). Data for occurrences comes from the present work, as explained in the Introduction to the Species Chapters (Section IV).

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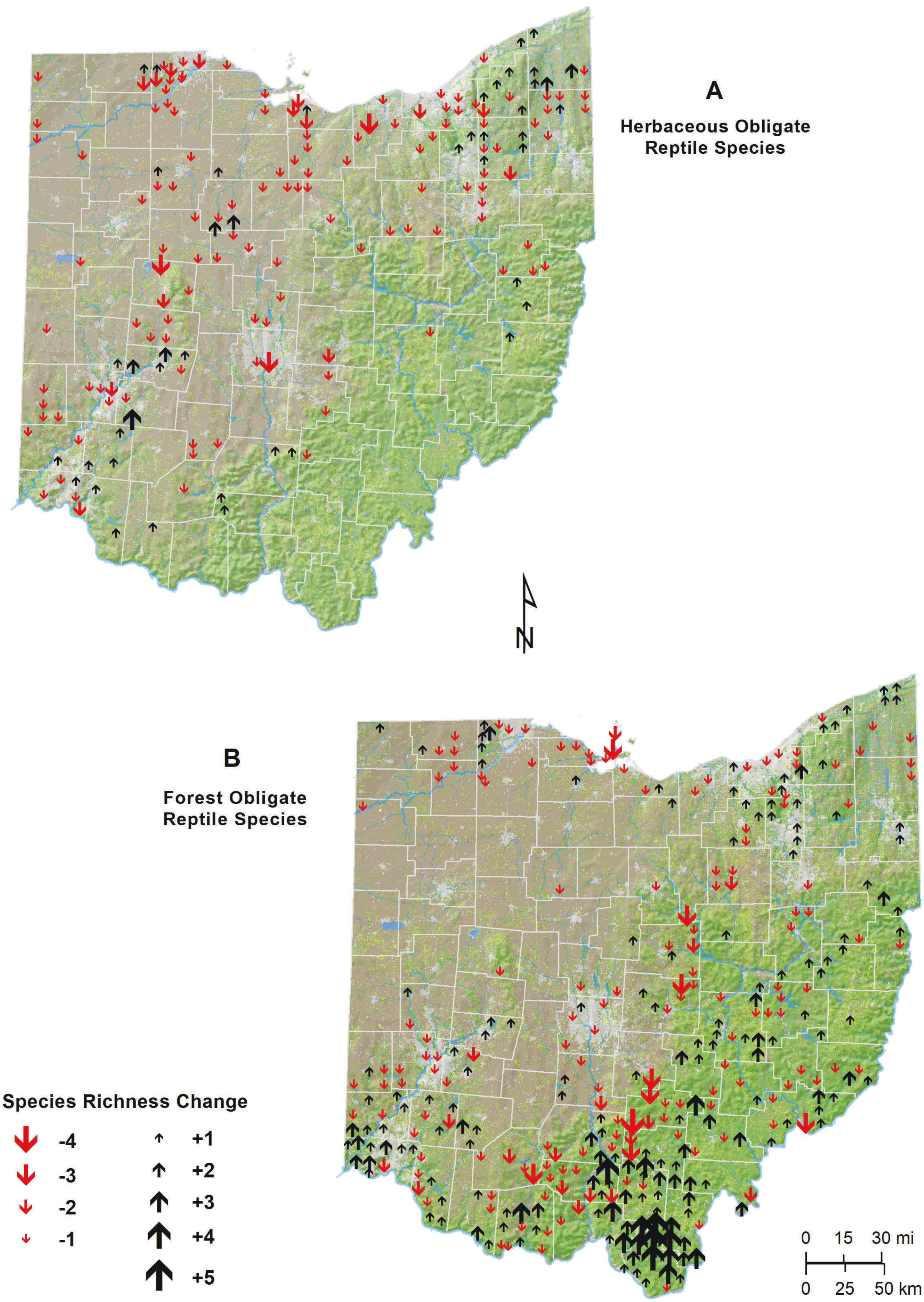

that have been expended on research related to the five herbaceous-obligate species since 1989.

That forest-reliant species are faring relatively better than those that rely on grasslands should not come as a surprise, given the changes in Ohio's landscape. This trend is likely occurring throughout the Midwest. In one of the longest-term studies of a native reptile community, Fitch (2006) found that a large portion of the herpetofauna of the 293 ha (724 acre) University of Kansas Natural History Reservation had been reduced by natural succession over the 58 year period of study. In the decades following the removal of cattle, horses, and sheep, and the subsequent succession of the pastures that covered one-half of the area, captures of many species changed drastically. In the first season following the removal of the livestock and the reversion of the pastures to a "luxuriant grass-weed mixture," there was a population explosion in the Prairie Vole, leading to a subsequent increase in its predators, including many snake species. As **vegetative succession** led to dense woody vegetation in these areas, though, many species became rare with several disappearing altogether. Most of the lizard species were the first to go, followed by the snakes. The elimination of disturbance, both natural (fire) and anthropogenic (livestock grazing), resulted in a natural area that is more homogeneous, more forested, and with less reptile diversity.

I have witnessed events similar to those of Fitch (2006), albeit on a shorter timescale. At two sites in Ohio, row-cropped agricultural fields adjacent to fields containing Eastern Massasaugas (*Sistrurus catenatus*) were removed from agriculture and allowed to revert to a mix of native and non-native herbaceous vegetation. In each case, Meadow Voles became incredibly abundant, with individuals seen scurrying with every few steps through the sparse vegetation. It's likely that the small mammal populations had been subsidized by the plentiful waste seed (corn and soybean) from previous farming. In both cases, Eastern Massasaugas colonized the former farm fields and became very abundant, with one having an estimated population density of 15 Massasaugas per hectare in only 2–3 years post-farming (Figure X-3). Other snake species that do not feed on mammals apparently benefitted too, including Butler's Gartersnakes (*Thamnophis butleri*), which were abundant in one of these "new" fields. Meanwhile, snake captures dropped precipitously in adjacent fields that were undergoing succession and becoming dominated by woody vegetation.

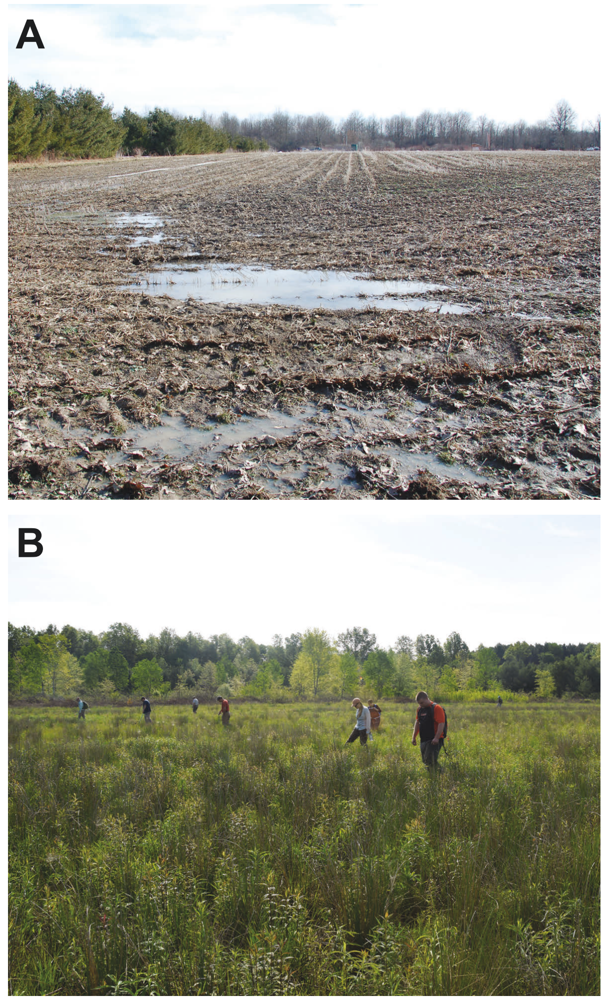

Figure X-3. A. Ashtabula County farm field purchased in 2011. **B.** Volunteers participate in a survey for the Eastern Massasauga at this same site in 2016. Disabling of the drain tiles, removal of pine trees, and treatment of invasive plant species occurred in the intervening years. Based on capture-mark-recapture data, the density of Massasaugas inhabiting this field was estimated at 15 snakes/ha. Greg Lipps, Jr. photos.

While it is relatively easy to understand how the loss of natural and semi-natural open-canopy herbaceous habitats affects species that spend all of their lives in them, such as the Spotted Turtle (*Clemmys guttata*), Eastern Massasauga, Butler's Gartersnake, and Smooth Greensnake (*Opheodrys vernalis*), less appreciated is how this impacts nearly all other reptile species. For example, Fitch (2006) noted that the formerly common Timber Rattlesnake (*Crotalus horridus*) declined, then disappeared, from his study area in the 1960s, apparently due to the spread of thick stands of deciduous trees along the limestone outcrops, eliminating critical basking areas for the species.

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Even for forest-dwelling reptile species, open areas are critically important.

Ohio's turtles are also affected by vegetative succession, particularly as it degrades nesting habitat. Turtles generally deposit their eggs in friable soils where nests can be easily excavated by females, and where sunlight reaching the ground will ensure incubation temperatures necessary for embryo development (Weisrock and Janzen 1999). For aquatic species, eggs are laid some distance from the water, but not so far as to make it impossible for at least some of the hatchlings to successfully make the journey to water after leaving the nest (reviewed by Steen et al. 2012). All too often, however, these areas are being lost, either to succession, the proliferation of invasive plant species, or to development. At Michigan's E.S. George Reserve, a fenced-in natural area where turtles have been protected and studied for decades (Congdon et al. 1987, 1993, 2003, 2011), recruitment has been severely curtailed due to nesting areas being overtaken by woody and invasive plant species (Justin Congdon, pers. comm.).

The degradation of nesting areas has particular importance for turtle species that have temperature dependent sex determination (TSD), which in Ohio is all except for the two softshell species. In general, more female hatchlings are produced in warmer nests, and nests are warmer where there is less vegetation (more solar insolation). The growth of vegetation, whether from native or exotic invasive plants, can cause shading that reduces nest temperatures, potentially resulting in the failure of embryos to develop or nests that are male biased.

If the data from snakes and turtles is not convincing, the much more thoroughly studied bird populations provide additional evidence of the widespread decline of species requiring grassland habitats (Hudson et al. 2017). Trends in grassland bird populations are most clearly associated with trends in available habitat, with both declining historically and recently (Hill et al. 2014). Similar concerns over the widespread loss of pollinators, especially bees and butterflies (Potts et al. 2010; Wepprich et al. 2019), have awoken many to the issue of the loss of our "natural treeless" areas.

One of the effects of the loss of natural herbaceous habitat is that many reptile populations have an increased reliance on alternative—and usually more marginal—habitats for fulfilling portions of their life history. For some turtle populations, the side of the road offers the best available nesting habitat (Figure X-4). Turtle road kills spike every year in Ohio in late May–early June, coinciding with nesting activity. While the advice to help turtles across the road in the direction they are travelling is sound, it doesn't address the issue that many of these animals aren't attempting to cross the road; the road is their destination! Obviously, the dangers of roadside nesting are great, both for the nesting female and any resulting hatchlings. The successful use of artificially created nesting areas (piles of sandy, friable soil) for turtles is promising (Beaudry et al. 2010; Paterson et al. 2013), and more work is needed to understand if their strategic placement could help reduce turtle road mortality.

Other suboptimal habitats used for turtle nesting include trails and agricultural fields. Row crops (predominantly corn and soybean) are the most common land-cover in Ohio but, like road berms, may be an ecological trap for nesting turtles. At the time when nesting is occurring, the young, short crops surrounded by bare soil may appear to be a suitable place for a female to lay her eggs. In just a few weeks, though, these sites are likely to be completely shaded by the growing crop plants, and in many cases are unlikely to provide the solar insolation required for successful development of the embryos (see Chapter 4, Blanding's Turtle).

Utility corridors—for powerlines, pipelines, and transportation networks—have also come to be an important alternative open-canopy habitat for many Ohio reptiles. In northwest Ohio's Lucas County, utility corridors can be a refuge of Twigrush wet prairie habitat in areas that have been otherwise

Figure X-4. Road berms are often used by turtles for nesting, due to their exposure to the sun. Midland Painted Turtle. Trumbull County. Greg Lipps, Jr. photo.

degraded by the invasion of exotic buckthorn and the suppression of fire (Figure X-5). In at least one of these corridors, Spotted Turtles (*Clemmys guttata*) thrive, even using the corridor for nesting (see Chapter 3, Spotted Turtle), as was also documented in a South Carolina population (Litzgus and Mousseau 2004).

While analyzing radiotelemetry location data and constructing minimum convex polygon home ranges for a population of Timber Rattlesnakes in southeast Ohio, I began to notice an odd convergence of points and home ranges for multiple individuals along a linear route. Once a background map was added, the line was shown to be a utility corridor. In a mostly forested area, the corridor was obviously attractive to the snakes, most likely due to the thermoregulatory opportunities it provided. Similarly, research on a Timber Rattlesnake population living along the Nelsonville Bypass in Wayne National Forest (Athens County) found that the roadcut and stone piles installed as drainage control structures were being used extensively by snakes and providing thermally superior habitat to that of the forest, especially for gravid females and those preparing to shed (Sisson and Roosenburg 2017; Hopkins et al. 2018). The researchers recommended that these areas be preserved and not reforested, as they were likely benefitting the population. Utility corridors have received increasing attention for their potential role as wildlife habitat (reviewed by Ouedraogo et al. 2020) and some results are promising (e.g., Yahner et al. 2001, 2004; Wagner et al. 2019), but in general, under what circumstances they may contribute to reptile conservation is in need of much more research.

Another potential “alternative” treeless habitat in Ohio that is worthy of additional study is the numerous sand, gravel, and limestone quarries that dot the state. In New Hampshire, 11% of the snake and turtle records in the state’s Natural Heritage Database were within 500 m of a quarry, despite quarries comprising less than 0.5% of the state (Livaitis et al. 2018). Quarries may offer higher surface temperatures with more open areas, preferred for turtle nesting and snake and lizard basking. The boulder piles and crevices can offer refugia and access to areas beneath the frostline for overwintering. The New Hampshire study found quarries to be especially attractive to North American Racers (*Coluber constrictor*), a species which has become increasingly uncommon in northern Ohio, but which is known to inhabit at least a couple of quarries in the region.

Figure X-5. A Twigrush wet prairie in the Oak Openings Region of Lucas County, home to Spotted Turtles and Northern Ribbonsnakes. This patch is located along a utility corridor, the management of which kept it from becoming overtaken by Glossy Buckthorn and trees. Recent management of the surrounding areas, made possible by funding from the Great Lakes Restoration Initiative, has greatly expanded the amount of this habitat available by removing woody and invasive species and conducting prescribed burns. Greg Lipps, Jr. photo.

A final example of an alternative open-canopy habitat that is used by reptiles is worthy of mention because of the potential for human-wildlife conflict. Campgrounds and other recreational areas constructed in forested areas can sometimes be a haven for the venomous Eastern Copperhead (*Agkistrodon contortrix*). At a southern Indiana park, 54% of radiotracked Copperhead locations were within 3 m of a trail or artificial forest gap (lookout tower and overlook), whereas only 2.5% of locations would be expected within 3 m if snakes were using these areas in relation to their availability (Carter et al. 2014). The gaps appeared to be important gestating and birthing areas for the snakes. Similarly, large numbers of Eastern Copperheads (261 captures of up to 45 individuals) were documented at a campground in an otherwise forested area of Kentucky (Hendricks 2019). At the Kentucky site, the snakes used the campground exclusively to forage on cicadas. In both instances, researchers noted that one possible management strategy to reduce human-snake conflicts was the creation of artificial canopy gaps away from human-use areas. Ironically, these areas of potential conflict were receiving intensive management (i.e., vegetation control) that made them attractive to snakes precisely because they were being used by humans, and artificial canopy gaps are unlikely to remain open without similar attention (Carter et al. 2014).

One of the more sobering realizations concerning open-canopy habitats is that we can no longer rely on natural processes to create and maintain them in the locations and extents that are necessary to conserve the reptile diversity of Ohio. Ohioans who partake in the management of turf grasses that cover 6% of Ohio (Milesi et al. 2005) are well aware that maintaining herbaceous areas—even lawns of exotic grasses with little ecological value—requires constant human intervention to keep them from reverting to forest. Historically, dynamic processes such as fires and floods would have created natural treeless areas. In the Sandusky Plains of Crawford, Wyandot, and Marion Counties, over 77,000 ha (19,000 acres) of fine-textured, low permeability soils historically resulted in alternating between saturated soils in the spring followed by very dry soils in the summer, resulting in frequent fires, all of which maintained the state's largest area of prairies and savannas (Whitney and Steiger 1985). Ditches, tiling, fire suppression, and the conversion to agriculture have all but eliminated this habitat, and what remains today does so only due to intensive management. Similarly, the amount of prairie habitat at the famed Lynx Prairie of Adams County dwindled from covering 47% of the area in 1938 to only 16% in 1971, due to ecological succession (Annala et al. 1983). Like the Sandusky Plains, what remains of Lynx Prairie is entirely the result of intensive efforts to control the junipers and deciduous trees invading the prairies.

The North American Beaver, once common and widespread in Ohio, undoubtedly created many important natural herbaceous habitats. Beaver ponds can flood sizeable areas, submerging and killing trees. As resources dwindle, Beavers move on, abandoning their dams which eventually fall apart leaving the formerly inundated area to slowly revert to an early successional wet meadow, habitat for species such as the Spotted Turtle and Eastern Massasauga. Gone from Ohio from 1830–1936 (Chapman 1949), Beavers have made a comeback in the state, but their activities are mostly controlled in all but the most remote areas.

Even small-scale processes such as tree tip-ups ("hurricanes") likely played an important role in creating gaps in otherwise forested areas. In a survey of the few remaining plots of virgin, old growth forest, trees had a mean diameter of 109 cm and height of 30 m (Auten 1941). It's not difficult to imagine very valuable canopy gaps resulting from one or more of these giants being toppled in a storm. Today, the forests are more fragmented, consist of younger and smaller trees, and gaps are often quickly colonized by invasive plants.

Without human intervention—controlling invasive plant species, beating back forests, and arresting succession (Spieles 2010)—natural and semi-natural herbaceous areas will largely disappear from Ohio. While these activities are commonly acknowledged as important for improving reptile habitat (Shoemaker et al. 2009; Pike et al. 2011; Johnson et al. 2016; Clifford et al. 2020), they can bring their own set of problems. Prescribed fire, mowing, rotational cropping (with disking or plowing), logging, herbicides, and water level manipulations, are all techniques employed to provide the disturbance necessary for creating and maintaining natural open-canopy areas, but all can, and often do, result in wildlife mortality (Figure X-6). Prescribed fire and its effects on reptiles have been a focus of many studies (Russell et al. 1999; Hu et al. 2013; Cross et al. 2015; Grundel et al. 2015; Howey et al. 2016; Hromada et al. 2018; Harris et al. 2020; Roe et al. 2020).

An actual evaluation of the costs and benefits of habitat management for reptiles requires combining knowledge of the site and the organisms inhabiting it, while remaining cognizant of scale. For example, Beaupre and Douglas (2013) described the

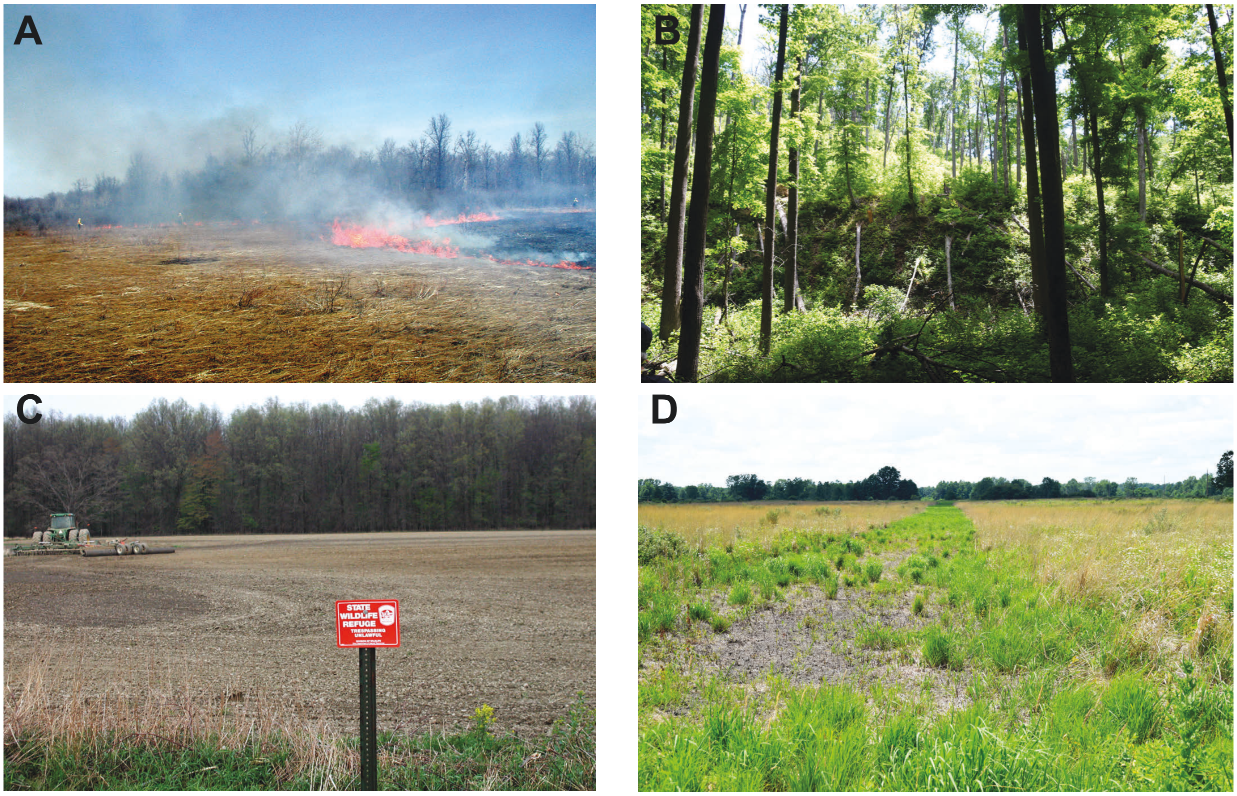

Figure X-6. Management techniques used to set back succession and maintain areas of herbaceous habitats include **A.** prescribed fire (Lucas County); **B.** logging (Ross County); **C.** farming (Trumbull County); and, **D.** strip mowing (Wyandot County). Other techniques not shown include the use of herbicides and periodic flooding. Management is necessary for maintaining suitable habitat for supporting populations but can also cause injury and death to reptiles. The technique(s) used, as well as the timing, frequency, and scale of application can result in very different outcomes. Careful consideration of both the life history and behavior of the species present, as well as current and future desired conditions of the site is critical for maximizing benefits to reptiles. Greg Lipps, Jr. photos.

manipulation (fire and logging) of Arkansas forests that resulted in a near total loss of Timber Rattlesnakes at one burned den complex (the only survivors being two held in the lab for processing), but also increases in growth rates and body condition for snakes foraging in logged and burned areas compared to controls. At the site where snakes were eliminated, new animals began colonizing the area three years later, but the population had still not reached its pre-burn numbers and individuals were smaller (presumably younger) 12 years after the fire. Does this research have implications for management of Timber Rattlesnake habitat in Ohio? Perhaps, but only after first considering the differences that likely exist between the Arkansas and Ohio landscapes and the size and distribution of populations. For many sites occupied by Timber Rattlesnakes in Ohio, natural colonization following a catastrophe may not be possible.

Similar paradoxes of habitat management—finding that it is both necessary and beneficial, while also having the potential to extirpate populations—are not limited to Timber Rattlesnakes or to fire and logging; in fact, they are most common for species

Figure X-7. Beaver impoundments can be beneficial in their creation of habitats but can also be problematic in the fragmented habitat of modern-day Ohio. This impoundment flooded an area inhabited by Eastern Massasaugas, causing a large decline in the population. Clark County. Jeffrey G. Davis photo.

that are associated with disturbance-dependent, early successional habitats. Even "natural" events that set back succession may be beneficial in one circumstance, but determinantal in another. For example, the aforementioned positive role of Beavers in creating habitat seems contradictory to the massive decline of a Clark County population of Eastern Massasaugas whose habitat was flooded by a beaver pond (Figure X-7; Jeff Davis, unpublished data). This is less difficult to understand, though, after examining the fragmented habitat of the area that prohibits immigration. Scale matters. The process is natural, the landscape is not. A similar paradox is seen in the response of different taxa to some forms of habitat management. Cooperative farming, used extensively on Ohio wildlife areas to control succession (Figure X-6C), may benefit grassland birds that can fly back in after row cropping is ended, but the same is often not possible for the less vagile grassland reptiles.

Experts often disagree about the application of various habitat management techniques and the role of natural processes. Sometimes, data is cherry-picked, and important issues such as differences in the scale of research with contradictory findings is glossed over. While additional research should provide more guidance on the cost-benefit analyses of the various forms of habitat management in relation to reptiles and

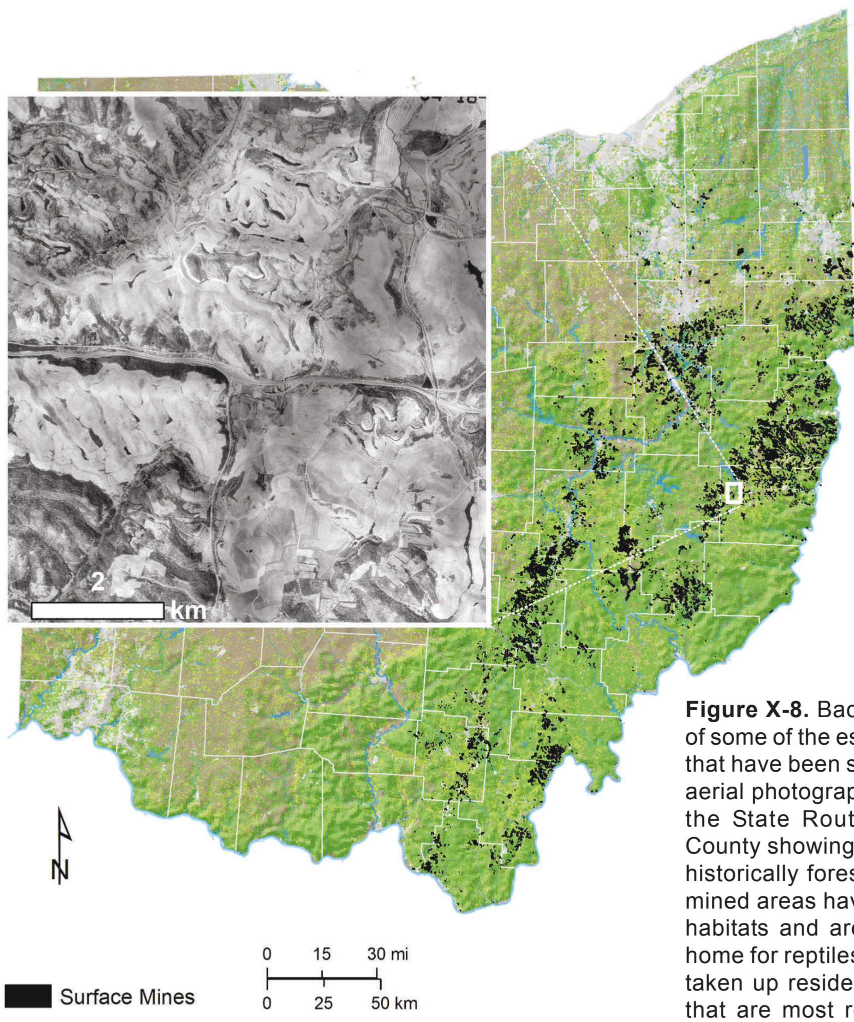

Figure X-8. Background map shows the location of some of the estimated 291,000 hectares of Ohio that have been surface mined. The inset is a 1990 aerial photograph of the area surrounding I-70 at the State Route 800 interchange in Belmont County showing the aftermath of strip mining of a historically forested area. A significant portion of mined areas have been "reclaimed" as grassland habitats and are celebrated by many as a new home for reptiles that can fly (i.e., birds) that have taken up residence. Snakes, lizards, and turtles that are most reliant on such habitats, though, generally range to the west and north (in the glaciated portion of the state, where grasslands were naturally most common) and these species are unlikely to ever naturally colonize the former strip mines. Surface mine data from the Ohio Department of Natural Resources. Aerial photograph from the Ohio Department of Transportation photo archives.

the places they reside, it should be clear that Ohio's natural landscapes have been altered to such a degree that relying solely on natural processes to create and maintain suitable habitats is not feasible, and arguing for such is irresponsible.

Herbaceous habitats have significantly increased in one area of Ohio, but ironically this has had limited benefit for the Ohio reptile species that most rely on them. Surface mining for coal, mostly from 1940 into the 1980s, ravaged much of the coal fields of eastern Ohio (Figure X-8). Most of the surface mining was completed prior to the passage of state and federal environmental laws in the mid-1970s that placed some restrictions on the practice and required some "reclamation" of the land. The loss of topsoil and compaction of the remaining rocky ground hinders widespread reforestation, but grasslands, both native and pasture grasses, have been established throughout these areas, creating sizable patches of grassland habitats. Grassland birds, historically rare in this previously forested area of Ohio, are now common in some areas (Ingold 2002; Ingold and Dooley 2013; Lautenbach et al. 2019). Birdwatching tours, mostly focused on grassland species such as Grasshopper Sparrows, Henslow's Sparrows, and Short-eared Owls, as well as tours focused on bees, butterflies, and their habitats, are now offered at The Wilds, a 3,700 ha (9,150 acres) formerly strip mined area in Muskingum County where these species are now abundant. While it's understandable that there is excitement about these "new" grasslands, any consideration of the role they can and will play in the conservation of Ohio's wildlife must not forget the flightless, grassland-dependent reptiles with no nearby source populations to naturally colonize these areas.

In addition to the outright destruction of habitat, **fragmentation** is also a serious threat to reptile populations in Ohio. Fragmentation is the breaking up of suitable habitat that impedes or prevents the movement of organisms. While this can be caused by natural features such as rivers or mountains, of concern to the conservation practitioner is the human-caused fragmentation due to changes in land-use and land-cover. Common examples of this in Ohio are agricultural fields, urban areas, transportation corridors, and dams and reservoirs that can block the movement of animals and cause populations to become isolated. This can result in smaller populations that are less likely to recover after stochastic events (such as fires, floods, and droughts) and are more likely to suffer from inbreeding depression, genetic drift, and the Allee effect, all of which increase the probability of population extirpation.

Habitat fragmentation is not difficult to see in Ohio. Of what remains of natural and semi-natural (i.e., recreational open spaces) terrestrial land cover, 90% is located within contiguous patches of 11 hectares or less (Figure X-9). There are only 370 patches of 1,000 contiguous hectares or larger remaining in the state and, like the largest patch at Shawnee State Forest in Scioto County, these are mostly clustered in the rugged unglaciated landscape of southeast Ohio.

One of the most common and widespread sources of habitat fragmentation in Ohio comes from **roads**. Their impacts on reptiles extend across time and space, beginning with the construction of the road to its eventual daily use by vehicles (Andrews et al. 2006). Ohio's 198,258 km of roads equates to a density of 1.87 km/km^2, the seventh highest of all 50 states (U.S. Department of Transportation 2011). Over 9.8 million vehicles are registered in the state, and nearly 112 million miles are traveled on Ohio's roads each year. It's difficult to escape roads in Ohio, as 90% of the state is within 600 meters of one (Figure X-10).

The most obvious impacts of roads on reptiles are the loss of habitat during construction and the direct mortality and injury of animals by vehicles using the road. Reptiles are more likely to appear on roads that separate different habitats (e.g., overwintering and foraging habitats), are located near water, or where open areas for thermoregulating and nesting are scarcer. The number of reptiles killed on roads can be staggering and is usually much greater than those that are observed. In one experiment, researchers repeatedly placed 14 snake carcasses along a road at locations where road-killed snakes were previously observed and found that 52% were removed by scavengers within two days (Winton et al. 2018). The researchers estimated that the actual number of Western Rattlesnakes (*Crotalus oreganus*) killed on this 11.7 km stretch of road was 2.7 times greater than the 92 road-killed individuals observed during the two-year study.

Other studies have counted equally shocking numbers: 73% of 1,172 snakes on roads in Florida's Everglades National Park over two years were injured or dead and an average of 22.5 snakes per kilometer of road were killed each year in Arizona's Organ Pipe Cactus National Monument (reviewed by Forman et al. 2003). In four years of surveys along the Long Point Causeway (Ontario, Canada), 864 individuals of ten reptile species were counted dead on the road (Ashley and Robinson 1996).

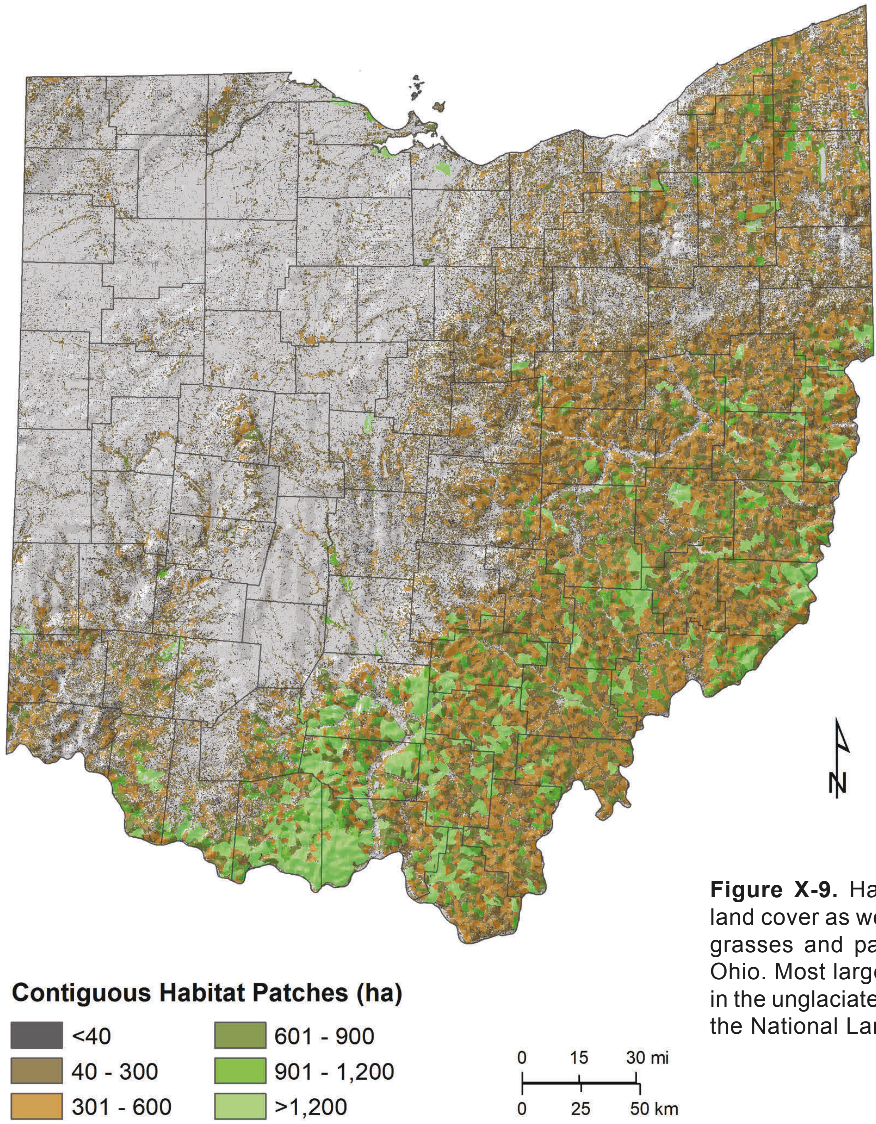

Figure X-9. Habitat, defined here as natural land cover as well as undeveloped recreational grasses and pasture, is highly fragmented in Ohio. Most large contiguous areas are located in the unglaciated portion of the state. Data from the National Landcover Database, 2016.

Researchers working at Carlyle Lake in Illinois, home to the state's largest population of Eastern Massasaugas, documented 321 road kills of six turtle and nine snake species over a three year period, including 42 Eastern Massasaugas (Shepard et al. 2008). During weekly visits along a 1.6 km stretch of road in Athens County, 14 road-killed reptiles were documented over a 14-month study, including nine Woodland Box Turtles (*Terrapene carolina carolina*) (Seibert and Conover 1991).

Roads are particularly problematic for turtles, as females are more often found on roads than males (Steen et al. 2006) and their increased mortality has resulted in U.S. turtle populations becoming more male biased over the past century (Gibbs and Steen 2005). In aquatic species such as the Painted Turtle (*Chrysemys picta*) and Snapping Turtle (*Chelydra serpentina*), males may leave their aquatic home less often than females, the latter of which must travel to nesting sites and are therefore killed on roads more frequently, resulting in increasingly male biased sex ratios correlated with road density (Steen and Gibbs 2004). The life history of many turtles requires females to have long lives with low mortality for population growth rates to remain positive, thus road mortality can threaten the viability of populations.

Research to understand the relationship of roads and reptiles has sought to determine not just mortality rates, but also if and how they alter habitat selection, movement, behavior, and gene flow. Distance to the nearest road, road density, and traffic volumes are often found to be negatively correlated to the presence of reptiles, especially

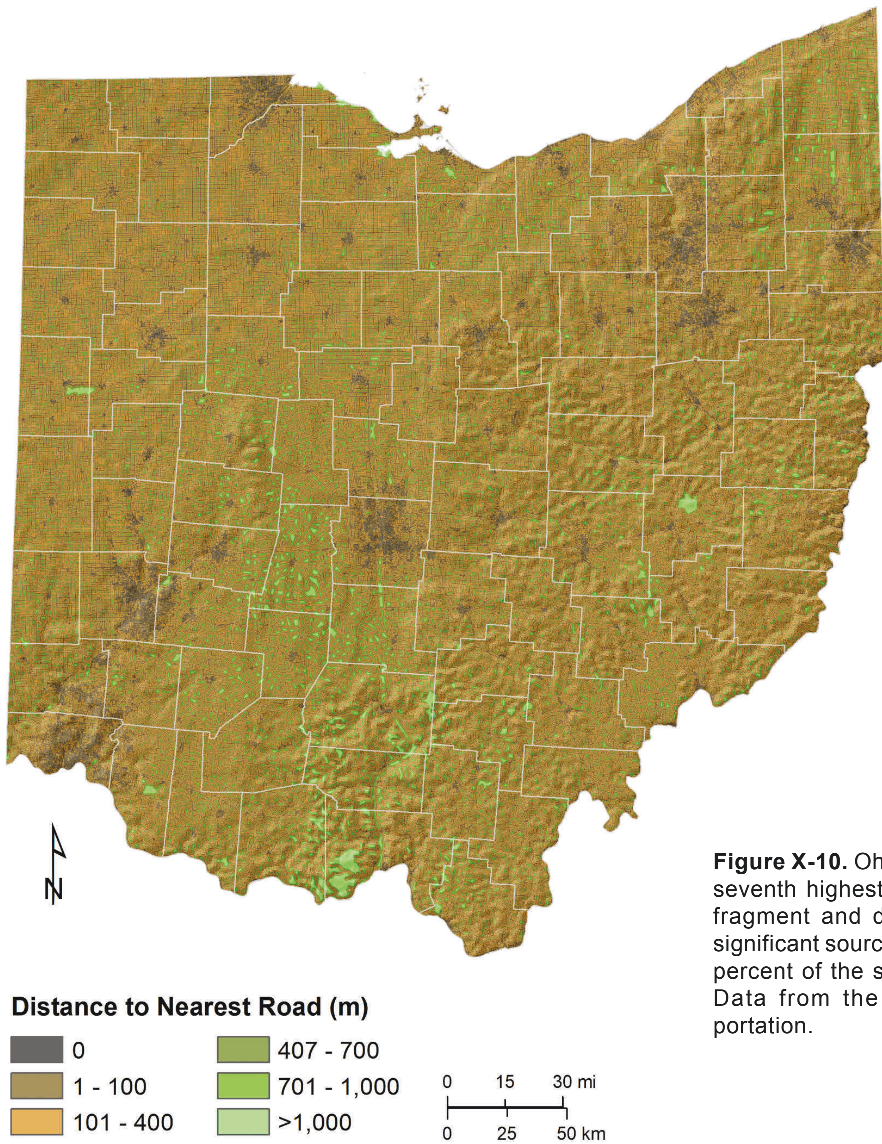

Figure X-10. Ohio has 198,258 km of roads, the seventh highest density in the country. Roads fragment and degrade habitat and can be a significant source of mortality for reptiles. Ninety percent of the state is within 600 m of a road. Data from the Ohio Department of Transportation.

species that are more vagile and those with larger home ranges (Attum et al. 2008; Hamer et al. 2016; Markle et al. 2018b). Species either avoid areas with roads or populations become extirpated due to increased mortality or habitat degradation and fragmentation associated with them.

Behaviorally, there is evidence that reptiles avoid crossing roads, and when they do cross, they most often minimize the distance traveled on the road, going straight across (Shine et al. 2004; Andrews and Gibbons 2005). Road avoidance has been documented in a wide range of snake and turtle species (Shine et al. 2004; Andrews and Gibbons 2005; Paterson et al. 2019), although one study failed to find roads acting as a barrier to a population of ratsnakes (Row et al. 2007). In response to oncoming danger, such as an approaching vehicle, some snakes will stop moving, increasing the time spent on the road and their vulnerability to traffic (Andrews and Gibbons 2005).

Researchers continue to study the interaction of roads and reptiles, most often to determine what actions might be undertaken to mitigate road impacts. This often includes attempts to determine if there may be geographic, temporal, or other factors that can be used to predict road crossings (Shepard et al. 2008; Patrick et al. 2012; Siers et al. 2016; Lutterschmidt et al. 2019) or which species may be most at risk due to roads (Brehme et al. 2018). Often, occurrences on the road correspond to life history events, such as the increased movement in the late summer by mate-searching

Lipps Jr GJ. 2021. Reptile Conservation. Pages 889-920 in: Davis JG, Lipps Jr GJ, Wynn D, Armitage BJ, Matson TO, Pfingsten RA, and Caldwell C (editors). Reptiles of Ohio. Ohio Biological Survey Bulletin New Series, Columbus, Ohio.

Eastern Massasaugas (Shepard et al. 2008) or movements to and from overwintering and nesting areas by turtles (Ashley and Robinson 1996; Steen et al. 2012). The hope is that by better understanding why and where reptiles enter roadways, strategies for reducing road kills can be implemented.

One such strategy to reduce wildlife road kills that has become increasingly popular is the construction of tunnels under the road (Figure X-11). These "**ecopassages**" are usually constructed with exclusion fencing on either side to restrict animals from reaching the road, funneling them to the tunnel. For many of these projects, the available data does not allow for a rigorous assessment of their effectiveness. For those that have been thoroughly studied, the results have ranged from complete failures to somewhat successful, some of which are covered in the preceding species accounts. While these road-crossing structures may be warranted in some areas, their high cost and the required ongoing maintenance of associated exclusion fencing must be taken into consideration. Jochimsen et al. (2004) reviewed road-crossing structures and other issues related to roads and measures to minimize their effects on amphibians and reptiles. Technical guidance on wildlife road crossing structures was provided by Clevenger and Huijser (2011). Building roads away from areas important to wildlife remains the most effective and efficient method for reducing their impact.

Diseases—There are several diseases of reptiles that are of conservation concern, particularly as they may add additional mortality or stress to populations that are struggling to remain viable due to other threats. In recent decades, the global emergence of fungal infections of plants and wildlife has received increasing attention. Emerging fungal diseases appear to pose a greater threat to biodiversity than other pathogens and this threat is increasing, likely due to their high virulence, long-lived environmental stages, and ability to infect a broad array of hosts (Fisher et al. 2012). The flexible genetic architecture of fungi combined with accidental introductions associated with increases in global trade further exacerbates the threat (Fisher et al. 2016).

The fungus *Ophidiomyces ophiodiicola* can cause ophidiomycosis, commonly referred to as **Snake Fungal Disease** (**SFD**). The disease process can result in increased shedding, epidermal flaking and crusting, scale disfiguration, and swelling and lesions on infected snakes (Baker et al. 2019). In severe cases, necrosis of the skin and underlying tissues can result in significant lesions, and swelling, especially in the head, which can be mistaken for trauma (Figure X-12). Infected snakes often have poor body condition and are lethargic. SFD has been implicated in declines of Timber Rattlesnakes in New Hampshire (Clark et al. 2011) and Eastern Massasaugas in Illinois (Allender et al. 2016) and all species of snakes appear to be

Figure X-11. One of two small wildlife ecopassages constructed under the Nelsonville Bypass (Athens County) to allow Timber Rattlesnakes (found in the adjacent forests and road right-of-way) and other species to safely cross under the road. Three larger ecopassages were also included as part of this project. Tracking of five Timber Rattlesnakes using radio-telemetry as well as continuous camera trap monitoring of the tunnels revealed very limited use by amphibians or reptiles (Hopkins et al. 2018). Garrett Sisson photo.

Figure X-12. Infection by the fungus *Ophidiomyces ophiodiicola* can result in Snake Fungal Disease with clinical signs including increased shedding, epidermal flaking and crusting, raised scales, swelling, disfiguration, and lesions. This very lethargic Northern Watersnake presented with all of these symptoms. DNA of *O. ophiodiicola* was detected from swabs passed over the body of this individual. Erie County. Greg Lipps, Jr. photo.

Table X-1. Species and counties in Ohio where Snake Fungal Disease has been confirmed as of 2020. Data from Smeenk et al. (2016), Long et al. (2019), and personal communications and unpublished data from Matt Allender, Greg Lipps, Jr., Bill Peterman, Megan Seymour, and Kristin Stanford.

Species	Counties
Northern Black Racer	Muskingum
Eastern Hog-nosed Snake	Scioto
Eastern Milksnake	Ashtabula, Mahoning, Muskingum, Preble
Plain-bellied Watersnake	Williams
Lake Erie Watersnake	Erie, Ottawa
Northern Watersnake	Ashland, Erie, Williams
Smooth Greensnake	Summit, Wyandot
Gray Ratsnake	Muskingum, Warren
Eastern Foxsnake	Erie, Ottawa
Queensnake	Erie
Plains Gartersnake	Wyandot
Northern Ribbonsnake	Williams
Eastern Gartersnake	Ashtabula, Muskingum
Timber Rattlesnake	Vinton
Eastern Massasauga	Trumbull, Wyandot

susceptible (Burbrink et al. 2017), although mortality rates appear to be highly variable among species. *Ophidiomyces* DNA was detected on a preserved Eastern Massasauga collected in 2000 in Illinois (Allender et al. 2016) and has been confirmed in more than 30 snake species in the U.S. and Europe (Allender et al. 2020). Both the prevalence of infected snakes and the severity of infections may vary among species, and the conservation and management implications of this disease are the focus of ongoing research (Matt Allender, pers. comm.).

SFD was first detected in Ohio from retroactive testing of Lake Erie Watersnakes (*Nerodia sipedon insularum*) collected in 2009 in Ottawa County (Lorch et al. 2016). The next documented occurrence in Ohio came in 2015 from the opposite end of the state, from a juvenile Eastern Hog-nosed Snake (*Heterodon platirhinos*) collected in southern Scioto County (Smeenk et al. 2016). Detections of the fungus are most often made through PCR assays of swabs passed repeatedly over the body of a snake. As of 2020, SFD has been detected on swabs collected from 14 species of snakes throughout Ohio (Table X-1). The majority of SFD detections have come from opportunistic sampling of only a few individuals, with the exception of sampling conducted in Ashtabula County (Smeenk et al. 2016) and at The Wilds in Muskingum County (Long et al. 2019). Only six species that have been tested have failed to result in at least one positive case, but for each of these species less than six individuals have been swabbed.

Considering the widespread distribution of SFD in Ohio, additional research is needed to understand differences in prevalence between species and geographically, what other factors may influence both the prevalence and severity of infections, and how different genetic strains of SFD may interact with snake species. Perhaps most important, there is a need to investigate what effect—if any—SFD is having on snake populations, by monitoring changes in population sizes and vital rates, as well as systematically scoring the severity of infections (Baker et al. 2019). Ongoing research projects with Lake Erie Watersnakes at Stone Laboratories and Timber Rattlesnakes in Vinton County are expected to provide additional information on SFD in Ohio.

Ulcerative shell disease has been observed in multiple zoological collections and in free-ranging populations of Western Pond Turtles (*Actinemys marmorata*) and a new genus of fungi was isolated from turtle shell lesions (Woodburn et al. 2019). Little else is known about *Emydomyces testavorans*, other than its association with shell lesions, but it should be considered yet another potential emerging threat facing turtles.

Ranaviruses, family Iridoviridae, are members of a group of double stranded DNA viruses that are known to infect over 175 ectothermic vertebrate species worldwide, including reptiles from at least 12 different families in the orders Testudines and Squamata. Wirth et al. (2018) reviewed the subject of ranaviruses as they pertain to reptiles, and the following information borrows heavily from their work. In general, pathogenesis and transmission of ranaviruses in reptiles is poorly understood, especially in comparison to research with amphibians and fish. Symptoms of ranavirus infection in reptiles can range from none (asymptomatic) to severe, most often presenting as respiratory disease in turtles, with nasal and oral discharge, and possibly as skin lesions in lizards. Infections are systemic, often causing extensive damage to multiple organs, especially the liver and spleen. Secondary infections commonly accompany ranavirus infections and may exacerbate the disease and make diagnosis more difficult. While amphibians and fish can contract ranavirus through multiple routes (water, skin contact, oral inoculation), reptiles may have fewer viable transmission routes. Reptiles sold in the wildlife trade have contributed to the global spread of ranaviruses, and mosquitoes were implicated as vectors in a ranavirus outbreak in a population of Woodland Box Turtles (*Terrapene carolina carolina*) in Indiana (Kimble et al. 2015).

Mass mortality events due to ranavirus infections have been documented in 15 reptile species (Marschang 2011; Behncke et al. 2013; Stöhr et al. 2013; Kimble et al. 2017). Mortality can often be rapid and range from 0–100%. Of 317 wild caught Woodland Box Turtles removed from a highway construction area and kept in a captive colony in Indiana, a ranavirus infection resulted in 71.6% mortality over a two-year period (Kimble et al. 2017). The first symptoms of the disease were conjunctivitis, with aural infections, esophageal necrosis, and mucoid stomatitis also found during necropsy. During repeated sampling, nasal discharge was the only clinical sign significantly associated with positive status. Of 22 marked Woodland Box Turtles showing signs of upper respiratory disease at a site in Berea, Kentucky, 17 died during a span of 76 days, with ranavirus and a rapid drop in temperature the likely culprits (Agha et al. 2017). Ranavirus was implicated in mass mortality observed at a Hancock County wetland, with two Midland Painted Turtles, 139 adult and larval frogs (American Bullfrogs, *Lithobates catesbeianus* and Green Frogs, *L. clamitans*), and three Bluegill fish found dead or moribund (Combs et al. 2015).

A particularly concerning characteristic of ranaviruses is their ability to jump among taxa (fish, amphibians, and reptiles) and through recombination create novel strains. A recombinant ranavirus with DNA from a strain in North America and one from Europe and Asia was found in an American Bullfrog farm in southern Georgia (Claytor et al. 2017). Further research showed the new virus to be highly virulent and have increased pathogenicity, underscoring the risk of the global movement of wildlife and their pathogens (Peace et al. 2019).

Paramyxovirus is a highly pathogenic virus that is most known for its reputation to spread through captive snake collections, where it can cause significant morbidity and mortalities, especially for members of the family Viperidae. Hyndman et al. (2013) reviewed paramyxoviruses in reptiles and what follows is summarized from their review. The virus has been detected in members of the families Colubridae, Elapidae, Viperidae, Crotalidae, Boidae, and Pythonidae. The virus is easily transmitted through both aerosols and contact. Signs of infection may be variable, non-specific, and subtle, but often involve the respiratory tract and neurological symptoms. In captive collections, the disease often presents with general lethargy, regurgitation, diarrhea, and abnormal posturing and head tremors. There are no specific treatments effective against the virus, but infected animals are often treated with broad spectrum antibiotics, as secondary bacterial infections are common. Serological testing using hemagglutination inhibition is most commonly used to detect exposure to the virus, although Allender et al. (2008) found considerable variation in the results from three commercial laboratories, which between them, used four different isolates of the virus as antigen. I am unaware of paramyxovirus being detected from wild Ohio snakes, but it has been repeatedly found in captive collections in the state, often resulting in significant mortalities.

Upper respiratory tract disease (URTD) in chelonians results from infection by *Mycoplasma* bacteria (*M. agassizii* or *M. testudineum*) and is one of the most well-studied reptile diseases. Jacobsen et al. (2014) reviewed what is known about the disease and what follows is summarized from their review. URTD was first discovered after major declines in Mohave Desert Tortoise (*Gopherus agassizii*) populations in the 1980s. Since then, the pathogen and disease outbreaks have been found in wild and captive populations of a variety of chelonians, including Gopher Tortoises (*G. polyphemus*), Woodland Box Turtles, and Red-eared Sliders (*Trachemys scripta elegans*). Clinical signs of disease include nasal and ocular discharge, conjunctivitis, and edema, although subclinical infections are not uncommon. URTD causes lesions and inflammation in the nasal cavity and the presence of nasal discharge was associated with a reduced ability to locate food and possibly mates. The disease appears to cause initial high mortality (up to 50% of Gopher Tortoises at one site) followed by high morbidity among survivors (chronic inflammation, abnormal hormone profiles, and changes in soluble proteins in shell scutes). Transmission is thought to be primarily through direct contact with infected individuals, including those that are not showing clinical signs.

Outbreaks of URTD can be caused by stressors such as toxicants and environmental perturbations, resulting in subclinical infections becoming clinical. Desert Tortoises further from human beings and paved roads were significantly less likely to be seropositive for *M. agassizii*, which could be an indication of human-mediated spread of the disease or tortoises in poorer habitat being more vulnerable to the disease due to physiological stress. Perhaps most important, there is compelling evidence that the escape or release of captive tortoises has been a significant factor accounting for URTD in wild populations.

The preceding treatment of reptile diseases is not meant to be comprehensive, but instead to bring awareness to some of the more worrisome pathogens that could be of conservation concern to Ohio populations. For the reptile researcher, being aware of these diseases and how they commonly present clinically is important so that the proportion of animals displaying symptoms and the severity of symptoms might be monitored as part of regular data collection protocols. If necessary, veterinarians with expertise in reptile pathology should be consulted to determine the best method(s) for diagnostic testing. For the lay person, identifying and reporting potential disease outbreaks to the Ohio Division of Wildlife can play an important role as a first line of defense in limiting their impact.

Above all, I hope that this discussion of disease imparts upon the reader a sense of personal responsibility for reducing the spread of potential pathogens. This means adhering to disinfection procedures between sites (see Appendix I) and not releasing animals except at their point of capture and only if they have not been kept longer than 30 days and not with other reptiles. These are not merely suggestions but are codified in Ohio's wildlife regulations (OAC 1501:31-25-04 (G)). Given the number of emerging pathogens that are facing Ohio's wildlife, it should be clear that the diseases we don't yet know about are as much of a concern as those that have been identified.

Pollution—Ohio will always be inexorably linked to pollution, for both good and bad. The repeated burning of Ohio rivers in the mid-1900s eventually received national attention, with Time Magazine famously covering the burning Cuyahoga River in its August 1969 edition, but including a photograph from a much more serious blaze that had occurred on the river in November 1952. The story of a river so polluted that it could burn tarnished the reputation of Cleveland, but it was also the impetus for action.

In the years following the infamous fire, the U.S. celebrated the first Earth Day in 1970, Congress passed the Federal Water Pollution Control Amendments of 1972, followed by the Clean Water Act of 1977, and the Water Quality Act of 1987. A month after the passage of the 1972 law, Ohio established the Ohio Environmental Protection Agency, following the formation of the U.S. EPA two years prior. The Endangered Species Act was passed by congress in 1972, and Ohio adopted its first list of state endangered wildlife in 1974. The environmental laws of the early 1970s and the agencies charged with enforcing them have perhaps done more to protect reptile habitat than anything else in modern history, in Ohio, and throughout the country.

While there have been great strides in reducing point-source pollution and improving water quality, the legacy of these pollutants, as well as the now more problematic non-point source pollution, continue to impact Ohio's reptiles. In a review that included 38 reptile species of conservation concern in the U.S., 53% were found to be imperiled by pollution (Wilcove et al. 1998). Across our northern border, Canada lists 13 reptile species as being threatened by at least one form of pollution (Lesbarrères et al. 2014). Heavy metals and synthetic chemicals, including organochlorines and polychlorinated biphenyls (PCBs), are often found in reptiles at concentrations that can cause health and reproductive problems. This is particularly true for aquatic species that have longer lives, allowing them to bioaccumulate toxins that persist in sediments (see Chapter 1, Snapping Turtle).

Compared to the much better studied amphibians, little is known about the effects of commonly used pesticides on reptiles. Organochlorines (including DDT and its metabolites) are still widely used globally, and although their use has been phased out in the U.S. and Canada, they continue to have effects on wildlife in these countries. Aural abscesses are seen with some regularity in wild and captive Woodland Box Turtles. In pet turtles, such as Red-eared Sliders and Painted Turtles, these are commonly associated with poor diets resulting in vitamin A deficiencies. In the wild, they may be caused by organochlorine pesticide toxicity. The pesticides, and their metabolites, may act by immunosuppression leading to infection by opportunistic pathogens (Tangredi and Evans 1997), or, alternatively, may induce hypovitaminosis A (Holladay et al. 2001).

Today, siltation is the principal source of impairment on the basis of stream distance impacted (USEPA 2000). Sediment, in the form of runoff from agricultural fields, roads, and other development, can reduce habitat quality and biodiversity. A decrease in reptile occupancy observed upstream of dams may have at least been in part due to increased sedimentation in these areas, which can embed microhabitats, and reduce habitat complexity, aquatic plant growth, and macro-invertebrate populations (Hunt et al. 2013). Macroinvertebrates can be an important food source not just for aquatic reptiles like turtles, but also for terrestrial reptiles that may feed heavily on aquatic-derived insects (Sabo and Power 2002).

Excessive nutrients entering waterways, often attached to silt particles, have received increasing attention since the nutrient-fueled **harmful algal blooms** (**HABs**) of *Microcystis* cyanobacteria in the western basin of Lake Erie resulted in more than a half million Ohioans being unable to use the public water supply for nearly three days in August 2014. *Microcystis*, fueled by phosphorus loading primarily from agricultural runoff, produces hepatotoxic microcystins. As water temperatures in Lake Erie rise *Microcystis* reproduces rapidly in the nitrogen and phosphorus rich waters of Lake Erie forming thick mats. Senesced cells sink through the water column and accumulate on the bottom adding to the existing benthic biomass where decomposer action consumes the oxygen present thereby creating a zone of hypoxia or anoxia in the hypolimnion (the “dead zone”). Bottom feeding dreissenid mussels reach high densities (Carrick 2004; Conroy and Culver 2005) and add both their feces and pseudofeces to the biomass. Low oxygen levels kill many dreissenids and bottom dwelling native fishes including freshwater drum and catfish and the exotic invasive Round Goby if they are unable to escape, further adding to the benthic detritus. Spores of *Clostrium botulinum*, an obligate anaerobic bacterium responsible for botulism, is also known from the Lake Erie sediment. The bacterium, or the neurotoxin it produces, has been detected in these fish which may serve as the vector to upper trophic levels, including Northern and Lake Erie Watersnakes and possibly freshwater turtles.

HABs are not limited to Lake Erie, as they have been increasingly causing problems in Ohio’s Grand Lake St. Marys and even the Ohio River. Changes in the frequency of heavy precipitation events (see Climate Change below) have increased runoff from agricultural fields causing increases in nutrient loading that fuel the HABs. Like so many other topics of conservation concern, there has been little research to understand how HABs may affect Ohio’s reptiles (Garcia 2019).

Pollution that impacts reptiles can also take the form of trash and other materials that enter the environment. **Erosion netting** has probably received more attention than any other pollutant, likely due to how effective it can be in entangling snakes and the visibility of its impacts (Stuart et al. 2001; Brown and Sleeman 2002; Barton and Kinkead 2005; Walley et al. 2005; Kapfer and Paloski 2011). Similar netting is also sold for wildlife exclusion (“deer fence,” “snake fence,” or “wildlife netting”) and deployed to keep animals from entering buildings, lawns, or gardens. Snakes that become entangled in netting may die due to trauma, dehydration, overheating, or predation. Ohio species that have been documented entangled in mesh netting include Northern and Lake Erie Watersnakes, Eastern Milksnakes, Northern Black Racers, and Eastern Massasaugas.

The use of biodegradable materials may help lessen the amount of time netting is able to trap snakes, but the use of alternative erosion control materials, such as loose layers of organic materials, would eliminate the risk altogether. If a mesh is necessary, then using one with larger apertures (>2.54 cm space between the mesh) with the individual strands unbounded, so that they can move independently should a snake pass through, is recommended (Kapfer and Paloski 2011). Any rigid material that can become entangled around a snake, even pulltabs from old beverage cans (Iverson 2010), should be considered a potential hazard and disposed of properly. Netting should not be used in locations known to be inhabited by snake species of conservation concern.

Reptiles that share their environment with anglers can also be impacted by fishing gear and other trash. Ingestion of tackle has caused intestinal perforations and lead poisoning in turtles (Borkowski 1997; Scheuhammer 2009), and the prevalence of fish hooks in 600 radiographed turtles in the southeast U.S. ranged from 0–33% (Steen et al. 2014). Lake Erie Watersnakes have been found dead after consuming fishing lures, drowning inside of submerged minnow traps, and becoming trapped inside of discarded beverage cans (Figure X-13).

Invasive Species—Invasive species are often categorized as plant or animal and as exotic or native. Exotic refers to their establishment outside of their original (pre-European settlement) range either intentionally or accidentally by humans.

Figure X-13. Entanglement in erosion netting and trash can be a source of mortality for snakes. This Lake Erie Watersnake perished after becoming entrapped inside a discarded beverage can. Ottawa County. Doug Wynn photo.

Native species can sometimes exhibit traits similar to invasive species when their densities grow to a level that threatens to extirpate other species. This is usually the result of human activities subsidizing a species, giving it a competitive advantage over others, or when predators are removed resulting in a “release” of a species from historically normal predation levels.

Exotic invasive plants are widespread in Ohio and can be found in every natural area of the state. Of the approximately 3,000 plant species known to occur in the wild in Ohio, about 75% are native, 25% are exotic, and fewer than 100 are known to be problems in natural areas (Ohio Invasive Plants Council 2020). Invasive plants are often species that change the plant community by replacing native plant species, not with ecological equivalents, but with aggressive, highly competitive species thereby diminishing biodiversity and often creating large monospecific stands that alter the structure of the system.

While there is a sizeable body of research concerning their effects on most taxa, including amphibians (reviewed by Lipps and Matson 2013), there is surprisingly little known about the effects of most exotic invasive plants on Ohio’s reptiles. Most studies examining habitat selection by reptiles find that structure is more important than vegetative species composition. Specifically, reptiles often choose areas with heterogeneous structure, including areas prone to disturbance with greater solar insolation. Unfortunately, disturbed habitat is also subject to increased invasion risk by exotic invasive plants, meaning that areas that would naturally provide good thermoregulatory opportunities for reptiles are also the same areas that are prone to being invaded by exotic plants that can degrade these qualities.

One of the few investigations of the effects of exotic invasive plant species on an Ohio native snake, the Eastern Copperhead, was carried out in an Indiana park (Carter et al. 2015). Researchers removed exotic plants in eight 20 x 20 m plots and compared their use by radio-tracked Copperheads compared to control plots dominated by a variety of invasive exotics, including Autumn Olive, Privet, Bush Honeysuckle, and Japanese Stiltgrass, among others. These areas were believed to be sparsely vegetated prior to the arrival of the exotic plants, being described as originally glade and glade-like habitat. The plots where the exotic plants were removed had higher environmental temperatures and greater leaf litter depths than the controls, and seven of the eight were used by 14 radio-tracked

Copperheads. The treated plots were used for gestating, birthing, and foraging by the Copperheads. Other reptiles were observed in them, too, including Woodland Box Turtles, Black Racers, Eastern Milksnakes, and Broad-headed Skinks. No reptiles were observed in the control plots dominated by exotic plants.

Unfortunately, the paradox of habitat management being both necessary for enhancing habitat quality, while also being potentially detrimental to the reptiles it is intended to help, was illustrated in subsequent work to control invasive species at this park (Carter et al. 2017). In follow-up treatments, 17 of 22 telemetered Copperheads suffered injury, 13 as a result of management operations. At least nine fatal injuries and all non-fatal injuries were the result of management operations. Injuries resulted from being crushed by machinery (including the tires of off-road vehicles used to apply herbicides) and being cut by mowers. The researchers concluded that the plots were acting as “ecological traps,” successfully creating thermally superior habitat preferred by Copperheads by controlling exotic plants, while decreasing fitness through the control methods. Suggestions to reduce injury and mortality included a combination of conducting management when species are less likely to be present and using less aggressive techniques in smaller areas.

Reed Canary Grass (*Phalaris arundinacea*; hereafter, RCG) is a widespread, tall, perennial species native to wetlands of North America that is thought to have become much more aggressive through introgression with European cultivars following their repeated introductions since the 1850s (Lavergne and Molofsky 2004). RCG forms dense monocultures in wetlands (Figure X-14) and accumulates large amounts of biomass. A Wisconsin study looked at the abundance of the generalist Eastern Gartersnake compared to that of the more specialized Butler’s Gartersnake in areas of different vegetative communities, including those dominated by RCG (Kapfer et al. 2013). Butler’s Gartersnakes were captured more often in grasslands than any other habitat and were never captured in greater numbers in RCG compared to other habitat types. Eastern Gartersnakes were captured more often in RCG than cattail or sedge dominated habitats, but less than grassland. More research is needed to understand if RCG is less hospitable to snakes than natural grasslands due the tall, dense monocultures interfering with thermoregulation, movement, foraging, and/or predator avoidance.

RCG has been valued for its rapid growth and is unfortunately still occasionally planted today to control erosion on recently disturbed areas. A now-retired wildlife area manager told me that as part of his wildlife management course at Ohio State University in 1968 or 69, students participated in the planting of RCG and Autumn Olive at Killdeer Plains Wildlife Area, ostensibly to improve habitat.

Figure X-14. Reed Canary Grass is one of the most significant invasive plants in Ohio reptile habitats, often forming dense monocultures that reduce the habitat heterogeneity found in herbaceous areas of native plants. Huron County. Greg Lipps, Jr. photo.

If this was a common practice of the time, then it may explain the especially large and vigorous stands of RCG found in many of the state's wildlife areas.

Phragmites australis (Common Reed) is a grass highly invasive to wetlands and waterways. The species has a cosmopolitan distribution, and 11 of the 27 recognized haplotypes are native to North America and have grown along the Atlantic coast of North America for several thousand years. A more aggressive form now referred to as *Phragmites australis* haplotype M (hereafter referred to as *Phragmites*) invaded North America by the early twentieth century from Europe and continental Asia and is the most common form (Saltonstall 2002). Based upon genetic data and historical information haplotype M was introduced into the St. Lawrence River–Great Lakes watershed during the early 1900s (LeBlanc et al. 2010). *Phragmites* is known to have negative impacts on biodiversity of vascular plants and upon hydrology of coastal salt and brackish marshes and freshwater marshes, but little is known about the impacts on vertebrates of freshwater marshes (LeBlanc et al. 2010).

Phragmites outcompetes native plants for resources and growing space and rapidly reproduces vegetatively through rhizomal spreading and lateral runners, but it also disperses by seed (Saltonstall 2002). Habitat alteration occurs primarily through clonal growth (vegetative reproduction) with *Phragmites* forming extensive monocultures (Figure X-15). Within North America only 5 phytophagous species are known to forage on haplotype M, whereas over 170 herbivorous species feed upon it in Eurasia (Tallamy 2004). Within wetlands *Phragmites* replaces native species and fragments the system. The extensive growth slows water flow through wetlands and decreases drainage through creeks. Fallen and senesced stems further reduce water flow and increase the rate of sedimentation thereby increasing the rate at which wetlands fill; fallen and senesced stems also smooth the microtopography of the marsh surface and in sum, lower the standing water (Hagan et al. 2007) and decrease the hydroperiod (Rogalski and Skelly 2012). Plants grow to heights up to 4 m with shoot densities varying 30–400 shoots/m^2 (Bolton and Brooks 2010) and above ground biomass ranging 1–3 kg/m^2 (Rogalski and Skelly 2012), dependent upon the stage of invasion.

Phragmites has been investigated for its potential to degrade freshwater turtle habitats in North America. At Long Point National Wildlife Area in Ontario (Canada), data was collected on 38 Eastern Spiny Softshell (*Apalone spinifera spinifera*) nests that were all constructed in areas with constant sun exposure during the day (Bolton and Brooks 2010). At five of these nests, *Phragmites* grew up to almost entirely shade the nests and the root systems of the plants grew in and around the egg mass. Three of these five nests failed, while the remaining two experienced lower temperatures resulting in incubation periods of 83 and 85 days, significantly longer than the 72 days (mean) for the unshaded

Figure X-15. Large, dense stands of *Phragmites* (Common Reed) are present in numerous Ohio wetlands. Senesced stems from the previous year and new growth are present in the abandoned Grand River channel at Mentor Marsh State Nature Preserve in Lake County. Photo of Shipman Pond taken on June 5, 2013. Timothy O. Matson photo.

nests. The researchers noted that due to the speed at which *Phragmites* can spread through rhizomes in the sand, an area that appears ideal for oviposition during the nesting season can quickly become unsuitable for embryonic development. A similar study with Diamondback Terrapins (*Malaclemys terrapin*) on a barrier island in Virginia's Delmarva Peninsula found that this species rarely nested in areas with dense growth of *Phragmites*, and coverage of <50% was unlikely to alter sex ratios of hatchlings (Cook et al. 2018).

At Point Pelee National Park on Lake Erie's northern shore, classification of historical aerial images dating back to the 1930s helped to explain why an area protected for over a century has lost a significant amount of its reptile and amphibian diversity (six snakes and five amphibian species extirpated) while other species continue to decline (Markle et al. 2018a). The 80% decrease in graminoid shallow marsh the researchers documented was largely due to the invasion of *Phragmites*, which also had formed a dense barrier between the beach and marsh, possibly reducing the ability of species to move between these two habitats. While other factors have contributed to the population declines, *Phragmites* was singled out for its role in reducing marsh habitat diversity.

Blanding's Turtles (n=46) were radio-tracked at two sites in southern Ontario (Canada) to examine their use of habitats in relation to *Phragmites*, which covered 14% of the total wetland area (Markle and Chow-Fraser 2018). Patches of *Phragmites* were located closer to random locations within home ranges than to random locations within the population range, likely because *Phragmites* invades the same shallow marshes preferred by the turtles. At the individual home range scale, though, Blanding's Turtles selected aquatic and mixed organic marshes, avoiding untreated patches of *Phragmites*. This relationship did not hold for females if their nesting migration was included in their home range, perhaps indicating that their route to nesting areas was not influenced by *Phragmites*. The finding of a male Blanding's Turtle apparently stuck and desiccated in a dense *Phragmites* patch reveals that in addition to reducing the amount of suitable habitat, attempted movement through *Phragmites* patches may be costly to turtles. Larger turtles (linked to sex in some species) may have more difficulty maneuvering through *Phragmites*, potentially producing a sex-biased effect that is worthy of further study (Frank and Bouchard 2008).

It is beyond the scope of this section to detail all of the invasive exotic plants that impact Ohio's reptiles. Short synopses for a few additional species are provided below. All of these are well established in Ohio, and in some areas they may dominate the local vegetation. While their impacts on reptile habitats are often obvious to the researcher—such as turning a former field or forest understory into an impenetrable thicket where little sunlight reaches the ground—there has been surprisingly little research on the subject, a deficiency that will hopefully be rectified by future investigators.

The planting of exotic Autumn Olive (*Elaeagnus umbellata*) and Russian Olive (*E. angustifolia*) was encouraged by state and federal agencies to revegetate surface mines, stabilize road banks, beautify urban areas, and (ironically) as wildlife habitat. Both of these species aggressively outcompete native plants and shrubs, grow rapidly, re-sprout quickly after cutting or burning, and produce a prolific amount of fruit consumed by birds which then spread the seeds (Ohio Invasive Plants Council 2020). Olives are especially plentiful in the former strip-mined areas of eastern Ohio, where their prevalence is not only apparent to the eye, but also to the nose during their springtime bloom.

Common Buckthorn (*Rhamnus cathartica*) and Glossy Buckthorn (*Frangula alnus*) were both introduced from Eurasia for medicinal purposes (Kurylo and Endress 2012) and spread as ornamental shrubs for fence rows, and as wildlife habitat, where they have taken to forming dense thickets that displace native species (Ohio Invasive Plants Council 2020). Glossy Buckthorn is a serious threat to shallow water wetlands, such as wet prairies, while Common Buckthorn commonly takes over in more upland habitats. The impacts of Common Buckthorn on ecosystems include changes in soil nitrogen, elimination of the leaf litter layer, possible facilitation of earthworm invasions, and possibly allelopathic effects on native plant species (reviewed by Knight et al. 2007). The removal of Glossy Buckthorn has been a major part of restoration work in the Oak Openings Region of northwest Ohio, leading to increased amounts of Twigrush wet prairie habitat used by many reptiles, including Spotted Turtles, Blanding's Turtles, and Northern Ribbonsnakes.

Invasive honeysuckles include four species in Ohio (*Lonicera japonica, L. maackii, L. morrowii, L. tatarica*), all of which grow vigorously, shade out native species, and produce fruits that are consumed by birds which subsequently spread the seeds (Ohio Invasive Plants Council 2020). Honeysuckles have greatly altered the forests of southwest Ohio, where their near complete colonization of the understory of many forests is visible in the early spring and fall, as they leaf-out earlier and retain their foliage later than the native vegetation. The wide-ranging effects of Amur Honeysuckle on species composition, community structure, ecosystem function, and successional trajectories was reviewed by McNeish and McEwan (2016), while McEvoy and Durtsche (2004) examined the plant's effects on amphibian and reptile diversity.

When it comes to mitigating the impacts of invasive exotic plant species on Ohio's reptiles and their habitats, one message that is clear is that prevention is much more efficient and effective than control. Larger, more established patches of plants can be extremely difficult to eradicate, as was illustrated in attempts to control 346 *Phragmites* patches in Adirondack Park in upstate New York (Quirion et al. 2018). While their control efforts were mostly successful (no live stems for at least three years post-treatment) in the smallest patches, success was only achieved in 26% of medium (45 m^2) and 2% of large (>3,000 m^2) patches. This was despite an average of 4.5 treatments with foliar spray each year over a seven-year period and the mechanical removal of dead stands to encourage revegetation by native species, all at a cost of ~$100,000. The authors concluded that an **early detection, rapid response** (EDRR; National Invasive Species Council 2003) framework was most suited for dealing with this species, a finding that is common for invasive plants. It is understandable that attacking the largest stands might seem to make the most sense, but the most effective efforts focus on "keeping the good habitats good," which usually means treating very small infestations before they spread. I have witnessed EDRR effectively implemented by The Nature Conservancy in the Grand River Lowlands of Ashtabula County resulting in nearly invasive-free Eastern Massasauga habitat. Considering that mechanical treatments of invasives can cause morbidity and mortality, relatively little is known about the impacts of herbicides on reptiles and their prey, and that removal of large, established stands may be a "pipe dream," (Simberloff 2014, cited in Quirion et al. 2018), EDRR appears to be the least bad option of those currently available.

Ohio currently has relatively few **exotic invasive animals** that are of conservation concern to the state's native reptile populations. There is only one species of exotic reptile that has become established in Ohio. The Common Wall Lizard (*Podarcis muralis*, Chapter 12) was introduced from northern Italy to Hamilton County in the 1950s and has continued to spread throughout southwest Ohio where they often reach extremely high densities. Despite being in Ohio for 70 years, there is still much to be learned about this species, including its effects on prey, predators, and Ohio's native lizard species. At the very least, efforts to stem the human-assisted spread of this species are needed.

The Red-eared Slider (Chapter 8) is believed to be native to the lower Scioto River valley in Ohio but has been introduced throughout the state where it may compete with native species. Its spread was in part due to its popularity as the "dime store" turtle that so many families purchased, then released, in the mid-1900s. Ohio Division of Wildlife regulations put into place in 2000 have curtailed the sale of native reptile species—including the Red-eared Slider—although the subsequent increase in Yellow-bellied Sliders (*Trachemys scripta scripta*) being released in the state is likely an unintended consequence (see Section VIII, Potential Occurrences and Exclusions). The Ohio Division of Wildlife encourages researchers and land managers to humanely dispatch invasive non-native free-ranging terrestrial vertebrates to lessen the chances that they will become established and to minimize their impacts to native species (Policy 41, Ohio Division of Wildlife).

Domestic cats, both feral and pets that are allowed to roam outdoors, can be a serious predator of native wildlife, including reptiles. In island ecosystems, where their impacts have been the most studied, cats have been documented to prey upon 34 species of reptiles (Bonnaud et al. 2011). In the U.S., 228–871 million reptiles are estimated to be killed by cats each year (Loss et al. 2013). Cats have contributed to at least 63 vertebrate extinctions, including 26% of reptile, bird, and mammal extinctions (reviewed by Loss et al. 2013). By any objective measure, their impact on wildlife collectively is immense. The topic of feral and free-ranging cats is politically fraught, but wildlife professionals have recognized that this is a human caused problem for wildlife that must be dealt with by humans, calling for the humane elimination of feral cat populations (The Wildlife Society 2016). While programs to trap-neuter-release (TNR) feral cats commonly spring-up around Ohio (often with the support of local governments), these are largely ineffective for dealing with the problem and are unethical on animal welfare grounds (Crawford et al. 2019).

Some potential effects of exotic animals on Ohio's native reptiles are not as commonly recognized. For example, the fact that exotic species are sometimes

Lipps Jr GJ. 2021. Reptile Conservation. Pages 889-920 in: Davis JG, Lipps Jr GJ, Wynn D, Armitage BJ, Matson TO, Pfingsten RA, and Caldwell C (editors). Reptiles of Ohio. Ohio Biological Survey Bulletin New Series, Columbus, Ohio.

found in the state (see Section VIII, Potential Occurrences and Exclusions) is sometimes used as an excuse by people to kill native species. How can you be sure it isn't an escaped cobra? Exotic species can also bring with them exotic pathogens, as has been documented in the case of introduced Burmese Pythons (*Python bivittatus*) transmitting parasites to native snakes in Florida (Miller et al. 2017; Farrell et al. 2019). Finally, introduced species can sometimes subsidize reptiles, as was seen with the introduction of the Round Goby to Lake Erie, that resulted in dramatic positive effects on Lake Erie Watersnake growth, body size, reproduction, and population growth (Chapter 25, Lake Erie Watersnake).

As mentioned earlier, native animals can also pose conservation challenges similar to exotic species, usually as a result of human changes to ecosystems. The increase in mammalian **mesopredators** throughout Ohio can pose a serious threat to native reptile populations. While not precisely defined, mesopredators are generally considered those that are "mid-sized" between the original apex predators and the smallest carnivores, and the increase in their numbers may be in part due to the elimination of large predators (Prugh et al. 2009). In Ohio, the apex predators included Gray Wolves and Mountain Lions, both of which have been extirpated from the state, while mesopredators include Raccoons, Red and Gray Foxes, Striped Skunks, Virginia Opossums, American Mink, and North American River Otters.

Raccoons are "considered by turtle biologists to be the single-most important predator of turtles in North America" (Mitchell and Klemens 2000) and their numbers have skyrocketed in Ohio since the 1980s (Figure X-16). Raccoons are very effective predators of turtle nests, with recent research finding that they locate nests primarily by detecting geosmin, an organic compound produced by Actinobacteria that is released when soil is disturbed (Edmunds et al. 2018). The increase in Raccoons is largely a result of human subsidization of both food (e.g., refuse) and shelters (e.g., sewers and dilapidated structures), which can lead to very high population densities in urban areas (Prange et al. 2003; Prange and Gehrt 2004). Densities of >15 Raccoons/km^2 are considered high, with some areas in Ohio having >50 Raccoons/km^2 (USDA 2011). The impacts of Raccoons can be exacerbated when turtle nests are concentrated along beaches, dikes, railroad embankments, or reduced due to invasive plants (Figure X-17; also, see Chapter 1, Snapping Turtle). Removal of

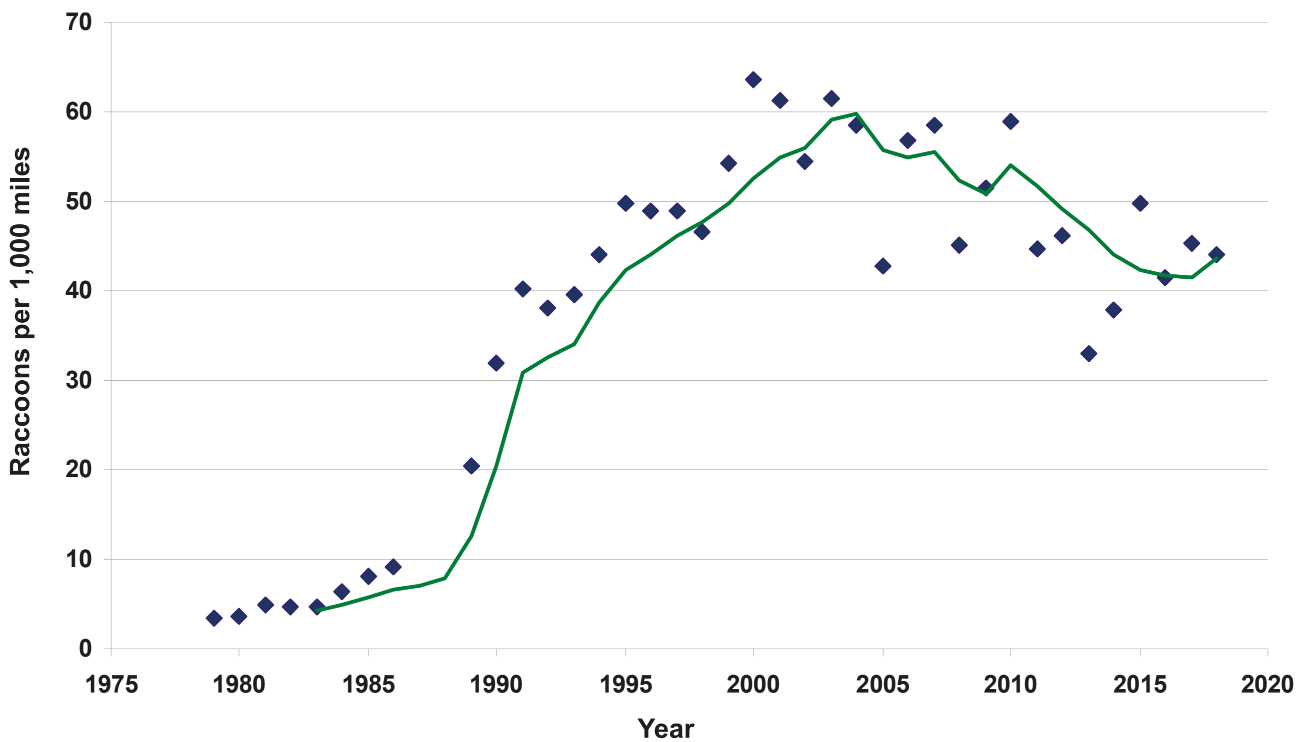

Figure X-16. Spring roadkill index for Raccoons in Ohio indicates a substantial increase in numbers since 1979. A similar trend is seen in the Ohio bowhunter survey of Raccoons begun in 1990 (data not shown). Dots are actual data values; solid line is the five year moving average. Racoons are an important predator of reptiles and are especially adept at finding and destroying turtle nests. Data from the Ohio Division of Wildlife.

Raccoons and the protection of turtle nests have been documented to increase turtle survival (reviewed by Mitchell and Klemens 2000). The Midwest Regional Working Group of Partners in Amphibian and Reptile Conservation undertook a review of the literature and produced a whitepaper advocating for efforts to reduce the impacts of Raccoons (MWPARC 2009).

Evidence of the positive impacts of mesopredator control on turtles has been seen at multiple sites in Ohio. In 2011, the USDA's Wildlife Services program in Ohio initiated an integrated approach consisting of trapping and removal of Raccoons, Striped Skunks, and Virginia Opossums along with predator exclusion and monitoring at important turtle nesting areas (USDA 2011). This followed successful efforts to increase turtle recruitment at Sheldon Marsh State Nature Preserve (Erie County), where nearly 100% of nests were predated and only one Blanding's Turtle hatchling was observed emerging from nests from 1985 to 2006. Following the removal of 47 Raccoons at Sheldon Marsh in 2007–2008, only 10 nests were destroyed by predators, more than a dozen Blanding's Turtles successfully emerged, and tracks in the sand indicated an additional 250 turtle hatchlings (unknown species) had emerged in 2008 (USDA 2011). Similarly, at Gott Fen State Nature Preserve (Portage County), the removal of 115 Raccoons and 7 Virginia Opossums from 2011 to 2018 corresponded to the detection of juvenile Spotted Turtles (carapace length=5–7 cm) for the first time in 2017–2018 (Smeenk, Lipps, and Wellman, unpublished data).

The **American Bullfrog** (*Lithobates catesbeianus*) is a native Ohio frog that has also taken advantage of human-created changes in the state. In the first statewide treatment of the frogs of Ohio, Walker (1946) found the species to be relatively uncommon, but the construction of ponds, lakes, and other impoundments, along with the active stocking of the species has led to it now being documented in all 88 counties where it is often locally abundant (Krishna and Krishna 2013). Bullfrogs are voracious predators that will consume just about any invertebrate or vertebrate they can fit into their large mouths, including snakes and turtles (reviewed by Krishna and Krishna 2013). Notably, Bullfrogs were historically not known to occur in or around a large swath of the historic Sandusky Plains, including Killdeer Plains Wildlife Area (Walker 1946). With the construction of permanent wetlands and reservoirs, though, they are now common and widespread throughout the area. Plains Gartersnakes that had been head-started and released began disappearing near these ponds and reservoirs, leading researchers to suspect predation by

Figure X-17. A Raccoon searching for turtle nests is captured on a trail camera placed along a railroad corridor adjacent to a Portage County wetland. Increased mesopredator populations and predation on nests may result in little or no recruitment of young turtles into populations, especially where suitable nesting sites are limited and concentrated. USDA Wildlife Services photo courtesy of Caleb Wellman.

Bullfrogs (Reichenbach et al. 2020). My own experience watching neonate Northern Watersnakes (*Nerodia sipedon sipedon*) I had just released being consumed by Bullfrogs charging from the margins of the pond (Krishna and Krishna 2013) certainly validates their role as a snake predator but is merely anecdotal. American Bullfrogs are also an important vector for diseases, including ranaviruses that can infect reptiles. A more thorough investigation of the potential effects of Bullfrogs on Ohio reptiles is yet another topic in need of further investigation.

The increasing numbers of other predators is also worthy of mention, even if there is not yet evidence that these currently threaten Ohio's reptile populations. The Virginia Opossum is an opportunistic predator that is naturally immune to the venom of Ohio's pit vipers. A trail camera positioned outside of a birthing log in southeast Ohio captured an Opossum feeding on a young Timber Rattlesnake (Carl Brune, pers. comm.). North American River Otters, extirpated from Ohio in the 1950s, have spread throughout the state following a successful repatriation program (Ellington et al. 2018). The potential for Otters to be a significant predator of turtle populations is well documented (Brooks et al. 1991; Ligon and Reasor 2007; Stacy et al. 2014). Many birds that prey on reptiles have also experienced large increases in their populations in Ohio. Among them are Red-Tailed Hawks, Bald Eagles, and Great Blue Herons (Sauer et al. 2017). The impacts of the increasing numbers of predators on Ohio's reptile populations, especially the predators that are human-subsidized and reptile species that are of conservation concern, is worthy of further research.

Climate Change— Conservation of reptiles must also take into account changes in Ohio's climate. While this topic is sometimes politicized, the scientific evidence clearly shows a gradually warming planet due mainly to the increase in human-released greenhouse gasses in the atmosphere (Pachauri et al. 2014). Ohio has slowly been warming and this trend is expected to continue with an increase of 1–2° C expected in the next 20–30 years. The state has also become wetter, but the overall average amount of annual precipitation is not expected to change much more in the future. What is expected, however, are changes in seasonal precipitation and an increase in the frequency of extreme events, including floods (Neri et al. 2020). Already, precipitation has become less frequent but more intense across the Midwest (Figure X-18; Kunkel et al. 1999; Saunders et al. 2012).

The response of reptiles to the changing climate will likely include both short-term effects on populations and longer-term effects that may cause shifts in species' distributions (Currie 2001; Weatherhead and Madsen 2009). In the short-term, global changes to climate are likely to cause changes to life-history traits that are already known to have plasticity in response to local weather variations, including: alterations to food intake, growth rates, time to maturity, nesting/birthing timing, fecundity, digestion times, and the timing of daily and seasonal activity (Weatherhead and Madsen 2009). Shifts in distributions are difficult to predict, as there is little understanding of exactly how climate limits current distributions, or if reptiles will be able to shift their ranges quickly enough, especially given the fragmented habitat that hinders dispersal and colonization.

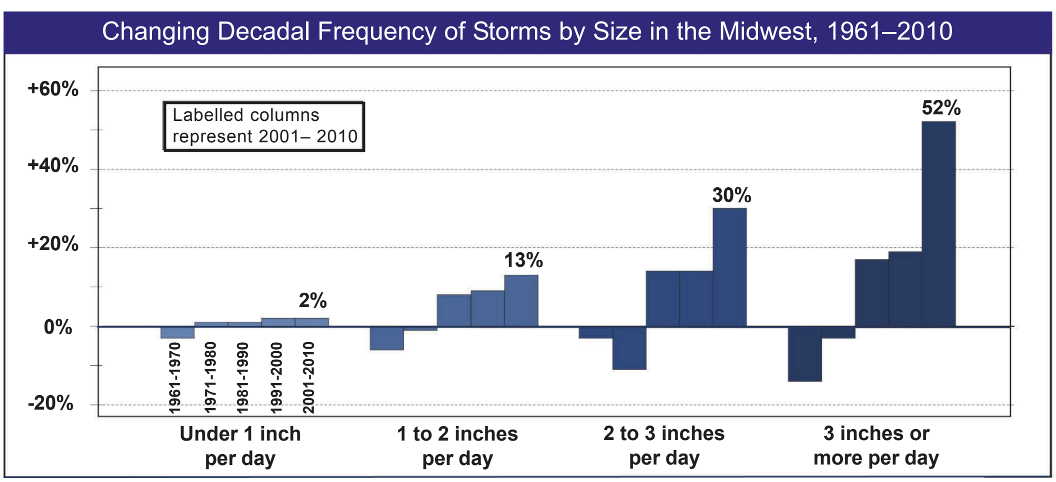

Figure X-18. Changes in frequencies of storms in the Midwest, by category of storm size for five decades, 1961–1970 through 2001–2010. Comparisons are to frequencies in 1961–1990. The larger the storms, the more their frequency increased. And the increases have been greatest in recent years. Modified from Saunders et al. (2012).

A warming climate is also expected to impact species with temperature sex determination. At a long-term study site on a Mississippi River island in Illinois, the sex ratio of Painted Turtle nests could be accurately predicted from temperatures during July (Janzen 1994). While the majority of nests each year produced hatchlings of only one sex, which sex varied from year-to-year, resulting in a prediction of 47.8% males being produced over the past 49 years; however, an increase in the mean July temperature of just 1.8°C would cause 100% female offspring in an average year.

Ohio's reptiles generally survive winter by avoiding freezing while remaining in areas that are sufficiently cold enough to reduce metabolism and energy use. Changes in winter weather could be especially problematic for overwintering reptiles. For overwintering animals, a blanket of snow is an excellent insulator from subfreezing air temperatures. An unusually light winter snow cover at the famed snake dens of Manitoba, Canada resulted in the death of an estimated 60,000 Red-sided Gartersnakes (*Thamnophis sirtalis parietalis*) due to freezing (Shine and Mason 2004). Ironically, a similarly large mortality event was recorded decades earlier from flooding resulting from snowmelt following unusually heavy winter snows.

In Illinois, an unusual warm spell in February 2017 that brought radiotracked Woodland Box Turtles to the surface was followed by a rapid drop in temperatures and the death of seven individuals (Rayl et al. 2020). The researchers attributed the deaths to "an acute stressor challenging their physiologic tolerance of the cold rather than prolonged warmth impacting turtle metabolism." Extreme weather events such as this—predicted to be more common in a warming climate—could pose an additional threat to reptile populations.

There has been an extraordinary increase in the number of peer-reviewed publications in the conservation literature concerning the vulnerability of wildlife and habitats to climate change, as well as potential adaptations and management strategies that may lessen these impacts. It is clear that conservation biologists see climate change as a serious threat to wildlife. What is often missing, however, and what will possibly have a much larger impact on wildlife living in a densely populated state such as Ohio, is how humans are likely to respond and adapt (Watson 2014). Failure to predict how human activities—already the primary cause of species' declines and extinctions—will change as a consequence of climate change will result in flawed conservation planning and ineffective strategies. Often referred to as "indirect impacts" of climate change that are not prioritized by major funders of climate change research (Maxwell et al. 2015), the response of Ohioans to climate change could have big consequences for the conservation of our reptile fauna.

One example of this can be seen in the reaction of citizens and politicians to repeated flooding of the Blanchard River in northwest Ohio's Hancock County. The river runs through the middle of the city of Findlay, the county seat (population 41,000), much of which is within the 100-year flood zone. Flooding is nothing new to this area, but multiple floods of the river from 2007–2017 have caused millions of dollars in damage. About 150 flood-prone properties have been acquired and removed from the floodplain using local, state, and federal funds since 2007 and work is underway to remove four low-level dams and widen the river to increase its capacity.

As a resident of northwest Ohio, I have seen political ads for Hancock County Commissioner candidates, and as the local newspaper attests, the contests are dominated by talk of the Blanchard River and flooding (Grant 2014). One candidate ran television ads promising to dredge the river and was quoted comparing the river to a clogged drain that needed to be unclogged. He scoffed at environmental concerns related to dredging, questioning "why a few mussels and the Indiana Bat are more important than the people" (Grant 2014). A study by the U.S. Army Corps of Engineers was expected to offer flood-control projects with an eventual price tag of $111–200 million, while the Hancock County Farm Bureau expressed its opposition "to anything more than cleaning the Blanchard River" (Grant 2016).

With increased extreme precipitation events predicted for Ohio, flooding and calls for government action should also be expected to become more common. In June 2019, Lake Erie set a new all time high water level record "obliterating beaches across the Ohio coast" and causing millions of dollars in damage to infrastructure (Johnston 2020). Some reactions to these threats to human health and property could be beneficial to reptiles, such as the removal of dams or the return of flood prone properties to greenspace. Alternatively, Ohioans could respond with increased stream channelization, dredging, and the removal of woody debris that is so important for basking and habitat, and the hardening of banks, removing the shallow littoral zones and sandy nesting areas relied on by many species for foraging and nesting.

Persecution and Unsustainable Use—Reptiles, particularly snakes, have long suffered from a fear and hatred that has often led to their **persecution**. As was previously covered in Section VII (Introduction to Snakes), polling has found the fear of snakes to be the number one phobia among Americans. It is this attitude that has often caused indiscriminate killing leading to population declines and even extirpations. Historical accounts of snake slaughters in Ohio are not difficult to find. For example, in the History of Portage County (Brown and Norris 1885), European settlers are said to have encountered two kinds of rattlesnakes: the "black" rattlesnakes "which usually frequented the wet or swampy lands" (presumably Eastern Massasaugas) and the "yellow" rattlesnakes found in the "hilly or dry ground" (presumably Timber Rattlesnakes).

> "*Hundreds of those "yellow-skins," as they were commonly called, were killed, during the first few years of settlement, in nearly every township in the county. Regular hunting parties were sometimes organized in the spring-time, to invade their dens among the ledges, and by this means those dangerous pests were rapidly exterminated…it is fortunately now nearly or altogether extinct.*
>
> *In the ledge of rocks on the land where Justin Eddy settled, there was an immense den of yellow rattle snakes, and the boys used to pass many a Sunday killing the "varmints." Seventy-two were killed at one sitting, as it were, and the Jumbo of the lot was hauled out and tormented by having sticks poked at him, until, finally, a green stick with the bark taken off was thrust at him, into which he struck his fangs, and the virus could be seen, we are told, ascending through the pores of the wood, twenty-two inches, and almost dripping out of the end of the stick!*"

No modern-day records for Timber Rattlesnakes exist for Portage County, while Eastern Massasaugas were last documented from the county in 1939 (Dexter 1944). Judging from similar accounts of early settlers, this war against Ohio's snakes appears to have been widespread.

In some of my first visits to the Lake Erie islands in the mid-1990s, residents would openly talk about their disdain for Lake Erie Watersnakes (LEWS). It seemed that everyone had a story of "plinking" snakes with rifles while they basked on docks or the shoreline. As female LEWS are larger and individuals bask more when incubating young, they were particularly vulnerable, and their removal was especially problematic for population viability. Persecution by humans was judged to be the most significant and well documented factor in the decline of LEWS populations, resulting in their federal listing as threatened in 1999 (Chapter 25, Lake Erie Watersnake). This attention was not welcomed by all the island residents, as evidenced by a colleague who entered a lakeside store while we waited for a ferry to arrive after spending a day helping researchers from Northern Illinois University (NIU) with an early survey of LEWS. When the proprietor learned of his involvement with the snake, she angrily demanded he leave not just the store, but the property entirely.

Efforts to reduce persecution of LEWS were extremely successful and offer lessons for others wishing to change human behavior. A public opinion survey of island residents conducted nine years after recovery activities began found that 83% of respondents indicated an increase in their knowledge of LEWS since listing, with 66% reporting a generally positive or neutral attitude towards the snake (USFWS 2011). Most important, only 4% indicated they had knowingly killed a LEWS since the time of listing, and only 14% said they would do so if it was no longer protected by state or federal laws. This is impressive, considering the high densities of LEWS that are often present in areas frequented for recreation and tourism.

Public outreach to change the behavior of islanders towards LEWS took various forms, including a biannual newsletter ("LEWS News"), signage at docks and along beaches, and various other media sources that combined resulted in 94% of survey respondents reporting being aware of its protected status (USFWS 2011). The public face of these efforts was the "Island Snake Lady" (Kristin Stanford), an NIU graduate student who became a resident of the community, wrote a regular column for the newspaper, was featured on television shows, offered "snake camps" for the local youth, and responded to a public email address established for residents to ask questions, all while continuing research on LEWS.

In my subsequent visits to the islands, it was easy to see the changes, with residents frequently stopping Kristin to ask questions about dealing with snake problems, for example, snakes using docked boats as basking platforms. While there was not universal admiration for LEWS (34% of residents still reported generally negative attitudes towards the snakes; USFWS (2011)), there was growing respect for Kristin—who every resident seemed to know personally—if not for the snakes themselves. And some residents who may have still been inclined to kill snakes no longer did so to avoid the scorn of their children or grandchildren, attendees of Kristin's "snake camps" that had turned them into snake advocates. Visitors to the Lake Erie islands today cannot miss the ongoing outreach programs, with signs in prominent places declaring “Water Snakes Welcome Here,” including outside of that lakeside shop where not so long ago even an association with LEWS made you unwelcome (Figure X-19).

Public outreach programs for reptiles are often designed and carried out by biologists and naturalists, who tend to focus on providing knowledge about species and sound reasoning for supporting their conservation. This knowledge-deficit model of behavior change – *if they knew what I know, they would act like I act* – has been debunked by numerous research studies that show the relationship between knowledge and behavior is weak or nonexistent (Grajal et al. 2017). The effectiveness of delivering messages and providing experiences to change attitudes and behaviors can vary widely depending on how those messages are delivered, who is delivering the messages, the audience, and their previous experiences, among other factors. As just one example, it is now widely accepted that conservation messages to young

Figure X-19. The Lake Erie Watersnake was removed from the U.S. Endangered Species List in 2011, at the time being only the 23rd species delisted due to recovery efforts. Public outreach to reduce persecution of the snakes included these signs which are prominently posted throughout the islands. Carolyn Caldwell photo.

children should not emphasize “doom and gloom” which can result in distancing them from nature, rather than connecting them to the natural world (Sobel 1996). Readers wanting more information on effective outreach for changing behaviors should consult the growing literature in the fields of conservation psychology and human dimensions of wildlife management (Christoffel 2007; Ballouard et al. 2012; Hartel et al. 2015; Keener-Eck et al. 2020), although this is another area where more reptile-focused research is greatly needed.

Reptiles may also be removed from the wild for food or to be kept, sold, or traded as pets, making **unsustainable use** yet another threat to their populations. As the agency responsible for ensuring the wise use of the state’s wildlife resources now and for future generations, the Ohio Division of Wildlife adopted rules for the collection of amphibians and reptiles in 2000 (OAC 1501:31-25-04). In general, these rules identify “collectible” reptile species that may be removed in limited numbers for personal use and also require native species that are kept captive to be permanently marked with a passive integrated transponder (microchip) and registered with the state. The sale of native reptiles removed from the wild in Ohio is prohibited.

Three species of reptiles in Ohio may be harvested with a fishing license: Snapping Turtles, Eastern Spiny Softshells, and Midland Smooth Softshells. A discussion of the rules surrounding turtle harvest and rule changes made in 2016 are covered in the conservation section of Chapter 1 (Snapping Turtles). Notably, only processed turtles (meat) can now be legally exported outside of the state. Previously, at least some Ohio Snapping Turtles were part of the booming international trade in the species (Cain et al. 2017), with reported U.S. exports increasing from 7,279 in 1999 to 1,324,089 in 2014 (Colteaux and Johnson 2017), most of which were sent to China.

The life history of many turtle species results in only very low levels of harvest being sustainable. Many have long lives, take many years to reach sexual maturity, and have naturally high mortality of eggs and juveniles, offset by the long reproductive lives of adults. Those trained in traditional game management of mammals and birds are often unaware that reptiles fail to have compensatory changes to life history values when population densities decrease. Whitetail Deer, for example, will rapidly increase their reproductive output when population densities are low (McCullough 1982), thus compensating for increased harvests. This partly explains why 180,000 of Ohio’s estimated

670,000 Whitetail Deer can be harvested annually without causing the population to decline. There is no evidence that Ohio's turtle species compensate, as values related to reproduction are not altered by changing population densities. In practical terms, this leads to conclusions such as a Missouri Snapping Turtle population estimated to be able to sustain a maximum annual harvest of only 2.3% of the population (Zimmer-Shaffer et al. 2014). Ohio's currently liberal regulations for turtle harvest could be insufficient for maintaining sustainable populations, particularly if cultural or demographic changes of Ohio residents result in an increase in harvesting. Monitoring of harvested turtle species in Ohio is needed.

Reptiles are big business. A review of the impacts of the **trade** in amphibians and reptiles was conducted by Schlaepfer et al. (2005), while the human use of chelonians was reviewed by Thorbjarnarson et al. (2000). The international demand and trade in native species of chelonians is staggering, with 18.4 million turtles (predominantly farm-raised hatchlings) legally exported from the U.S. in 2013–2018 (Boundy 2019, cited in Association of Fish & Wildlife Agencies 2020).

Aside from legal trade, reptiles are also subjected to illegal **poaching** and smuggling on an international scale (Christy 2008; Smith 2011). An investigation into illegal amphibian and reptile sales codenamed "Operation Shellshock" was led by the New York State Department of Environmental Conservation from 2006–2009 and resulted in charges against 32 individuals in six U.S. states and Canada for illegal collection and sales of native animals. In one case, an individual was arrested with 33 Eastern Massasaugas illegally collected from Canada which he had brought over the border to trade for Timber Rattlesnakes from an undercover agent. In general, the rarer the species, the higher the price it fetched, but more common species were also being exploited. Investigators uncovered thousands of Snapping Turtle eggs being collected in New York, with the resulting hatchlings being laundered through a Louisiana turtle farm which exported the turtles as a product of the farm.

There is increasing awareness that poachers use any means available to seek out information on where to find rare species that can sometimes fetch thousands of dollars. The demand for rare reptiles is revealed in the dark humor of a joke among reptile smugglers (Christy 2008): what's the first thing that happens when a new reptile or amphibian species is discovered? Answer: two Germans buy plane tickets. Brown (1993) cites the "lack of judgement" of those sharing sensitive knowledge about snake overwintering sites as the factor most responsible for the massive exploitation of Timber Rattlesnakes that resulted in some populations being extirpated. The documented cases of reptiles being harmed by collection has fueled calls by researchers to end the practice of including locality data in publications concerning species threatened by collection, including newly described species (Stuart et al. 2006; Lindenmayer and Scheele 2017). The Ohio Division of Wildlife has explicit authority (ORC 1531.04) to withhold information that could be detrimental to the conservation of a species, such as the location of a population of rare reptiles, and scientific collecting permits issued by the Division prohibit similar disclosures by researchers.

For the reptile enthusiast, the excitement of being able to show someone a rare reptile in the wild is understandable but can be problematic. In the case of the Canadian poacher of Eastern Massasaugas discussed above, the location of the animals collected was revealed by someone posting images to a popular forum for "field herpers." While the location was never revealed on the internet, the poacher convinced the poster to take him to the site, ostensibly to photograph the snakes. I am aware of similar instances in Ohio, where individuals accompanying researchers have returned to sites with acquaintances made on internet forums. At two Ohio sites where Eastern Massasaugas have been studied in recent years, residents have reported being approached by individuals looking to collect the snakes (Lipps and Smeenk 2017).

The Future—While the massive tome of this current work might trick a casual reader into thinking that our current knowledge of Ohio's reptiles is complete, a skeptical eye will see vast deficiencies. These gaps aren't just limited to techniques for conserving Ohio's reptile diversity. For many species, the basic data that forms the underpinnings of effective conservation and management are lacking. Surely, our knowledge will continue to grow, but each new discovery seems to raise even more questions and shed more light on how little we know. Throughout the compilation of this book, I've had constant reminders of this, reminiscent of this Aldo Leopold quote:

> "*The ordinary citizen today assumes that science knows what makes the community clock tick; the scientist is equally sure that he does not. He knows that the biotic mechanism is so complex that its workings may never be fully understood.*"

For example, did you know that turtles audibly communicate with one another and, at least in one species, the communication is used to provide parental care (Ferrara et al. 2013)? Or that snakes can have complex social lives that go beyond simple maternal trailing by neonates to include having social networks (Schuett et al. 2016)? How about the finding that juvenile Painted Turtles can navigate to alternative water sources, and can precisely remember those paths as adults, but their ability to learn appears to be limited to a critical time during their youth (Roth and Krochmal 2015; Krochmal et al. 2018)?

Discoveries such as these, in addition to increasing our fascination with reptiles, should also be a check on our hubris when it comes to our ability to fix what we should not have allowed to be broken in the first place. When it comes to the conservation of reptiles in Ohio, there are (to paraphrase Orr 2004) legitimate grounds for hope, but not one speck of ground for wishful thinking. New technologies and discoveries will certainly be a help, especially as wildlife managers come to recognize that even "recovered" populations are often reliant on continued human interventions for the foreseeable future, including control of other predators and competitors, active habitat management, and artificial recruitment (Scott et al. 2010). Head-start programs to augment populations (such as the one described for the Plains Gartersnake, Chapter 36) and repatriation programs to stock areas where populations have been extirpated are laudable, and likely to grow increasingly common in the future, but they shouldn't lull us into thinking that we fully understand "what makes the community clock tick." Ultimately, success will depend on the countless Ohioans engaged in the protection and management of natural habitats and whether the citizens and their leaders deem their work worthy of support.

Acknowledging all of the challenges facing reptiles might leave some to wonder how these incredible species have managed to survive at all, or to question whether conservation efforts are an exercise in futility. We should not forget, however, that the long evolutionary history of reptiles means they have survived through cataclysmic events, such as the end of the Cretaceous Period when nearly three-quarters of the plant and animal species on Earth went extinct. If one is looking for more modern inspiration, they need to look no further than the recovery of species such as the White-tailed Deer, Wild Turkey, and North American Beaver. These species were all but gone from Ohio at the turn of the twentieth century, while today they are found throughout the state, and sometimes in very high densities.

Ohio's natural areas and their inhabitants have also benefited greatly from the work of countless individuals, organizations, and agencies who have dedicated tremendous resources to the protection of habitats important for Ohio's reptiles. From visionaries like William Stinchcomb, who in 1905 envisioned a chain of parks encircling the city of Cleveland (today's celebrated "Emerald Necklace"), to all of Ohio's modern day park districts, land trusts, and state agencies that continue to protect and manage natural areas, there is reason to be hopeful for the future conservation of Ohio's reptiles. Many of the recent conservation victories owe their success to the diverse partnerships that have formed to tackle today's complex issues, including the Grand River Partnership, Lake Erie Allegheny Partnership for Biodiversity (LEAP), and the Oak Openings Green Ribbon Initiative, to name but a few. Perhaps even more fundamental to recent successes has been public support, by way of local tax levies to support park districts, state bonds to fund the Clean Ohio Program, the H2Ohio program to restore water quality, and federal programs such as the Great Lakes Restoration Initiative and the State Wildlife Grant Program. The promise of the Recovering America's Wildlife Act is perhaps most exciting of all. Should this pass, it would for the first time put non-game wildlife management on the same footing as that of the species that are pursued by hunters and anglers, species that are flourishing now thanks to the commitments made in 1937 (Pittman-Robertson Act) and 1950 (Dingell-Johnson Act).

Effective conservation must be more than simply increasing our scientific knowledge (Ehrenfeld 2000) or developing theoretical models and giving each other advice on what others should be doing (Whitten et al. 2001). If conservation efforts are to have their desired effect—secure, thriving populations of reptiles throughout the state—it is important that not every conservation action be required to be a research project. Instead of being overwhelming, the numerous conservation challenges presented in this chapter, along with the voluminous information on the biology of Ohio's reptile species found throughout this book, will hopefully be used to implement effective plans, strategies, and policies for ensuring that all of Ohio's native reptile species continue to contribute to the rich natural heritage of our state.