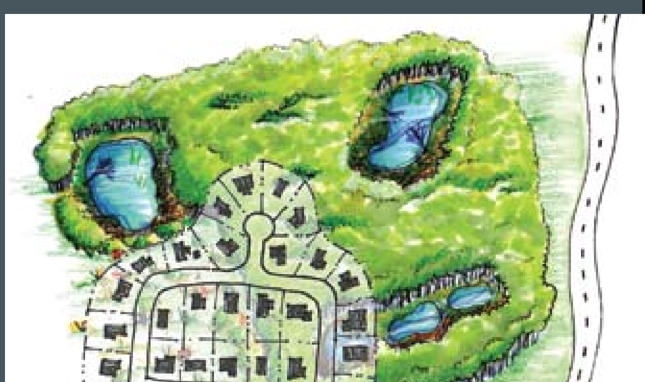


Michigan Amphibian & Reptile Best Management Practices





Herpetological Resource & Management, LLC

Michigan Amphibian and Reptile Best Management Practices

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1. Introduction

Purpose and Intended Use of This Manual

This manual was created for the Michigan Department of Environmental Quality (MDEQ) to provide a comprehensive guide to Best Management Practices (BMPs) to improve and maintain the viability of Michigan amphibian and reptile populations. This manual addresses threats to Michigan's amphibian and reptile (i.e., herpetofauna) communities posed by development and conservation management practices. The manual contains alternatives that are based on the best available science to facilitate conservation actions to protect specific species and the communities that support them. These BMPs are designed to inform land management and, development, and conservation activities, including restoration. This BMP manual is a Michigan-focused guide that provides specific recommendations to regulators, agency land managers, consultants, commercial and residential developers, and private citizens to protect, preserve, and restore the herpetofauna of Michigan.

To be of value, BMPs must be supported by scientifically sound information, and as such, must be both monitored to assess their effectiveness and revised to reflect new information. As the BMPs are implemented and evaluated, the new information will be used to refine protection efforts. The process should reduce costs while maximizing wildlife protection value. This manual, while primarily targeted at amphibian and reptile communities, complements the ecosystem management approach described in the Michigan Department of Natural Resources (MDNR) Wildlife Action Plan (WAP) (Eagle, Hay-Chmielewski et al. 2005) and incorporates current climate change adaptation recommendations (Hall 2012).

1. The State Threatened Spotted Turtle is a habitat specialist and Species of Greatest Conservation Need in Michigan.

This work was initially started in 1999 in an effort to provide an introduction to the habitat needs, management, and conservation of turtles and amphibians in Southeast Michigan for the MDNR and MDEQ. This document is still in use by resource managers and was a catalyst for developing a more comprehensive and detailed document focused on all of Michigan's amphibians and reptiles. The need for this manual is driven by the significant decline in amphibian and reptile populations in Michigan and the need for increased conservation actions. At the time of

Jim Harding

1.Copper-bellied Watersnake is State Endangered with a very limited range in Michigan. This species is one of many likely to benefit from conservation efforts through the implementation of Best Management Practices. Observations of this and all other reptiles and amphibians should be reported to the Michigan Herp Atlas.

publishing, over 60% of Michigan herpetofauna is considered rare or Species of Greatest Conservation Need (SGCN), as identified by the MDNR WAP (Eagle, Hay-Chmielewski et al. 2005). Most of these species are wetland dependent at some phase in their lives. Habitat destruction, degradation, and fragmentation are the main factors for decline of many amphibian and reptile species in Michigan and the United States (Dodd, Smith et al. 2003; Marchand and Litvaitis 2004; Weyrauch and Grubb 2004; Cushman 2006; Gardner, Barlow et al. 2007). Decreases in water quality, habitat patch size, and connectivity coupled with invasive species, environmental contaminants, pathogens, illegal collection, and high densities of subsidized mesopredators pose a significant threat to many species in Michigan (Harding 1997; Roe, Kingsbury et al. 2003; Bell 2005; Moore and Gillingham 2006; Ryan, Conner et al. 2008; Michigan Natural Feature Inventory 2012). The unique natural histories and biological characteristics of amphibians and reptiles make these animals vulnerable to both aquatic and terrestrial disturbances. The guidelines proposed in this manual have the potential to reduce negative pressures on herpetofauna populations in Michigan and contribute to their protection and preservation.

This manual is to be used as a quick-reference guide throughout all phases of site development and construction, mitigation, restoration, and management. Specific laws and applicable BMPs for the mitigation of potential impacts to amphibians and reptiles are provided. These are listed and described within the appropriate BMP section to best address specific concerns as they are encountered while a project moves into implementation. It is our hope that this resource will be a living document and work in progress. As new threats, technologies, and management techniques arise revisions will be made to help best manage and protect Michigan's herpetofauna.

2. Wood Turtles, generally uncommon to very rare across the Great Lakes range, benefit from environments with low disturbance.

3. Wood Frog adults are mainly terrestrial except during the breeding season when they rely on seasonal wetlands absent of fish for reproduction.

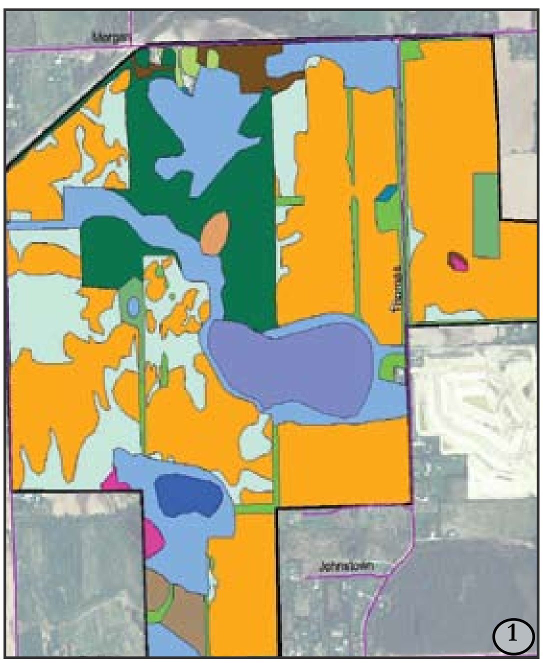
2. Project Planning

The strategies and practices discussed in this manual reflect general principles of ecological sustainability. Specific application of these principles can be enhanced through site-specific knowledge of herpetofauna. In planning for a 'herp-friendly' project, keep in mind these general principles:

Obtain the appropriate permits- Before any construction or other activities can begin on a site, permits from government agencies may be required. Permits are issued by a number of different agencies and may be needed regardless of whether the land is owned by an individual, business, or government agency. Information to determine what permits may be necessary to continue a project can be found by reviewing USFWS, MDEQ and MDNR websites.

Know which natural communities are present - This is the first step needed to develop a piece of land or implement a management, restoration, or stewardship plan. Also, it is important to keep in mind that just because a site may be degraded or not as natural as desired, it may still provide important ecological function and value as well as support a rich diversity of herpetofauna.

1. Knowing existing community types is an important tool in understanding community composition and management needs. The below map illustrates natural features mapping and adjacent land uses.



Know the species and habitat targeted for protection - Inventory and monitoring by qualified professionals is critical to determine which species are present or likely to occur and the functions the habitat provides. This inventory will provide a more complete picture of the ecological interactions needed for planning and help direct which BMPs to use and how these practices can be tailored to a site. Be aware of the seasonal life histories of all species present so the timing of maintenance and development actions can be planned to avoid or minimize impact to herpetofauna. Also, conduct site inventories at a large enough scale to capture all relevant habitat components for species present.

Preserve habitat to maintain connectivity and a mosaic of communities – This will help to provide suitable conditions for a variety of herpetofauna at various life stages and maintain subpopulations in several locations. Most species require an exchange of individuals between locations to ensure genetically diverse populations. These populations are more resilient to catastrophic events and can recolonize areas if a catastrophic event eliminates one subpopulation (Reh and Seitz 1990).

1. American Toads can be locally abundant however, they have experienced recent declines in parts of Michigan and their Great Lakes region.

2. Conducting baseline surveys is an important component to assessing project objectives and management approach.

Provide appropriate habitat structure – Each species has specific requirements for vegetation types, water sources, nesting sites, overwintering sites (hibernacula), basking sites, and feeding grounds/food sources that compose suitable habitat. In some cases this can include human made or modified structures. Providing for species' needs at all life stages can significantly influence community health and diversity.

Mimic historic hydrologic processes and allow for animal movements – Most species of herpetofauna rely heavily on the natural hydrologic cycle in their native range to complete their life cycle and to move through the landscape. Mimicking or maintaining these fluctuations is necessary to preserve species' continued presence on the landscape.

Educate the public and site users – Conservation success relies on public support and compliance by the people who use a site. The greatest tool we have is the group of educated constituents who are positively engaged in the conservation and preservation of amphibians and reptiles.

Control subsidized predators and invasive species – Maintaining the balance of native predators and prey in an ecosystem helps to conserve amphibians, reptiles, and other native wildlife. Much of Michigan has been altered and the current landscape represents a new shift in community composition. Though eradication of invasive species can be a target, healthy communities should be the overall goal.

Weigh potential costs and benefits of various development and management scenarios and develop a long-term adaptive management plan – By considering the social, economic, and environmental consequences and the role of all stakeholders, long-term, sustainable solutions can be achieved. Habitat quality, overall area, level of landscape connectivity, and other relevant factors should be considered when weighing environmental outcomes. It is important to consider preserving areas that help to maintain contiguous habitat areas and maximize site connectivity and landscape connectivity. Careful consideration of the overall functions and values and the cost- benefit analysis is necessary, especially on larger projects.

Plan for post-implementation monitoring - Monitoring amphibian and reptile richness and distribution post-construction or after a site has been restored is useful in determining the success of a project as a metric. Monitoring efforts may target the following:

- Target species, such as sensitive species or those that require specific habitat types, as indicators.
- The presence of plants or objects that provide the necessary structure and services to meet the species' needs.
- Species distribution and presence of multiple life stages indicating the successful recruitment of new individuals into the population.

3. Amphibians and Reptiles of Michigan

Amphibians (frogs, toads, and salamanders) and reptiles (turtles, snakes, and lizards) are two diverse groups of animals which, though not closely related, are traditionally studied under the biological discipline of herpetology. Michigan's herpetofauna is ecologically important as they fulfill an essential mid-level position in food webs (as predators, scavengers, and an important prey base for other animals) and help maintain a balance of invertebrate and rodent populations and aquatic vegetation as mid-level consumers (Lagler 1943; Klimstra and Newsome 1960; Rowe 1992; Harding 1997; Walls and Williams 2001; Congdon and Keinath 2006). Amphibians and reptiles are also important as they are key bioindicators of environmental health and habitat quality (Cooperrider, Boyd et al. 1986; Adamus and Brandt 1990; Welsh Jr and Ollivier 1998; Shear, Stadler-Salt et al. 2003; Guilfoyle 2010).

Despite the ecological importance of the state's herpetofauna, these groups have not been as comprehensively surveyed or studied as compared to other vertebrate groups such as birds, mammals, or game fish. This may be partly due to a historical disregard for non-game species in Michigan by biologists and state agencies (Mangun and Shaw 1984) and a general apathy or even antagonism towards certain herpetofauna (i.e. snakes) by the public. Confounding the problem is that many amphibian and reptile species are cryptic and inconspicuous and thus difficult to survey. As a result, gaps in knowledge have left Michigan herpetofauna poorly understood and the true status of many species remains undetermined. The limited number of herpetological studies that have been conducted in Michigan indicate significant population declines for over 60% of species (Eagle, Hay-Chmielewski et al. 2005), and there is plentiful anecdotal evidence that the abundance and distribution of many (even formerly common) amphibian and reptile species have declined significantly. It is well documented that amphibians and reptiles are sensitive to ecological degradation and to impacts associated with wetland conversion, upland commercial, residential, and recreational development, and maintenance (Knutson, Sauer et al. 1999; McKinney 2002; Dodd, Smith et al. 2003; Marchand and Litvaitis 2004; Weyrauch and Grubb 2004; Saumure, Herman et al. 2007; Skidds, Golet et al. 2007; Humbert, Ghazoul et al. 2009; Böhm, Collen et al. 2012). It is clear that additional protections, education measures, and management are necessary to ensure the continued existence and possible recovery of amphibian and reptile populations on a landscape shared with humans.

Nick Scobel

1. These Spotted Turtles control their body temperature by basking on sunny logs in a wetland. The logs also provide cover for the turtles when they dive into the water. These turtles use a variety of habitats seasonally, demonstrating the need for contiguous ecosystems.

1. Vernal pools such as this can seasonally support a dozen or more species of herpetofauna. Preserving these wetlands is key to the survival of many amphibian and reptile species.

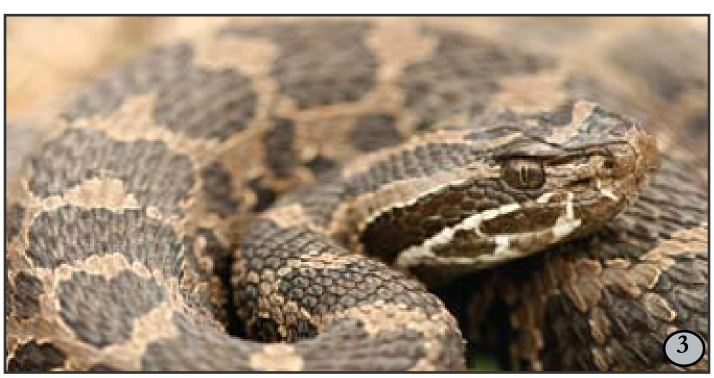
Natural History of Herpetofauna in Michigan

Amphibians and reptiles have unique physiological (functional) and morphological (physical) characteristics that allow them to fill niche roles in ecosystems that are essential to the maintenance of biodiversity and ecological functionality. Some of these biological traits include behavioral thermoregulation by exchanging heat with their surroundings, hibernation (or more technically, brumation: a hibernation-like state), biphasic (aquatic and terrestrial) life cycles, and metamorphosis (Heath 1964; Harding 1997; Semlitsch 2008). Amphibians and reptiles are ectothermic, meaning that their body temperature is largely dependent on the ambient temperature of the surrounding environment.

Most species of amphibian and many reptiles in Michigan rely on the presence of water for at least one or more life cycle stage (e.g., larval stage, breeding) (Harding 1997; Holman 2012). Amphibians have moist, highly-permeable skin and generally require close proximity to a water source (Hecnar 2004). They typically also lay their eggs in water, and larvae are completely dependent on aquatic habitats. Reptiles generally have less permeable skin covered with keratinaceous scales. These animals may also require high levels of moisture in their preferred habitats, and several species (e.g., Eastern Massasauga Rattlesnakes, *Sistrurus catenatus*; Spotted Turtles, *Clemmys guttata*; Blanding's Turtles, *Emydoidea blandingii*) live in wetlands for at least part of the year (Harding 1997; Lee 1999; Lee 2000; Lee and Legge 2000; Moore and Gillingham 2006; Beaudry, Demaynadier et al. 2009; Smith 2009). Since many amphibians and reptiles have extensive contact with water, high water quality is imperative for viability of diverse amphibian and reptile communities.

2. Turtles eggs--like the Eastern Snapping Turtle eggs pictured above-- require specific nest conditions in order for eggs to develop. Creating and maintaining nesting sites is vital for long-term turtle population viability.

Many species of amphibians and reptiles are seasonally wetland dependent and rely on uplands adjacent to wetlands during the remainder of their annual cycle (Porej, Micacchion et al. 2004; Attum, Lee et al. 2008; Attum, Lee et al. 2009). Many species, such as Copper-bellied Water Snakes (*Nerodia erythrogaster neglecta*), Wood Frogs (*Rana sylvatica*), and Eastern Tiger Salamanders (*Ambystoma tigrinum*) seasonally migrate between wetland and upland areas for breeding, nesting, and foraging. These species require a mosaic of wetland types with intact upland habitat communities adjoining them. These species rely on linkages between uplands and wetlands to maintain population stability.



3. The Eastern Massasauga Rattlesnake, which was recently elevated to full species status is listed as a Michigan species of Special Concern and classified by the MDNR Action Plan as a Species of Greatest Conservation Need. It is also a federal candidate species under the U.S. Endangered Species Act.

1. Fallen trees and old logs can be repurposed as basking structures for turtles.

2. Evidence of recruitment--such as this young of year spring peeper--is an indicator of community health.

3. Salamanders require submerged vegetation, such as this branch, to attach their egg masses to.

This chapter describes the herpetofauna of Michigan and their habitats. Understanding the ecology, life cycles, and specific habitat requirements of reptiles and amphibians is critical to developing and managing landscapes in ways that support and promote biodiversity.

At Present the Herpetofauna of Michigan is Comprised of the Following

- 18 species of Snakes
- 11 species of Turtles
- 2 species of Lizards
- 14 species of Frogs and Toads
- 14 species of Salamanders

Michigan Herpetofauna: Ecological and Habitat Requirements

Amphibians and reptiles in Michigan live in a variety of community types with supporting habitat features (Appendix A). These animals are constrained by their physiology to occupy specific areas that provide these key features. These usually include:

Basking structures – Areas where amphibians and reptiles can warm themselves to regulate their body temperature. Amphibians and reptiles can warm themselves on or under sun-exposed rocks and logs or in gaps in the vegetation canopy where the sun shines. It is equally important that structurally diverse areas of vegetation and substrates that provide shade or cooler temperatures are adjacent to basking areas. Amphibians and reptiles can regulate their body temperature behaviorally by moving between these microclimates.

Shelter – Spaces that provide protection from predators and the elements include areas of dense vegetation, rocks, logs, tree roots, subterranean structures (e.g., burrows, or soils where burrows can be made), and suitable water bodies.

Foraging areas – Areas that contain a suitable food source. Depending on the life stages present, these areas can vary among a species.

Hibernacula – Places to hibernate in the winter, typically a protected area. Depending on the species, a hibernaculum can range from a dry, abandoned mammal burrow, to a burrow under thick leaf litter on the forest floor, to a submerged substrate in a pond, lake, or stream.

Nesting and egg laying sites – Lizards, turtles, and many snakes lay shelled eggs and typically require well-drained, moist soils on a south-facing slope for their nests. Frogs and most

2. Tiger Salamanders are one of the earliest species to emerge in spring to breed. They are also our largest terrestrial salamander.

3. Strings of Eastern American Toad eggs are laid amongst submerged vegetation and will hatch in 2-14 days.

4. Male Northern Spring Peepers call in early spring to attract females to mate with.

salamanders typically require submerged vegetation, rocks, branches, or other structures for egg attachment.

1. Painted Turtles require well-drained soils for their nesting sites. Turtles construct nests by touch, never seeing the eggs.

Several resources on the natural history and distribution of Michigan herpetofauna are available online. You can also learn more about Michigan amphibians and reptiles by visiting the Michigan Herp Atlas (www.MIHerpatlas.org). The Michigan Herp Atlas is the most comprehensive and continuously updated database of herpetofauna observations in Michigan. The Michigan Natural Features Inventory (MNFI) Rare Species Explorer provides information about state and federally listed species, including optimal times to survey, status, and the natural communities where species occur. The University of Michigan Animal Diversity Web and the MDNR websites also provide useful information relating to amphibians and reptiles natural history, range, and conservation status. This manual utilizes commonly accepted and used nomenclature for Michigan herpetofauna (Holman 2012). Taxonomic reclassification continues as more genetic information is obtained and the naming used within this document may be revised in the future. For a complete list of North American herpetofauna nomenclature, see Crother et al. 2012.

Amphibians

Some of the characteristics that typically define amphibians as a group include aquatic eggs, a gilled larval stage (in most but not all species), glandular skin that is variably permeable to water, and a lack of claws and keratinaceous scales. Since all amphibians in Michigan rely on the presence of water to fulfill their basic needs, they must live in damp or aquatic habitats. Michigan amphibians include the following groups:

Salamanders

Salamanders are most abundant in temperate zones and have peak diversity in the U.S. All salamanders are carnivores, feeding largely on invertebrates in aquatic and terrestrial ecosystems. Michigan is home to several species of salamanders, including a unique hybrid complex of unisexual polyploid salamanders (*Ambystoma sp.*), which incorporates the genetic material of several species.

Frogs and Toads

Frogs and toads (frogs with warty skin and hopping gait) are defined by their elongated hind limbs that are adapted for swimming and jumping, buccopharyngeal respiration (gas exchange facilitated by rapid pulsing of the throat), and distinct breeding calls that can be used for field identification (Harding 1997). They are mainly herbivorous or omnivorous as larvae (tadpoles), and fully carnivorous as adults, feeding largely on invertebrates Frogs and toads are mid-level consumers in both aquatic and terrestrial food webs, as they eat vegetation (as larvae), invertebrates, small vertebrates and also provide food for other animals at higher trophic levels. Adults often lay masses or strings of hundreds to thousands of eggs, however, in most instances the majority of their eggs and the resulting tadpoles become a meal for another animal before they can complete metamorphosis.

1. Butler's Garter Snakes primarily eat earthworms, but will also feed on slugs, leeches, salamanders, and small frogs. In Canada, presence of earthworms is used as an indicator for potential presence of this declining and cryptic species.

Reptiles

Some of the characteristics that traditionally define reptiles include claws and a body covering of keratinaceous scales or scutes (in turtles). Most reptiles produce shelled (amniotic) eggs that are laid in a variety of environments; however, some reptiles (e.g., Eastern Massasauga Rattlesnakes, Garter Snakes and Water Snakes) give birth to fully formed live young. Reptiles in Michigan rely on a variety of natural communities within both uplands and wetlands to fulfill their life requisites, but are often closely associated with wetland communities at least seasonally. Michigan reptiles include the following groups:

Snakes

Snakes are defined by elongated legless bodies and skeletal structure that contains from 150 to over 400 ribs. Some lizards are also legless, but possess eyelids and external ears that snakes lack. Snakes are entirely carnivorous, eating rodents, birds, eggs, amphibians, and insects. Most snakes in Michigan hibernate in holes, old mammal burrows, and crevices in the ground during winter. Snakes have either smooth or somewhat rough, dry skin, the outer layer of which is molted in a single piece. A shed skin will remain in the environment for a week or two and occasionally up to a month(Gray 2012). Sheds can sometimes be identified to species and indicate the presence of a snake even if the snake is not observed.

2. The upper and lower portions of the shell - the carapace and plastron - help protect this Spotted Turtle from predation. This simple but effective design has been in use by turtles for 200 million years.

Turtles

Turtles are characterized by a hard outer shell that consists of two parts, the upper shell (carapace) and the lower shell (plastron). The shell is reduced in some species for extra mobility (e.g., Snapping and Softshell Turtles) while other species possess a hinged plastron that allows them to withdw and cover their limbs, head, and tail completely (e.g., Box and Blanding's Turtles). All turtles are toothless with sharp, beak-like jaws that can slice through food items. Some species in Michigan are mostly carnivorous while others are omnivorous. Turtles are generally long-lived animals and the typical lifespan for most turtle species

is at least several decades, though some species are known to surpass the century mark. Longevity is necessary to make up for the naturally high mortality of turtle eggs and hatchlings, as well as the long time periods needed for young turtles to reach sexual maturity.

Lizards

Michigan has two species of lizards known to breed within the state. These species exist in isolated areas and are more abundant in southern Michigan. Lizards are characterized by having four limbs (though legless species exist in other states) and long tails that, in many species, can be detached as a defense mechanism. Michigan's lizards are predators and feed mostly on insects and other small invertebrates. While most species contribute no parental care after laying their eggs, one Michigan lizard species, the Five-lined Skink (*Plestiodon fasciatus*) is known to guard its eggs until hatching. Lizards are generally short-lived compared to turtles and typically live less than 10 years.

1. Six-lined Racerunners are a State Threatened species, with only one known isolated colony occurring in Tuscola County. These lizards prefer sandy, sunny sites. Observations of this species should be reported to the Michigan Herp Atlas.

2. Everything that contributes to habitat for amphibians and reptiles - including plants, other animals, and even fungi - should be considered when working to conserve the herpetofauna of an area. Mushrooms are an important food source for Eastern Box Turtles.

Michigan Herpetofauna Community Associations and Habitats

Identification of herpetofauna habitat is essential to the protection and conservation of Michigan's amphibians and reptiles. The potential habitats at a site largely depend on the number and size of natural communities that are present. Plants, animals, fungi, and detritus are all part of the natural community however the topography, water, soil, and rock are also important components of a habitat and should be surveyed for the potential features and functions they provide for amphibian and reptile species.

On larger sites that cannot easily be effectively surveyed on foot, general categories of natural communities often can be identified on aerial photographs. These photographs are available at no cost online (e.g., using Google Earth, Bing, etc.), and some sources provide historical images, which can enhance the understanding of the long-term ecological condition of the site. To a trained aerial interpreter, color differences in the images can be a good indication of what vegetation and hydrologic processes are present that could denote the presence of a particular community. Natural communities identified using aerial imagery must be field checked for accuracy confirmation.

Public and private natural resource professionals may be able to assist in identification of herpetofauna habitat and can work to create a strategic plan that balances primary objectives (development, maintenance, restoration, or ongoing stewardship activities) with the incorporation of wise natural resource management practices.

Refer to Appendix A for the community types where Michigan herpetofauna may usually be found.

4. Threats to Amphibians and Reptiles

Shane DeSolla

1. Eastern Massasauga Rattlesnakes live in wetlands for most of the year and are seldom seen by humans. This species is cryptic and in decline throughout their range.

2. This Snapping Turtle egg was incubated in asphalt. Pollutants in these materials may likely impact nest success.

Habitat Loss, Degradation, Fragmentation, and Urbanization

Habitat destruction, degradation, and fragmentation (secondary effect of habitat destruction and degradation) are among the most serious causes of current and future reptile and amphibian population declines and species extinctions (Knutson, Sauer et al. 1999; Dodd, Smith et al. 2003; Marchand and Litvaitis 2004; Weyrauch and Grubb 2004; Böhm, Collen et al. 2012). Freshwater systems face significant reductions in biodiversity, which can be linked to overexploitation, water pollution, flow modification, destruction or degradation of habitat, and invasion by exotic species. North American freshwater species (including reptiles and amphibians) are currently experiencing pressures that will likely lead to several extinctions by the end of the century, with projected rates of 4% extinction per decade (Ricciardi and Rasmussen 2001). Herpetofauna in Michigan rely on wetland and adjacent upland communities for specific habitat features and frequently move between communities on a seasonal basis. Connectivity is therefore essential for long-term viability of amphibian and reptile populations on a landscape level. Habitat fragmentation occurs when existing populations become isolated because corridors between specific habitat features have been lost. Fragmentation can result in increased mortality, reduced genetic diversity, increased predation pressure, increased edge habitat, reduced habitat quality, reduced critical zones - areas that are critical for life function, and invasive species colonization (Fahrig and Merriam 1985; Petranka, Harp et al. 2007; Bennett, Keevil et al. 2010; Bennett and Litzgus 2012; Row, Blouin-Demers et al. 2012).

Historically, Michigan had abundant wetlands, streams, lakes, and terrestrial areas that provided suitable communities for amphibians and reptiles (Holman 2012). However, Michigan lost approximately 50% of these important habitats between the 1780s and mid-1980s (Dahl 1990). Several wetland protection, loss mitigation, and restoration programs have been established through the MDEQ, United States Department of Agriculture's Natural Resources Conservation Service (NRCS), the United States Fish and Wildlife Service (USFWS), the MDNR, and several nonprofit conservation organizations including Ducks Unlimited. While the wetlands created

1. Basking sites help amphibians and reptiles, like these Northern Map Turtles, to maintain an ideal body temperature and are a critical microhabitat feature.

2. Roads (especially with curbs) can play a significant role in fragmenting landscapes. This female Northern Leopard Frog was migrating across the road to reach a breeding site.

3. It is important to monitor and take corrective measures to prevent mitigations from becoming dominated by invasives.

through these programs provide some ecological services (e.g., flood control and waterfowl habitat), these wetlands are often open-water ponds that support predatory fish populations that threaten the survival of amphibian larvae (Ficetola and De Bernardi 2004; Porej, Micacchion et al. 2004; Cunningham, Calhoun et al. 2007). These open-water wetlands do not replace ecological functions and values of most destroyed and degraded vernal pools (seasonal forested pools that provide critical breeding habitat for several amphibian and reptile species), swamps, emergent marshes, fens, bogs, and wet prairies (Shulse, Semlitsch et al. 2010). Mitigation wetlands seldom provide the appropriate food resources, cover, hydroperiod (– length of time surface water is present), sandy or gravel nesting areas with proper exposure, or hibernacula. Often, high-quality terrestrial areas necessary for survival and successful recruitment are lacking (Reinartz and Warne 1993; Zedler and Callaway 2002; Porej 2003; Vasconcelos and Calhoun 2004; Petranka, Harp et al. 2007; Shulse, Semlitsch et al. 2010). In addition, complete amphibian communities are generally absent from most created wetlands (Lehtinen and Galatowitsch 2001; Porej 2003; Mack and Micacchion 2006)and many created wetlands are geographically separated from existing wetlands, which limits colonization by amphibians and reptiles (Lehtinen and Galatowitsch 2001).

Construction and development can also remove amphibian and reptile habitat features from the landscape. This impacts specific amphibian and reptile species in the destroyed community as well as those that relied on that area as a connection between other habitat features (Knutson, Sauer et al. 1999; McKinney 2002; Skidds, Golet et al. 2007). Changing the natural contours and composition of a landscape can alter drainage patterns, thereby altering the hydroperiod, water depth, and overall community structure in wetlands and entirely alter the character of upland areas. Use of heavy equipment during construction can compact soil which can cause direct mortality to amphibians and reptiles in the project area (Bol 2007). Compacted soils also support only a limited variety of vegetation which may not provide the suitable canopy cover or duff layer required by various amphibian and reptile species (Gebauer, Neruda et al. 2012).

Construction, such as roads, can also have significant long-term effects on biodiversity and population sustainability (Findlay and Bourdages 1999). Roads

Carl May

1. Habitat conditions in degraded wetlands are typically not suitable for amphibians and reptiles. With restoration, these areas can serve as habitat again.

2. Roadways can impede amphibians and reptiles from moving through the landscape to nesting and hibernation areas.

3. Creating no-mow zones like this one in Lake St. Clair Metropark can reduce direct mortality of herpetofauna.

are a significant barrier for amphibian and reptile movement in the landscape, with tens of thousands of turtles, snakes, and frogs being killed along roadways every year (Steen and Gibbs 2004; Steen, Aresco et al. 2006; Row, Blouin-Demers et al. 2007; Patrick, Gibbs et al. 2011). In some places, roads are a significant source of mortality for herpetofauna, can threaten the existence of local populations (Beaudry, Demaynadier et al. 2010; Gunson, Ireland et al. 2012; Sarver and Walton 2012). Persistent mortality can reduce species abundance and diversity up to 2 miles away (Reh and Seitz 1990; Vos and Chardon 1998; DeMaynadier and Hunter Jr 2000). Frogs and some turtles can live in ditches created along roads and use these as movement corridors. Unfortunately, a short foray from the ditch can put these animals in the path of traffic. Roads built in areas of high quality communities or near reptile habitat features (e.g., snake hibernacula) have higher reptile mortality rates (Fortney, Poulin et al. 2013). Often, animals are killed as they attempt to access seasonal habitat features, nest in the warm, dry soil on the shoulder of a road, or bask on the warm road surface (Ashley and Robinson 1996; Steen and Gibbs 2004; Steen, Aresco et al. 2006; Szerlag and McRobert 2006; Row, Blouin-Demers et al. 2007; Shepard, Dreslik et al. 2008; Patrick, Gibbs et al. 2011; Fortney, Poulin et al. 2013). Roads can also function as corridors for amphibian and reptile predators, which increases predator movement along roadsides (Trombulak and Frissell 2000; Frid and Dill 2002; Andrews and Gibbons 2005; Aresco 2005; Barrientos and Bolonio 2009; Clark, Brown et al. 2010; Hawlena, Saltz et al. 2010). These predators can increase negative pressure on herpetofauna populations, as they may eat turtle eggs or amphibians and reptiles attracted to the warm road surface (Boarman, Sazaki et al. 1997). Roads also create a barrier for those amphibians and reptiles that avoid roads, thus restricting these species' range of movement and use of habitat features (Andrews and Gibbons 2005; Jaeger, Bowman et al. 2005; Andrews, Gibbons et al. 2008). Additionally, the presence of roads can alter microclimate conditions (e.g., temperature, humidity, and evaporation), which can reduce the suitability of habitat for herpetofauna (Mader 1984).

Activities associated with urbanization can create a varied array of potential threats or problems for amphibians and reptiles. Mowing can cause direct mortality to amphibians and reptiles (personal observation ; Saumure, Herman et al. 2007; Humbert, Ghazoul et al. 2009). Snakes, frogs and toads, and turtles in the process of nesting are particularly vulnerable to mowing because of their low profile and cryptic coloring. In addition to the potential injury or mortality, mowing contributes to loss of habitat for amphibians and reptiles. In or near urban areas, excessive aquatic vegetation growth triggered by high nutrient levels in waterways is often addressed by mechanical harvest or herbicide application. This method is only a temporary fix, as it does not address the cause of the problem - excessive nutrient inputs - and unfortunately


Nick Scobel

also harms amphibians and reptiles. Machines indiscriminately remove non-target flora and fauna, including amphibians and reptiles from the surface of the water and process them with the targeted vegetation, sometimes crushing the animals (Wile 1978; Haller, Shireman et al. 1980; Mikol 1985; Engel 1990; Booms 1999). In a best case scenario, these animals are displaced to the area where the unwanted vegetation is disposed. Mechanical weed harvesting also can disturb the bottom, releasing sediments and toxins into the waters that amphibians and reptiles use as part of their habitat (Washington State Department of Ecology 2003). Urban lighting has also been identified as potentially harmful to amphibian and reptile communities (Perry, Buchanan et al. 2008). Many amphibians and reptiles respond to visual cues, and life processes such as migrations, mating, nesting, and hibernation may be influenced by light pollution.

Although often used as a wildlife conservation and plant community restoration measure, controlled (prescribed) burns can cause injury and direct mortality to herpetofauna as well as alter habitat suitability (personal observation ; Durbian 2006; Woodley and Kingsbury 2011). The success of burns is often focused on vegetation community development and often does not consider the short- and long-term impacts to wildlife unless directed specifically as a target animal species. Such actions often do not take into account the implications of a highly-fragmented landscape that may limit colonization after the burn program has completed (Cole and Landres 1996). The full ramifications of fire on herpetofauna in Michigan are currently largely unknown due to a lack of study and the wide range of effects. Considerations of the types of fire, life histories of non-target species, and potential impacts to herpetofauna, specifically appear not to be evaluated. As a result, fire management (e.g., change in litter, vegetation structure, response in various life stages, effect on food source, etc.) can alter the site in ways that may negatively affect some species. However, turtle and snake mortality has been documented at burn sites in Michigan (personal observation ; Cross 2009; Gibson 2009; Woodley and Kingsbury 2011). Fire can unevenly affect species based on their mobility, as highly mobile groups, such as lizards, have lower levels of mortality associated with fire compared to frogs, salamanders, snakes, and turtles, and the community composition post-burn may have fewer and more generalist species than pre-burn (Rochester, Brehme et al. 2010). Use of fire alters percent canopy cover and the litter layer which offers cover for many amphibians and reptiles and is critical for maintaining humidity levels and provision of micro-habitats (McCleod and Gates 1998; Rochester, Brehme et al. 2010). The temporary decrease in abundance of post-burn insect communities that live closest to the ground (in the "fuel" layer (Siemann, Haarstad et al. 1997; Tooker and Hanks 2004)) may decrease the food base available to amphibians and reptiles directly after a burn.

1. Turtles nesting next to roads and any hatchlings produced by these nests are at risk of being run over by cars.

2. Spiny Softshell Turtles are at risk for collisions with motorized watercraft and aquatic weed harvesters as they are camouflaged and often bask by floating at the surface of the water.

3. This Eastern Box Turtle has suffered fatal injuries during a prescribed burn.


Joanna Gibson

1-3. Pollutants including fertilizer, herbicide, sewage, and stormwater runoff indirectly impact wildlife communities.

Chemical Pollution

Amphibians and some reptiles have highly permeable skin and typically have extensive contact with water or soils. These characteristics make them particularly sensitive to chemical pollution in soil and water and susceptible to bioaccumulation (biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment) of toxins and contaminants (Johnson, Franke et al. 1999; Unrine, Hopkins et al. 2007). Their sensitivity to chemical pollution and tendency towards bioaccumulation can result in decreased abundance and the extirpation of sensitive species (McNeely 1992). Other specialized physiological features of some amphibians and reptiles increase their sensitivity to toxins, as in the case of Eastern Spiny Softshells (*Apalone spinifera spinifera*) and Eastern Musk Turtles (*Sternotherus odoratus*), which can respire through specialized tissue in the cloaca and tongue (Heiss, Natchev et al. 2010). Reptile and amphibian population declines have been linked to increased pollution (Fontenot, Noblet et al. 2000; Johansson, Räsänen et al. 2001), but relatively little work has been done to document the response of amphibian and reptile communities to various types of chemical contaminants (Egea-Serrano, Relyea et al. 2012).

Development and land conversion for agriculture can result in several types of chemical pollution that have wide ranging, deleterious effects on amphibian and reptile populations. Industrial, commercial, transportation, and residential activities can also introduce high nutrient, pesticide, and herbicide levels and can result in acidification of the environment. All of these can adversely affect amphibian growth and development, and ultimately contribute to population declines (Bradford and Gordon 1995; Jung and Jagoe 1995; Mann and Bidwell 1997). Runoff from roads, parking lots, sidewalks, rooftops, lawns, and other surfaces has introduced high levels of road salts, de-icer chemicals, heavy metals, petroleum products and hydrocarbons from vehicle emissions into the local water supply and adjacent wetlands (Schueler 1994; Barnes 2001; Brabec, S. et al. 2002; Schueler 2003). Chemical contaminants may weaken the immune system of amphibians and reptiles and increase their susceptibility to parasites, disease and UV radiation (Blaustein, Romansic et al. 2003; Daszak, Cunningham et al. 2003; Gendron, Marcogliese et al. 2003).

Salts and Heavy Metals

Materials used for road maintenance include de-icers which can contain salts, sand, cinder, sodium ferrocyanide, and heavy metals (Oberts 1986). Hydrocarbons and heavy metals are also introduced from motor vehicle use. This suite of pollutants can affect water quality, which in turn can harm herpetofauna populations (Karraker 2006; Andrews, Gibbons et al. 2008; Bennett, Smith et al. 2011). These pollutants reduce water quality and degrade terrestrial resources on which amphibians and reptiles rely (Findlay and Kelly 2011). The full extent of the ecological ramifications of road salt and de-icer application is yet unknown; however, regulatory agencies such as the United States Environment Protection Agency (EPA) and Environment Canada have recognized the toxicity of road salt to ecosystems and wildlife and is actively working to reduce its use (United States Environmental Protection Agency 2005; Karraker 2006; Karraker, Gibbs et al. 2008). Environmental salinity from application of road salts can make wetlands unsuitable for wildlife, but it can also degrade smaller areas of larger wetlands that will support invasive species, such as Eurasian common reed (*Phragmites australis*, hereafter referred to as *Phragmites)* (Karraker 2006). Although lower-impact alternatives to conventional road salts are used and recommended by the Michigan Department of Transportation (Michigan Department of Transportation 2006), in winter 2006/2007 road salt use on municipal roads in Michigan was applied at an average of 22.78 tons per lane-mile (Michigan Department of Transportation 2008). This salt in the environment runs into surface waters and percolates through the soil into the ground water, increasing the long term baseline salinity of water resources critical to most amphibians and reptiles (Judd 1970; Demers and Sage 1990; Rosenberry, Bukaveckas et al. 1999; Paul and Meyer 2001; Jackson and Jobbágy 2005; Kaushal, Groffman et al. 2005).

1. Eastern Musk Turtle and several other reptile and amphibian species spend the majority of their life in contact with water and are extremely sensitive to chemical pollution.

2. This male Spotted Turtle was impacted by the 2010 oil spill in Marshall, Michigan. Long-term effects from chemical exposure and loss of habitat from the spill are still not known.

3. A Northern Map Turtle receiving treatment for oil exposure. Chemical burns on exposed surfaces and consuming of hydrocarbon pollutants were the most commonly observed sights early in the spill response.

Sean Zera

Polycyclic Aromatic Hydrocarbons (PAHs) and Other Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) and other hydrocarbons are pollutants that are commonly detected in the environment as a result of natural occurrences such as volcanoes and fires, but also result from anthropogenic sources such as urban and industrial runoff, wastewater treatment effluent, petroleum spills, and atmospheric deposition from combustion (Albers 2002). PAHs are endocrine disrupting compounds (ATSDR 1995) that can cause lethal and sublethal effects and deformations in wildlife (Albers 2002; Douben and Wiley 2003). These compounds have also have been linked to immune suppression (Dickerson, Hooper et al. 1994), hemolytic anemia (a condition in which red blood cells are destroyed), and cancer (Baumann and Harshbarger 1995). Relatively little work has been done to study the effects of PAHs in the environment on amphibians and reptiles (Pauli, Perrault et al. 2000), but these compounds likely have similar impacts to those demonstrated for other wildlife groups. Demonstrated impacts in amphibian and reptile species from exposure to PAHs include deformities in Eastern Snapping Turtle hatchlings (Van Meter, Spotila et al. 2006), reduced fertility and hatchling mortality in Eastern Snapping Turtles and Painted Turtles (*Chrysemys picta*; (Bell 2005)) and toxicity and cancer in amphibians (Balls 1964; Fernandez and L'Haridon 1992; Djomo, Ferrier et al. 1995).

Pharmaceuticals and Hormones

Pharmaceuticals and hormones (e.g., synthetic hormones, acetaminophen, triclosan [an antibacterial and antifungal agent common in soaps, toothpaste, cleaning supplies, and some plastics], and caffeine) are present in the environment and are increasing in human use. Pharmaceuticals are known to have endocrine disrupting properties with the potential to interfere with hormonal and developmental pathways in animals (Crump 2001). These chemicals have been detected in aquatic ecosystems around the world and are now commonly found in surface waters (Garric and Ferrari 2005) and in wastewater treatment plant effluent (Gross, Montgomery-Brown et al. 2009). The environmental contamination associated with pharmaceuticals are in part regulated by the Food and Drug Administration (FDA) that evaluates environmental impacts of drug use (U.S. Food and Drug Administration 2011) and the EPA that limits the discharge of pollutants into navigable waters of the United States and into wastewater treatment plants by existing and new pharmaceutical manufacturing facilities (United States Environmental Protection Agency 2006). The effect of these chemicals on amphibians and reptiles in aquatic systems is not well documented, however, there is evidence that these pollutants may be linked to developmental and behavioral abnormalities and lethality in amphibians (Sower, Reed et al. 2000). They potentially impact the metabolic processes of wildlife and other ecological processes (Länge and Dietrich 2002; Sumpter 2007; Williams and Cook 2007).

Matt Smar

1. Storm water runoff carries road salt, pollutants from vehicles, and warm water into storm sewers, some of which lead directly to rivers and other water bodies.

NASA

Shane DeSolla

2-3. Stormwater runoff from agricultural and urban areas increase the nutrient levels in the Saginaw Bay and other Great Lake water bodies, which has resulted in algal blooms and excessive plant growth.

Excess Nutrients

Nutrients (e.g., nitrogren and phosphorous) found throughout the Great Lakes basin associated with runoff from agricultural fields, industrial water treatment, and waste water treatment have been linked to deformities and have both sublethal and lethal effects in amphibians (Rouse, Bishop et al. 1999) and the expansion of *Phragmites* (King, Deluca et al. 2007). Chronic effects on amphibians (reduced feeding and swimming, disequilibrium of larvae, and developmental abnormalities) were observed in some species at nitrate concentrations well below the EPA Maximum Contaminant Level (MCL) for nitrate in drinking water (Rouse, Bishop et al. 1999). Nitrates may affect amphibian populations by encouraging algal growth which can lead to increases in *Planorbella* spp. These snails are believed to be the exclusive primary intermediate host for *Ribeiroia ondatrae*, a species of trematode that parasitizes amphibians and causes deformities (Johnson and Chase 2004)

Pesticides

Pesticides, including herbicides and insecticides commonly applied to agricultural fields and manicured landscapes can cause developmental



1-3. Eggs and larvae of amphibians, like Wood Frogs, are particularly sensitive to pesticides and herbicides.

abnormalities, deformities, and altered behavior and have been documented as the impetus for declines in several amphibian species (Mann and Bidwell 1997). Several commonly used herbicides and pesticides (e.g., Roundup®, Sevin®, malathion, 2,4-D) also reduce the number of overall species in aquatic communities and could have indirect effects on amphibians and reptiles that rely on a stable food supply (Relyea 2005).

Recent studies suggest that pesticides and fungicides may have extremely harmful effects on amphibians in terrestrial environments (Brühl, Schmidt et al. 2013). Reduced abundance of Mink Frogs (*Rana septentrionalis*) has been linked to large scale insecticide use (McAlpine, Burgess et al. 1998). Acute and chronic mortality and deformations in salamander and frog communities have been observed after insecticide applications (Ingermann, Bencic et al. 2002; Boone and James 2003). The historical use of DDT (Dichloro-Diphenyl-Trichloroethane) in the U.S. has been documented to cause significant mortality to amphibians and reptiles (U.S. Fish and Wildlife Service 1945; Herald 1949). Insecticide use can reduce the prey base for amphibians and reptiles, and some insecticides have a variable effect on amphibian species and can alter the amphibian community compositions (Boone, Semlitsch et al. 2004). Although not as widespread as in the past, chemical control of mosquitos is conducted as part of an integrated mosquito management strategy (MMCA 2013) through chemical applications to the surface of water bodies and by spraying into the air ("fogging"). Some of the chemicals used in fogging are to kill adult mosquitos (e.g., malathion), while organophosphates target mosquitos larvae stages, both are toxic to tadpoles (Berrill, Bertram et al. 1994; Sparling, Lowe et al. 1997; Relyea 2004) and may result in amphibian declines. Removal of larval and adult mosquitos from an ecosystem can also remove a significant food source for larval amphibians, fish, birds, and other wildlife (Blaustein and Kotler 1993; Blaustein, Friedman et al. 1996; Kumar and Hwang 2006). Organochlorine pesticides, such as lindane, endosulfan, dicofol, methoxychlor and pentachlorophenol, break down slowly and can be retained in tissue for long periods of time. These substances and banned organochloride pesticides, such as DDT, have been detected in turtle organs and eggs at levels that have implications for human consumption of turtles and for development of turtles (Solla and Fernie 2004).

Herbicides move via groundwater and surface runoff into wetlands where amphibians are likely to be affected. As of 2003, the United States EPA has approved over 20,000 insecticides, fungicides, and herbicides (United States Environmental Protection Agency 2003). The most extensively used herbicide is atrazine, which is toxic to aquatic organisms (United States Environmental

1. Atrazine, the most widely used herbicide in the United States, has been demonstrated to inhibit reproductive development and suppress immune system response of Northern Leopard Frogs.

2. Exposure of Green Frog tadpoles to glyphosate has been linked with decreased size at metamorphosis.

Protection Agency 2003), and for this reason has been banned by the European Union since 2004 (Sass and Colangelo 2006; Ackerman 2007). Atrazine has commonly been detected in surface waters, and concentrations generally peak following major storm events that occur within a few weeks of application. Atrazine has been linked to malformations, specifically in Northern Leopard Frogs (*Rana pipiens*), resulting in reproductively viable hermaphroditic transformations that skews sex ratios, disrupts population structure, and may reduce genetic diversity (Allran and Karasov 2000; Sower, Reed et al. 2000; Hayes, Haston et al. 2002; Hayes, Collins et al. 2002; Hayes, Haston et al. 2003; Coady, Murphy et al. 2004; Hayes, Khoury et al. 2010). Additionally, atrazine exposure can increase risk of desiccation for salamanders, even months after exposure likely due to the disruption of neuroendocrine processes associated with water-conserving behaviors (Rohr and Palmer 2009). Another herbicide, alachlor, has been shown by the EPA to cause skin and eye irritation; increased risk of renal, spleen and liver damage; and promotes cancer of the lining of nasal cavity and eyelids. This chemical has been banned in Europe since 2006 and in Canada since 1985 but continues to be used in the U.S. (United States Environmental Protection Agency 1998; Rotterdam Convention 2011). The pre-emergent herbicide, acetochlor, can have negative physiological effects and has been linked to hindered hind limb development for larvae and may lead to reduced population size for affected species including Northern Leopard Frog, Green Frog, and Bullfrog (Cheek, Ide et al. 1999; Mann, Hyne et al. 2009).

Glyphosate based herbicides (e.g., Roundup®, Rodeo®, Accord®) and surfactants (e.g., POEA, polyethoxylated tallowamine; NPE, nonlyphenol ethoxylates) are commonly used in land management (Dill, CaJacob et al. 2007). These herbicides have more severe negative effects and are moderately to highly toxic to amphibians. Larvae exposed to glyphosate and surfactants can produce smaller adults, mature slower, have deformations and abnormalities, and have higher mortality rates (Howe, Berrill et al. 2009; Relyea and Jones 2009). There is evidence to suggest that the surfactant rather than the active ingredient (isopropylamine salt of glyphosate) in these herbicides is responsible for the toxic effects (Trumbo 2005). As surfactants are proprietary mixtures protected under trade-secret laws, manufacturers are not required to list the chemical composition of these compounds. Glyphosate and atrazine applied for weed and invasive plant control in agricultural fields have been detected in nearby water bodies at concentrations that exceeded the freshwater aquatic life standard for their respective chemical compositions (Battaglin, Rice et al. 2009). These measurements are identified in the Canadian Environmental Quality Guidelines and have been set to provide protection of freshwater life from anthropogenic stressors such as chemical inputs or changes to physical components (Canadian Council of Ministers of the Environment 1999). Although glyphosate herbicides are deemed safe in part because they supposedly quickly degrade in the environment, concentrations of glyphosate greater than the LC50 (lethal concentration for 50% of the population) value for many amphibians (between 10

Jason Folt

Tom Beauvais

1-2. Application of lampricides often results in mortality of Mudpuppies in areas where these fully aquatic salamanders live.

3. Dams not only affect hydrologic processes but can also serve as a form of habitat fragmentation for wildlife.

and 1 mg acid equivalent/L) (Govindarajulu 2008) have been detected in nearby waterways one week after application (Battaglin, Rice et al. 2009). Additionally, some herbicides, such as triclopyr, can be detected in nearby aquatic systems up to 13 months after treatment (Battaglin, Rice et al. 2009). Impacts of these herbicides to aquatic ecosystems and specifically to amphibians and reptiles, is greatest when a buffer zone is not used and chemicals are used directly around aquatic systems (Trenham 2001; Trenham and Shaffer 2005; Battaglin, Rice et al. 2009).

Piscicides

Lampricide is used as a piscicide to kill invasive sea lamprey (*Petromyzon marinus*) in Michigan waters. Lampricide has deleterious effects on several non-target species (Boogaard, Bills et al. 2003; Dawson 2003; Hubert 2003). This chemical is toxic to many insects, including some beneficial insects (e.g., lady bugs), fish, and ticks, and slightly toxic to some bird species (Extoxnet 1996). Lampricide can be toxic to gill-breathing larval amphibians and adult amphibians, such as Mudpuppies (*Necturus maculosus*) and sometimes results in large-scale mortalities (Gilderhus and Johnson 1980; Kane, Day et al. 1993; Boogaard, Bills et al. 2003; Dawson 2003; Hubert 2003; Billman, St-Hilaire et al. 2011; State of Vermont 2011). Several turtle species may be impacted by lampricide, particularly Eastern Spiny Softshells and Eastern Musk Turtles, as these species respire through specialized tissue in the cloaca and tongue which likely increases sensitivity to toxins (Heiss, Natchev et al. 2010). Long-term accumulation of lamprey-killing chemicals in Mudpuppies may shorten the life span in these long-lived (~25 yrs.) amphibians and decrease their ability to reproduce (Parren and Hart 2012). Direct mortality sometimes in the hundreds of Mudpuppies in Michigan has been documented though efforts have been made to refine application techniques to reduce mortality. The full impact of lampricide on herpetofauna is largely unknown (State of Vermont 2011). Researchers have identified the need for further investigation on how non-target, non-fish vertebrate and invertebrate species (specifically larval amphibians, mollusks, and endangered species) are impacted (McDonald and Kolar 2007). Rotenone is a broad spectrum pesticide used to treat a problematic fish community. The application of rotenone during the winter when amphibians are in hibernation has not shown adverse effects on amphibian populations (Walston and Mullin 2007). Since cold weather also lengthens the half-life of rotenone (Dawson, Gingerich et al. 1991), the desired management effect is likely to be more successful.

Alterations to Hydrologic Processes

Massive efforts through the 1800s and 1900s to drain Michigan's wetlands and saturated soils for agriculture directly reduced herpetofauna habitat and ultimately resulted in a loss of over 11 million acres and 50% of the States's wetland (Dahl 1990). Watershed level alterations

Matt Smar

1. Impermeable surfaces increase runoff and decrease infiltration.

2-3. Not only is vegetation important for preventing runoff that leads to severe erosion, but it also provides habitat for amphibians and reptiles such as this Pickerel Frog.

in hydrologic processes can reduce habitat availability, connectivity, and suitability and recruitment success for various amphibians and reptiles (e.g., Eastern Massasauga Rattlesnake, Blanding's Turtle, Red-spotted Newt (*Notophthalmus viridescens viridescens*), Wood Frog, Spotted Salamander; *Ambystoma maculatum*) (Chin 1996; Willson and Dorcas 2003; Faulkner 2004; Riley, Busteed et al. 2005; Skidds, Golet et al. 2007; Hamer and McDonnell 2008; HRM 2013).

As Michigan became more developed, roads, sidewalks, and roofs replaced areas of vegetation. Vegetation typically reduces the impact of rain events by providing physical a barrier that breaks large rain drops into smaller droplets, allowing soil to absorb water over time and slowing the velocity of runoff. As the velocity of runoff is reduced, the water infiltrates the soil and reduces soil surface erosion. As the water reduces in velocity and infiltrates the soil, sediment and pollutants drop out of the runoff and attach to the soil surface where they are either adsorbed (bound to) onto soil particles or infiltrate into the soil where they are either broken into inert compounds by soil microbes or leach downwards into the subsoil. Open fields that lack dense herbaceous vegetation are vulnerable to erosion and runoff during heavy rain events. Impermeable surfaces do not allow for the infiltration of water and thus increase the rate of stormwater runoff, which generally has increased sediment loads containing higher concentrations of adsorbed pollutants (due to increased sediment loading with adsorbed contaminants) and is warmer than surface waters.

In vegetated areas, rain water is filtered as it slowly percolates through the soil and is slowly released into nearby water bodies via groundwater flows, which help feed streams during dry times. This allows for water to be released into water bodies on a nearly continuous basis and moderates fluctuations in water levels throughout the year. In areas where impermeable surfaces dominate the landscape, water bodies experience flashiness - quick changes in water level, rate of flow, and volume. In addition to the growing percentage of impermeable surfaces, detention of water has been lost in many areas as a result of wetland degradation and loss. Large quantities of rainfall are discharged into nearby water bodies during and directly after a storm, at other times ground-water inputs are minimal as water does not have an opportunity to infiltrate into the soil. Stormwater runoff in urban areas is often channeled to municipal sewers or discharged directly into surface waters (Booth and C.R. 1997). Although these combined sewer systems are less common today due to sewer separation efforts (United States Environmental Protection Agency 1999), use of combined storm and sanitary sewer systems result in overflows of raw sewage into streams and rivers during large and sometimes relatively small storm events resulting in the accumulation of contaminants in water bodies (Eganhouse and Sherblom 2001; United States Environmental Protection Agency 2001; United States environmental Protection Agency 2005). These alterations to natural hydrologic patterns result in extreme changes in water level and temperature and increased

erosion and pollution, which degrades aquatic communities that support amphibian and reptile populations (Murray and Hoing 2004; Massal, Snodgrass et al. 2007).

Removal of vegetation and the litter layer decreases infiltration, increases runoff, and increases the rate of wind and water erosion (Ash 1997). Increased runoff and stream velocity increase the erosive action in upland areas along the banks and in the streambed. The resulting channel incision and steep banks limit connectivity for amphibians and reptiles in the floodplain. These deepened waterways have reduced frequency and duration of inundation (flooding) as the water level is not able to crest the banks and dissipate the energy of the waterway and deposit sediments (Buijse, Coops et al. 2002). Sediment from upland and streambank erosion suspended in surface waters results in increased turbidity and reduced dissolved oxygen. Turbidity reduces water clarity and quality decreasing amphibian and reptile aquatic habitat suitability (Roy, Rosemond et al. 2003; Sacerdote and King 2009). Reduced levels of dissolved oxygen create unsuitable conditions for larval amphibians and Mudpuppies (which use gills for respiration). These effects extend to, fish, and aquatic invertebrates which form the prey base for many aquatic and terrestrial amphibians and reptiles (Spieles and Mitsch 2000; Morley and Karr 2001; United States Environmental Protection Agency 2009).

1. Crayfish chimneys are frequently used by overwintering herpetofauna and can serve as critical microhabitat. These structures demonstrate the importance of maintaining overall community health to sustain viable ecosystems.

2. Channelization reduces the amount of available habitat and alters the flow of water and sediments.

Stream morphology is also altered as a result of anthropogenic actions. Channelization (often in urban areas) has generally been achieved through use of concrete or rock construction. These structures typically remove macro- and micro-habitat features that amphibians and reptiles use for cover, hibernation, as foraging grounds, and for nesting (Bodie 2001). Hardening and straightening waterways alters the flow of water, changing the character of sediment transport and deposition, and decreases infiltration. Over 2,500 dams have been constructed throughout Michigan (Michigan Department of Natural Resources and Michigan Department of Environmental Quality 2004). Although dams were constructed to generate power, create impoundments for recreation and irrigation, to prevent flooding, they also dramatically impact native wildlife and fisheries resources. Dams often create barriers to amphibian and reptile movement and serve to fragment populations (Bennett, Keevil et al. 2010). These barriers alter hydrologic and thermal conditions that impact breeding, nesting, basking, and hibernation opportunities of riverine herpetofauna, altering their spatial distribution (Lind, Welsh Jr et al. 1996; Ashton, Bettaso et al. 2011; Bettaso 2013). Dams reduce areas of suitable aquatic communities upstream and downstream (Eskew, Price et al. 2012). For example, higher water levels upstream of a dam can inundate the sandy banks turtles use for nesting (Hunt, Guzy et al. 2013).

Manipulating water-levels for waterfowl management, recreational use, or restoration efforts can impact amphibians and reptiles. Drawdowns – water removals – are performed to manage aquatic vegetation as well as increase habitat for waterfowl and wildlife in managed wetlands however this method can result in high mortality of amphibian larvae and

1. Removing water from a wetland in the fall can leave hibernating herpetofauna, like Midland Painted Turtles vulnerable to freezing. Drawdowns in late summer can significantly minimize these risks.

young turtles if conducted at inappropriate times of the year (Kaltenecker, Beck et al. 1999). Late season drawdowns of lakes or other water bodies can result in significant mortality of hibernating animals using the lake shore and lake bottom as winter refugia (Bodie and Semlitsch 2000; Bodie and Semlitsch 2000). The lowered lake level exposes the shoreline and removes the insulating layer of ice resulting in frozen ground. Summer drawdowns for management can expose amphibians and reptiles to harsh, hot conditions and significant risk of predation. These individuals may attempt to wait for conditions to improve (i.e., estivate, burrow in the mud) and ultimately die, or individuals may travel overland to seek shelter elsewhere (Roe and Georges 2008). Traveling to suitable wetland areas has several risks, including road mortality, exposure to predators, and desiccation from heat exposure (Aresco 2005; Spencer and Thompson 2005). Duration of inundation of wetlands is also an important consideration. If water is not present for enough time, this could result in a disruption of life processes resulting in population declines for pond-breeding amphibians (Paton and Crouch III 2002). Additionally, adding water to an emergent marsh in early spring can drown herpetofauna like Midland Painted Turtle (*Chrysemys picta marginata*) hatchlings, which overwinter in terrestrial areas (Baker, Costanzo et al. 2007). Adding water during mid-spring to early summer in an area where turtles nest close to the shore may drown eggs of turtle species, like Eastern Spiny Softshell (Tucker, Janzen et al. 1997; Galois, Léveillé et al. 2002). If water is added to shallow areas that support amphibian development, fish may become established. When fish are introduced to a water body they will eat amphibian larvae and negatively affect amphibian reproduction (Snodgrass 2000; Snodgrass, Bryan et al. 2000). Many amphibians can chemically detect the presence of fish within a water body and will actively avoid these sites for breeding, even if they had previously bred at that location for decades (Hecnar 1997).

Anonymous

2-3. Populations of Eastern Box Turtle (2) and Spotted Turtle (3) as well as Blanding's Turtle, and Wood Turtle have experienced significant pressure from illegal collection.

Illegal Collection

Illegal collection for the national and international pet trade has reduced the viable (breeding) populations for some species in Michigan, such as the Wood Turtle (*Glyptemys insculpta*), Spotted Turtle and possibly Blanding's Turtle and Eastern Box Turtle (*Terrapene carolina carolina*) (Harding 1997; Lannoo 1998). Collection of adults and hatchlings of these long-lived animals can result in severe population declines as turtles have delayed sexual maturity and require high juvenile and adult survivorship to sustain populations (Congdon, Dunham et al. 1993; Congdon 1994; Harding 1997; Congdon and Keinath 2006).

Jim Harding

Sean Zera

Poaching and illegal collection can be, and historically was, a problem for herpetofauna in Michigan (Harding 1997). In addition, the high demand in overseas Asian food markets for turtles has put pressure on the poaching of some Michigan turtle species for export (Hylton 2007). Regulations have been enacted to prevent commercial overharvest of Eastern Snapping Turtles (Michigan Department of Natural Resources 2012), however enforcement is limited and difficult. There have been multiple examples of arrests made for trafficking of turtles and other herpetofauna in Michigan. Just across the border in Canada, dead and alive Blanding's Turtles, Spotted Turtles, and Eastern Massasauga Rattlesnakes have been confiscated from people who have collected these animals for food or other purposes (Cota-Larson 2009; Harding 2013) and unexplained declines in populations of Spotted Turtles point to likely poaching (Litzgus 2012). Although far more turtles are killed annually on roads than through illegal collection, illegal take of animals is a real problem in Michigan and needs to be mitigated.

Persecution

Herpetofauna is persecuted by humans for various reasons. Snakes are likely the most persecuted group, as people have misplaced social, religious, or cultural beliefs that snakes will harm them, are evil, reduce populations of game species, and are aggressive and venomous (Ceríaco 2012). It appears that larger snakes, such as the Black Rat Snake (*Pantherophis spiloides*) and Blue Racer (*Coluber constrictor foxii*), which mainly eat rodents, are more feared and therefore suffer greater persecution than smaller snakes. The Eastern Hog-nosed Snake (*Heterodon platirhinos*) and Eastern and Western Fox Snake (*Pantherophis gloydi* and *P. vulpinus*, respectively) are killed because they look similar to venomous copperheads or cobras. The only snake in Michigan that is venomous to humans is the Eastern Massasauga Rattlesnake which, due to its secretive and non-confrontational habits, is not usually encountered by humans.

Turtles and amphibians are also occasionally persecuted for eating game fish, waterfowl, and ornamental fish and are killed for "fun" or hit on roads in "sport". Accounts of people shooting turtles and frogs, dead turtles riddled

1-4. Unfortunately, reptiles and amphibians are often killed in the name of "sport". Wood Turtles (1,2) and other reptiles are shot or run over for fun throughout the state. Eastern Hog-nosed Snakes (4) are sometimes mistaken for a cobra or copperhead and are killed purposefully. However, these snakes are harmless to humans and often "play dead" when confronted. Black Rat Snakes (3) and other large species are also killed out of fear. It is illegal to shoot reptiles and amphibians in Michigan and such activities should be reported to the MDNR Report All Poaching (RAP) Hotline at 1-800-292-7800.

1. *Phragmites*, autumn olive, and other densely growing invasive plants often shade out critical habitat.

2. Where *Phragmites* grows in dense stands, turtles like this Eastern Snapping Turtle must travel farther distances to find nesting areas. This extra traveling can be exhausting to any animal, let alone a gravid turtle. These individuals are also more vulnerable to predation and persecution.

with bullet holes, and purposefully hitting turtles and snakes with cars pose threats to these populations (Ashley, Kosloski et al. 2007). Eastern Snapping Turtles, particularly, are subject to threats as this species is aggressive when approached on land. The Mudpuppy and Eastern Snapping Turtle, in particular, are killed because people unjustifiably believe they affect fishing success and reduce the abundance of game species (Bosch 2003; Siebert 2008).

Invasive Species

Invasive plant and animal species typically are able to quickly become established, have high reproductive success, advantageous life history traits (e.g., short time until reproductive maturity, multiple forms of reproduction), few predators, and adaptive capabilities (Klocker and Strayer 2004; Whitney and Gabler 2008; Campbell, Higman et al. 2010). The combination of these and other ecological factors allows these species to dominate an area and outcompete native, non-invasive species (Devin and Beisel 2007). Since invasive species have characteristics that generally allow them to thrive in harsh environments, after invasive species have become established they are difficult to remove. The continued presence of invasive species and/or the dominance of invasive species can diminish biodiversity and reduce the diversity of native plant and animal communities, including herpetofauna (Brown, Blossey et al. 2001; Brown and Blossey 2002; Kats and Ferrer 2003; Meyer 2003; Bolton and Brooks 2010). The introduction of non-native species can impact amphibians and reptiles through direct predation, competition for food, altered behavior, habitat structure, and disturbance cycles (e.g., fire regimes) (Gibbons, Scott et al. 2000). Unfortunately, methods to control invasive species can also have negative effects on herpetofauna (See Section 3 and 6).

Invasive species can be detrimental to native herpetofauna populations through habitat alteration, competition, and added predation pressure. The shade from dense stands of invasive plants can eliminate sunny basking areas and turtle nesting sites. Below is a subset of the current invasive species that threaten herpetofauna and their habitats.

Phragmites, **reed canary-grass** (*Phalaris arundinacea*), **glossy buckthorn** (*Frangula alnus*), **common buckthorn** (*Rhamnus cathartica*), and **purple loosestrife** (*Lythrum salicaria*) have dramatically altered wetlands and coastal areas throughout Michigan. These invasive plants grow in dense monocultures that do not provide necessary habitat components (basking areas, appropriate food base) for herpetofauna (Tesauro 2001; Bolton and Brooks 2010). Invasive plants can fragment herpetofauna habitat by creating physical barriers to movement across the landscape (Westbrooks 1998).

Phragmites typically grows in dense stands and currently dominates several wetland plant communities and threatens wetlands throughout Michigan (Lynch and Saltonstall 2002; Tulbure, Johnston et al. 2007; Tulbure and Johnston 2010; Mifsud 2013). Although amphibians can

Doug Watkinson

1. Amphibian larvae like these Western Chorus Frog eggs can experience deformities or mortality when developing in wetlands dominated by invasive buckthorn species.

2. Rusty Crayfish outcompete amphibian and reptile native food sources.

occupy small patches of *Phragmites*, few individuals occupy larger stands (Meyer 2003). Dense stands of *Phragmites* degrade habitat for nesting, which reduces turtle nesting success and recruitment (Committee on the Status of Endangered Wildlife in Canada 2002; Bolton and Brooks 2010) and restricts movements of turtles to upland nesting areas, movements of frog species to and from open water, and movements of herpetofauna from optimal thermoregulation (personal observation). Shade from *Phragmites* cools the water which can slow the growth of amphibian eggs and larvae and reduce the proportion of larvae that survive to metamorphosis (Cohen, Maerz et al. 2007). *Phragmites* is predicted to expand as Great Lake water levels recede related to climate change (Tulbure and Johnston 2010).

European buckthorn species grow aggressively in moist soils and wetland edges and affect microhabitats by reducing leaf litter, soil moisture, and wetland hydroperiod and increasing soil acidity. These species also produce the chemical emodin that can be found in nearby soil, pond sediment, and pond water. This metabolite is known to cause mortality and deformities in larval amphibians (Sacerdote and King In Press). Due to the low naturally low survival rate of larval stage amphibians, local populations may experience significant declines in areas heavily invaded by buckthorn species. Removal and long-term control of these aggressive growing invasives is strongly recommended. To reduce risk of continued contamination, cut material should be taken offsite.

Autumn olive (*Elaeagnus umbellata*), **honeysuckle** (*Lonicera* spp.), **garlic mustard**, **Japanese barberry** (*Berberis thunbergii*), and **multiflora rose (***Rosa multiflora***)** are common invasive plants in upland areas (Borland, Campbell et al. 2009). These dense invasive plants shade the ground, thus interfering with the thermoregulatory behavior of herpetofauna and reducing the suitability of these areas as basking sites for snakes or nesting sites for turtles.

Zebra mussels (*Dreissena polymorpha*) and other **aquatic invasive animals** transported via ballast water, boats, and bait dumping have altered habitat for native species (Glassner-Shwayder 2000). Rusty crayfish (*Orconectes rusticus*), round gobies (*Neogobius melanostomus*), and Eurasian ruffe (*Gymnocephalus cernuus*) consume eggs of native fish. Spiny waterfleas (*Bythotrephes longimanus*), fish hook waterfleas (*Cercopagis pengoi*), and round gobies compete with young native fishes for food. Rusty crayfish are a large aggressive species that consume large amounts of aquatic vegetation and outcompete native crayfish which are a primary food source for Queen Snakes (Ontario's Invading Species Awareness Program 2013)
Other invasives such as quagga mussels (*Dreissena rostriformis bugensis*) and sea lamprey alter food web and ecosystem functions which can indirectly impact herpetofauna (Gibbons, Scott et al. 2000). However, some reptile species, such as the Northern Map Turtle (*Graptemys geographica*), capitalize on the presence of these abundant nonnatives as a food source and help control these undesirable species (Lindeman 2006).

1. Mute Swans alter vegetation composition and make aquatic habitats unsuitable for some amphibian and reptile species.

Goldfish (*Carassius auratus*), are a non-native species that, when released into the 'wild' in Michigan, alters the ecosystem and increases competition for food and resources for native herpetofauna species. Goldfish also increase the turbidity of water and feed on eggs and larvae of amphibians (Wilson 2005).

Mute swan (*Cygnus olor*) are aggressive exotic birds that may force native waterfowl off of water bodies and attack, injure, or kill wetland birds (Petrie 2002; Perry, Osenton et al. 2004). Mute swans may also displace turtles from optimal basking sites. These swans heavily forage on aquatic vegetation year-round, thus altering the vegetation composition and structure (Søndergaard, Bruun et al. 1996; Bortolus, Iribarne et al. 1998; Allin and Husband 2003; Perry, Osenton et al. 2004) and reducing water quality with the large quantity of feces they produce (Reese 1975; Weisner, Strand et al. 1997; Czeczuga and Mazalska 2000; Perry, Osenton et al. 2004; Bailey, Petrie et al. 2008). Alterations of vegetation may make these water bodies unsuitable for omnivorous amphibians and reptiles or those that rely on vegetation for cover.

Feral swine (*Sus scrofa*) have been known to damage native plant communities and wetland structure by digging, rooting, and wallowing (Campbell and Long 2009). These wetland alterations could make conditions unsuitable for wetland-dwelling amphibian and reptile species. Feral swine also have been known to consume snakes, frogs and toads, lizards, and turtles and turtle eggs in large numbers (Lowe, Browne et al. 2000; Fordham, Georges et al. 2006; Jolley, Ditchkoff et al. 2010).

Raccoon (*Procyon lotor*), while a species native to Michigan, has become overabundant due to the alteration of available resources by humans. These unnaturally high densities of raccoons can result in 100% turtle nest mortality at some sites (HRM 2011). Raccoons often destroy most, if not all, turtle nests in areas of high raccoon density (Oldfield 1994; Geller 2012), which leads to low or no recruitment for turtle populations (Christiansen and Gallaway 1984; Browne and Hecnar 2007). Because many turtle species are long-lived with a slow rate to maturity and low reproductive capacity, mortality exceeding the normal rate of loss could lead to population declines and possible long-term population or species extirpation.

Ron Brooks

2. Artificially high densities of raccoons add significant pressure to turtle populations. In many parts of Michigan, annual nest mortality reaches an unsustainable 100%.

3. Small steps like properly disposing of refuse and locking bin covers can reduce subsidized predator impacts.

Emerald ash borer (*Agrilus planipennis*) and other **invasive insects** alter the composition of wetland and upland plant communities and the quality of habitat for salamanders, Eastern Box Turtles, and other upland-dependent herpetofauna that rely on appropriate levels of canopy cover, microclimate, and amount of understory vegetation (Poland and McCullough 2006).
Some non-native, invasive species, such as earthworms, have become incorporated into the diet of several amphibians and reptiles. Over time, these species learned to eat earthworms and now earthworms comprise a major portion of their diet (Ransom 2012). Though they can negatively impact landscapes, they have also become an important food resource. For species such as the Butler's Garter Snake, a declining species in Michigan, earthworms are a primary food source and a critical resource for this and other species of herpetofauna.

Feral cats (*Felis catus*), have been estimated to kill one billion birds per year in the United States (Dauphiné and Cooper 2009) and it is suggested that even more amphibians, reptiles, and small mammals are killed (Coleman, Temple et al. 1997; Calver, Thomas et al. 2007).

Jim Harding

1. Invasive insects like the emerald ash borer alter upland conditions that species like the Spotted Salamander require for survival.

2. "Red-leg" and other diseases can have significant impacts to amphibian populations.

Disease

Disease has been implicated as a factor in the decline of amphibian and reptile populations worldwide (Blaustein, Grant Hokit et al. 1994; Berger, Speare et al. 1998; Daszak, Berger et al. 1999; Kiesecker, Blaustein et al. 2001). Many of the previously mentioned factors that threaten herpetofauna populations can work synergistically, increasing stress on the animals and lowering their immune response, thereby causing them to become more susceptible to infectious diseases (Fellers, Green et al. 2001; Blaustein, Romansic et al. 2003).

Disease can be spread by anthropogenic vectors such as the collection and export of frogs for human consumption and use (Mazzoni, Cunningham et al. 2003; Schloegel, Picco et al. 2009; Bai, Garner et al. 2010; Schloegel, Toledo et al. 2012), the pet trade (Une, Kadekaru et al. 2008), and use as bait (Garner, Stephen et al. 2009). Many of these pathogens are highly virulent and transmissible between vertebrate classes (Farnsworth and Seigel 2012; McGuire, Gray et al. 2012). Examples of infectious diseases in reptiles and amphibians include viruses, bacteria, mycoplasmas, fungi, protozoans, and trematodes. These agents are associated with varying levels of mortality and population decline in herpetofauna (Wright and Whitaker 2001). The impacts from disease can be direct or indirect. Many species of reptiles (particularly snakes) feed on amphibians. If amphibian populations decline as a result of disease, the success of snakes and other predatory species will be reduced.

Christopher Smith

1. Emerging diseases such as Snake Fungal Disease (as shown on this Timber Rattlesnake from Minnesota) and Ranavirus can have significant impacts to herpetofauna populations.

Some of the causes and vectors of these diseases in herpetofauna are known. Limb deformities in amphibians have been linked to trematode worms (Johnson, Lunde et al. 2002). The disease known as "red-legged disease" is caused by the bacteria *Aeromonas hydrophila* and is believed to be responsible for massive seasonal die-offs in Northern Leopard Frogs (Harding 1997). Chytridiomycosis has been cited as "the largest infectious disease threat to biodiversity" and is a disease of amphibians caused by *Batrachochytrium dendrobatidis* (Voyles, Young et al. 2009; Kilpatrick, Briggs et al. 2010). This pathogenic fungus, which causes symptoms such as abnormal posture, lethargy and gross lesions, has been implicated in significant population decline of amphibians (Carey, Cohen et al. 1999). Currently, 520 species of amphibians have been diagnosed with infectious *B. dendrobatidis* (Aanensen 2013).

Ranavirus is an emerging and dangerous pathogen, which is a potential significant threat to Michigan herpetofauna. Infection and subsequent die-offs have occurred in other states in species also common to Michigan (e.g., Northern Leopard Frogs, Eastern Tiger Salamanders, Eastern Box Turtles) (Bollinger, Mao et al. 1999; Docherty, Meteyer et al. 2003; Snyder 2007; McGuire, Gray et al. 2012; United States Geological Survey 2012), thus transmission to Michigan populations may be possible. Since this disease is easily transferred and typically effects the entire herpetofauna population at an infected site, if strict preventative measures are not implemented it is likely Michigan herpetofauna will suffer this disease (Jancovich, Bremont et al. 2010). Snake Fungal disease (SFD) has recently been found among populations of wild snakes in the eastern and midwestern regions of the United States. This newly emerging disease is known to cause mortality, however population level impacts are not well known due to the cryptic nature of many snake species and a lack of long-term data. Currently, the pathogen has not been observed in Michigan snake populations however due the proximity to regions already affected it is possible that the condition has spread to some Michigan populations (United States Geological Survey 2013).

2. Northern Spring Peepers are one of the earliest calling Michigan frogs, but unseasonally warm weather can induce several species of frogs to call early in the season and potentially affect reproductive success.

Climate Change

Climate projections from multiple sources closely agree on temperatures and wind predictions for Michigan into the middle of the 21st century, but there is still great uncertainty in projected precipitation totals and intensity trends (Winkler, Arritt et al. 2012). As a general comparison, by the end of this century, the climate of Michigan is predicted to resemble the current climate of central Missouri and northern Arkansas (Union of Concerned Scientists). The predictions of various proposed climate change models show potentially significant shifts in plant communities and wetland conditions in Michigan and the United States (Hellmann, Nadelhoffer et al. 2010; Nelson, Elmer et al. 2011) which would affect amphibian and reptile populations. MDEQ has acknowledged that

Chris Hoving

David Dortman

wetland communities will play an important role in counteracting the negative effects of climate change, making it critical to protect and restore these ecosystems (Christie and Bostwick 2012). Changes in habitat availability may affect amphibian survival, growth, reproduction, dispersal, and access to food (Blaustein, Walls et al. 2010). Due to variation in their capacity to adapt to sudden changes, some species may benefit from changes in the environment, while other groups may be negatively affected (Hoving, Lee et al. 2013). For example, amphibian eggs and larvae may desiccate or drown as a result of altered local climate patterns. Kiesecker et al. (2001) found that in extreme dry years, reduced pond depth increases exposure of amphibian embryos to ultraviolet (UVB) radiation, which could lead to pathogen outbreaks and population declines. Climate change may also threaten the long-term viability of reptile and amphibian populations (Pounds, Fogden et al. 1999; Kiesecker, Blaustein et al. 2001) as it may alter their development, spatial distribution, abundance, and species interactions (Pounds, Fogden et al. 1999; Walther, Post et al. 2002). Amphibians have been observed to call and breed earlier in years with warmer temperatures (personal observation ; Walther, Post et al. 2002). In the case of reptiles, shifting climates may affect nesting success and timing. Insufficient time for incubation prior to cold weather can result in reduced productivity of reptile nests (Sommer, Lindqvist et al. 2009). Also, species for which the sex of individuals is determined by the temperature of incubation (e.g., Eastern Snapping Turtle; *Chelydra serpentina serpentina*) could experience skewed sex ratios (Janzen 1994; Ewert, Lang et al. 2004). However, analysis of long-term data reveals various responses among species (Blaustein, Belden et al. 2001).

1. Roads present a barrier to amphibian and reptile species that will seek new ranges due to climate change. Creating and restoring habitat connectivity will be a key factor in expansion of Michigan's herpetofauna distribution.

2. Thousands of Mudpuppies died along Lake Huron in the 2012 Superstorm Sandy. It is likely that as climate change progresses, large intense storms will become more frequent.

Climate change is expected to amplify current threats to wildlife populations and the communities that support them. As environmental conditions change, previously occupied habitats will become unsuitable. The potential for dispersal is limited in areas with significant habitat fragmentation, thus making populations vulnerable to extirpation. Herpetofauna and the community types they inhabit will be more sensitive to change in precipitation and hydroperiods in ranges where hydrologic processes have been altered by the addition of impermeable surfaces, stream channelization, and water level manipulations (Hall 2012). Impacts to amphibians caused by chemical pollution may increase in altered climates due to increased contaminate exposure time and mobility (Rohr and Palmer 2009). Climatic regimes often determine species ranges and warming trends will likely result in northern range shifts for both floral and faunal communities. These climate-linked expansions will result in the establishment of new species, which may benefit some taxa whose range will expand and increase northward. New species may also include invasives that have the potential to dramatically change existing community dynamics by increasing resource competition, and introducing new diseases (Walther, Post et al. 2002).

1. With increased climate variability, wetland hydrology will likely be impacted. Creating and preserving a diversity of variable seasonal hydroperiods will help maintain resiliant ecosystems and herpetofaunal communities.

Insufficient Assessment

Despite numerous threats to herpetofauna and the identified need for conservation, insufficient resources have been allocated to conduct species, population, and herpetofauna habitat status assessments. The unique natural history and biological characteristics of amphibians and reptiles make these animals vulnerable to habitat disturbances, degradation in water quality, alterations to hydrologic processes, climate change, and to the introduction of invasive species. The impacts of identified and potential threats are difficult to disentangle and many of these threats act synergistically such that components of the observed effect can be difficult to attribute to specific factors. Understanding the true effects of anthropogenic forces is further confounded by the natural ebb and flow of population and community dynamics, which is often not well understood. The need for greater data collection and conservation efforts focused on herpetofauna in Michigan is well documented and the State of Michigan, other non-governmental organizations, and individual citizens are making strides to align with these needs (Eagle, Hay-Chmielewski et al. 2005; PARC 2011; Michigan Herp Atlas 2013). Additionally, there is a great need to assess the implementation of conservation and restoration techniques in a variety of natural communities and settings in Michigan. By evaluating the implementation and success of these techniques, future implementation can better enhance amphibian and reptile populations.

2-4. Various sampling techniques-- dip net surveys, funnel traps, and coverboards as illustrated here-- and other methods are critical in assessing habitat and restoration.

5. Conservation Efforts

1-2. Though locally common, Blue-spotted Salamanders and Black Rat Snakes are listed as Species of Greatest Conservation Need. The Black Rat Snake is also a species of Special Concern. Habitat loss and fragmentation can greatly alter these populations.

Over the past several decades, even some of the most common species have become rare in many parts of Michigan. Conservation and protection must strive to **keep common species common** and to recover State and Federally Threatened and Endangered species and protect their habitats. Although traditional management and development activities have contributed to the decline of amphibians and reptiles, opportunities exist to mitigate impacts from these activities. Protection and restoration of landscape-level processes as well as of individual terrestrial and aquatic communities can have profound effects on the conservation of amphibians and reptiles. These opportunities to conserve and protect herpetofauna can only be realized if effective, science-based mitigation and management tools are available to developers, land managers, local governments, and the public.

Pre-construction planning that considers wildlife can maximize benefits for wildlife and expedite the permitting process and project completion. Post-construction management for herpetofauna can consist of simple changes in routine maintenance (e.g., mowing less frequently) that can even save money while benefiting herpetofauna. Other small changes to an existing developed site, such as removing curbs, can have minimal financial cost and tremendous gain for herpetofauna. Restoration of degraded aquatic and terrestrial habitat and protection of landscape-level processes can facilitate all species requirements (e.g. nesting, hibernation) for herpetofauna.

Using the techniques described in this BMP manual, all landscapes, from rural to highly-modified urban areas can provide important herpetofauna habitat.

The general goals of the management and development practices are to:

- Maintain and enhance healthy environments that support a diverse assemblage of amphibians and reptiles

Nick Scobel

Chris Hoving

1-3. Small-mouthed Salamander, Marbled Salamander, and Kirtland's Snake are State Endangered species.

4. Spotted Turtles are listed as State Threatened and regulated in commercial trade by CITES. It is illegal to collect this species without appropriate permits.

- Protect and create sufficient critical habitat and for essential activities
- Maintain and improve habitat quality and connectivity
- Maintain natural processes and develop methods for improvement and restoration

Existing Conservation Guidelines

The Michigan DNR created the Wildlife Action Plan (WAP) to provide a comprehensive framework and information source to coordinate statewide wildlife management and conservation efforts (Eagle, Hay-Chmielewski et al. 2005). This document cites the need to prioritize conservation actions for wildlife with "low or declining populations." This document supports the need to conserve Michigan herpetofauna as it identifies 44 of Michigan's 52 species as Threatened, Endangered, Special Concern, or as Species of Greatest Conservation Need. The MDNR and MDEQ have developed "Sustainable soil and water quality practices on forest land" which describes a set of voluntary forestry BMPs that protect the soil and water resources that amphibians and reptiles rely on while allowing appropriate use of forest resources. The manual should be used by anyone involved with growing, managing, and harvesting trees in conjunction with the BMPs described throughout this document.

Several publications provide recommendations for how Michigan can adapt quickly to potential climate change scenarios while maintaining the integrity of our natural resources base. The Climate Change Adaptation Plan for Coastal and Inland Wetlands in the State of Michigan (Christie and Bostwick 2012) is a whitepaper developed for the MDEQ. This document includes recommendations for strategic planning; monitoring and assessment; voluntary restoration, conservation, and management; revisions to current regulations; and integration with other water programs for watershed management. A whitepaper, "Climate Change in the Midwest: Impacts on Biodiversity and Ecosystems" (Hall 2012), was prepared by The Nature Conservancy for the U.S. Global Change Research Program, National Climate Assessment Midwest Technical Input Report. This paper aims to help humans provide for species and systems to adapt to climate change by linking climate impacts to species and system sensitivities, assessing

1. Engaging the public can help foster a stewardship attitude and provide long-term conservation.

2. Though similar in appearance to the State Threatened Eastern Fox Snake, the Western Fox Snake is found in the Upper Peninsula of Michigan with scattered accounts on Lake Michigan islands. The Western Fox Snake not only is geographically separated but this species inhabits only open woodlands and forest edge habitat compared to the Eastern Fox Snake which is most often associated with Great Lakes marsh, lake plain prairie, and wet meadow habitats.

vulnerabilities, and providing recommendations for land management. Changing Climate, Changing Wildlife A Vulnerability Assessment of 400 Species of Greatest Conservation Need and Game Species in Michigan (Hoving, Lee et al. 2013) was developed by the Michigan DNR Wildlife Division and assesses the potential degree of vulnerability that Michigan wildlife faces due to climate change.. The recommendations in these publications include wildlife, habitat, and environmental goals and recommendations that can help to enhance and increase the long-term viability of Michigan's herpetofauna populations.

Partners in Amphibian and Reptile Conservation (PARC) created a handbook entitled "Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States" (Kingsbury and Gibson 2011). This publication has a broad audience of landowners, state and federal agencies, and other stakeholders from across the nation and provides information and recommendations about land management to benefit United States herpetofauna.

State, Federal, and International Regulations

Several laws and regulations offer protection to the environment, herpetofauna, and other wildlife in Michigan, the United States, and the world. The MDNR regulates impacts on amphibians and reptiles and their habitats through two regulations.

The MDNR Fisheries Division Order 224.13 sets limits and regulations regarding take methods, acceptable species, seasons, minimum size, daily possession limit, and total possession limit (Michigan Department of Natural Resources 2013). An all-species fishing license is required to take non-protected amphibians and reptiles, and take must abide by the limitations outlined by the Michigan DNR in the Michigan Fishing Guide (Michigan Department of Natural Resources 2013). Sale, including commercial trade, of amphibians and reptiles is not permitted. Prior to 2008, Eastern Snapping Turtles could be commercially harvested. Commercial harvest in Michigan ended in 2008. Cultural or Scientific Collector's Permits can be applied for through the MDNR Fisheries Division to allow for collection of amphibians and reptiles not covered under a State of Michigan Fishing License.

3. In some cases, the highest quality wetland is not the most important site to save if it results in physical isolation and loss of a large continuous habitat. Consider context when evaluating habitat impacts.

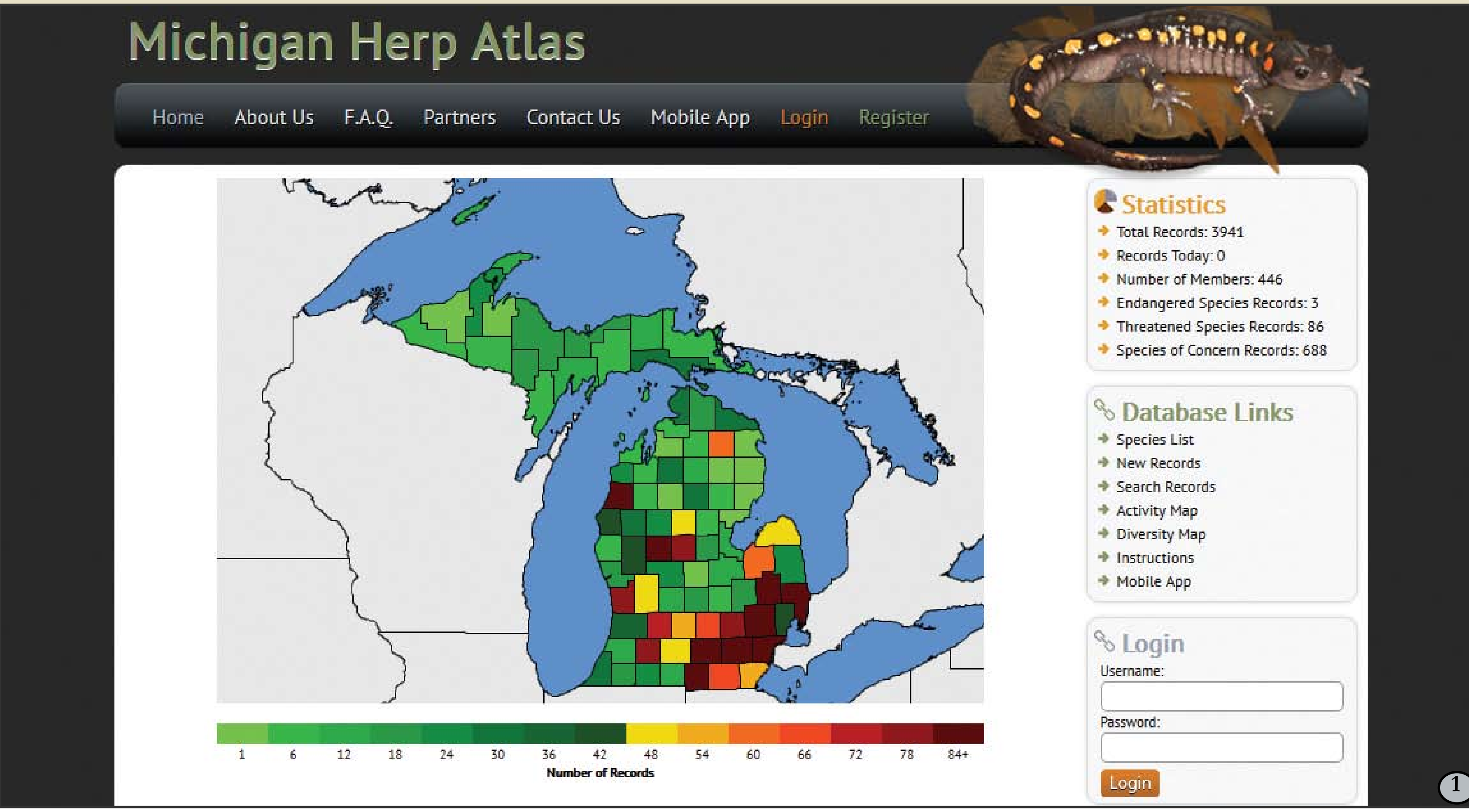
Part 365, Endangered Species Protection, of The Natural Resources and Environmental Protection Act (NREPA Public Act 451 of 1994 as amended), administered by the MDNR Wildlife Division, provides for the conservation and protection of State Threatened and Endangered species. This law prohibits the collection or take of Threatened and Endangered species, including Spotted Turtles, Eastern Fox Snakes, Copper-bellied Water Snakes, Kirtland's Snakes (*Clonophis kirtlandii)*, Six-lined Racerunners, Blanchard's Cricket Frogs, Small-mouthed Salamanders (*Ambystoma texanum*), and Marbled Salamanders (Appendix A). Threatened and Endangered Species monitoring permits are required whenever listed species might be harmed, handled, or disturbed, even if conservation activity is likely to benefit those species long-term and can be applied for through the MDNR Wildlife Division.

The Federal Endangered Species Act of 1973 (ESA) also provides protection for any critical habitats of listed species on public and private lands (Department Of The Interior and U.S. Fish and Wildlife Service 2004). In Michigan, there are currently no critical habitats designated for the three species of amphibians and five species of reptiles listed under the act. This act also mandates that a recovery plan for each Endangered and Threatened species be created and that post-recovery monitoring be conducted for de-listed species. Although it is illegal to destroy these protected species and their habitats according to the ESA, enforcement can be difficult since many individuals and habitats occur on private lands. Also, the ESA remains a contentious piece of legislation concerning the quality of protection for listed species, the economic repercussions of these actions, and government involvement in natural resource management (Brown and Shogren 1998). Although the ESA is a good starting point for conservation, several amphibian and reptile species not listed under the ESA are vulnerable to habitat loss and degradation, illegal collection, and persecution (See Section 3).

1-2. Targeted inventory of a site can reveal what herpetofauna is present and help guide best management of the area.

3. Basking sites and hibernacula are important to sustain amphibian and reptile populations.

International regulations regarding herpetofauna include the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), an international agreement between governments to protect endangered species by trade restrictions. The CITES agreement does not provide in-country habitat or management regulations and restrictions (CITES 2012). Eastern Box Turtles, Blanding's Turtles, and Spotted Turtles, once exploited for international pet trade, are currently listed in CITES Appendix II, meaning that there are population level concerns for these species, but that regulated commercial trade is allowed.



Although these regulations provide a good regulatory framework for conservation, several amphibian and reptile species continue to be threatened by habitat loss and degradation, illegal collection, and persecution (See Section 3). See Appendix B for more information on these regulations.

1-2. Everyone can submit observations of amphibians and reptiles to the the Michigan Herp Atlas.

The Michigan Herp Atlas

The Michigan Herp Atlas is a comprehensive, inclusive, publicly accessible database of herpetofauna observations within the state of Michigan. This valuable resource provides evidence of changes in species distributions and population health over time, and can be used to demonstrate declines in herpetofauna populations and potential recovery resulting from conservation efforts. The comprehensive data collected through the Michigan Herp Atlas allows for future evaluation of Michigan's herpetofauna status to be made based on science. The Herp Atlas is the primary source for the most comprehensive and up-to-date accounts for Michigan herpetofauna.

The Michigan Herp Atlas presents an opportunity for everyone to contribute to conservation of amphibians and reptiles. Observations of a frog at a construction site, a dead snake on the road, a turtle at a restoration site, and all other herpetofauna observations are valuable and should be submitted to the Michigan Herp Atlas.

Please visit and contribute to the Michigan Herp Atlas at www.MiHerpAtlas.org.

6. Management and Development Planning

1-3. Before beginning any project, it is important to determine what amphibian or reptile species may be present and plan to avoid any negative impacts.

This section provides information for land managers, planners, designers, and contractors about how the initial planning phases of a project can help protect amphibians, reptiles and other wildlife throughout the entire life-cycle of a project. Whether maintaining an existing development, actively managing natural resources, or developing new construction, your decisions and actions have an effect on amphibians, reptiles, and other wildlife. Amphibians and reptiles are sensitive to disturbance, pollution, and land degradation. Everyone involved in land use decisions can help minimize these threats and help conserve sensitive herpetofauna as well as natural communities.

Evaluating the Site

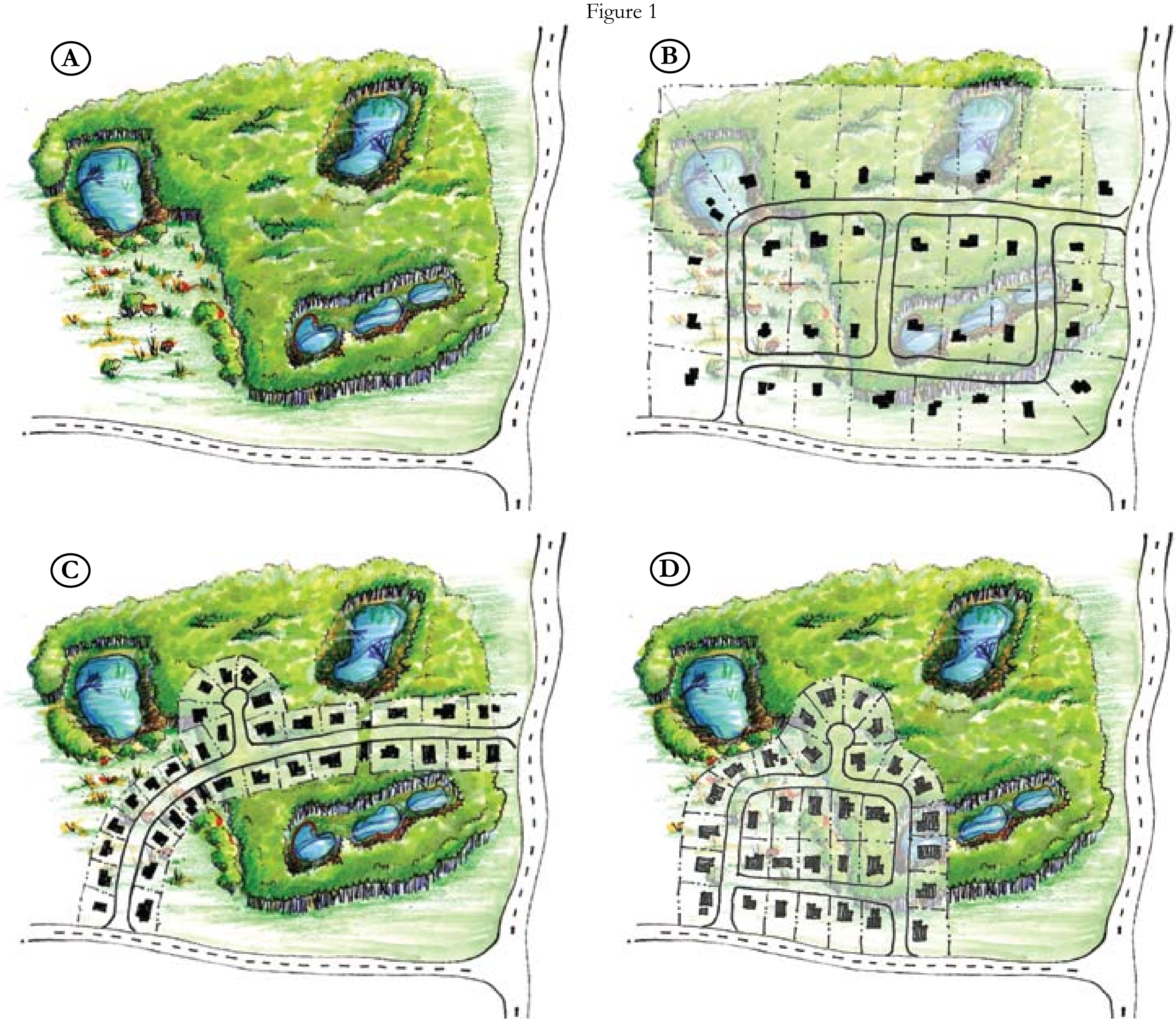
Although habitat destruction, degradation, and fragmentation are the main reasons for decline of amphibians and reptiles (Dodd, Smith et al. 2003; Marchand and Litvaitis 2004; Weyrauch and Grubb 2004), land use planning and pre-construction planning can help mitigate these problems (Calhoun, Miller et al. 2005). As part of this process, a professional wildlife biologist with demonstrated experience and expertise in working with amphibians and reptiles should be consulted to minimize negative impacts to wildlife communities.

Identify natural resources - Natural community type and wildlife communities potentially present should be identified. During this process, amphibian and reptile habitat and potential annual movement corridors should be identified. Even if a specific species is not observed on site, the species may be present. Several Michigan species are cryptic and it is highly unlikely that all species present will be detected during surveys. Site visits, when possible should be timed to coincide with optimal observation windows based on the species natural histories.

Figure 1. Thoughtful and creative design approaches can significantly minimize impacts while still meeting project objectives. Homes adjacent to natural areas also have higher values. Predevelopment (A). Typical development (B). Fragmented site (C). Loss of some high quality wetland to maintain greater connectivity (D).

Assess habitat connectivity – All areas of wildlife habitat cannot be preserved, thus the importance of preservation of habitat areas should be ranked according to ecological value. Quality of habitat and connectivity should be considered when assessing ecological value, as an isolated area of high-quality habitat may not be able to support wide-ranging animals that require large contiguous areas for food, seasonal migrations, and reproduction. When such areas are preserved as part of development and management, they can degrade and become low-quality habitat often supporting invasive species. Conversely, areas of lower quality habitat that connect areas of high-quality habitat may be critical to facilitate species movements necessary for breeding and long-term population viability – the ability for a population to persist and avoid extinction. Habitat assessments should include a review of any threats facing the site including those that may occur as a result of the project. These threats should be addressed and mitigated when possible.

Figure 1



1.Even the Red-backed Salamander, a terrestrial species, relies on moisture in the environment under logs and in the duff layer on the forest floor.

2. Buffer zones minimize the impact of human disturbances on herpetofauna, like Four-toed Salamander populations.

3. Floodplains and wetlands alleviate threats of flooding and provide critical amphibian and reptile habitat.

The presence of rare and threatened species, breeding species, and the ability of the area to support reproduction should be considered when evaluating ecological value of a site (Calhoun, Miller et al. 2005). The presence of a variety of wetlands and uplands also has great ecological value. The presence of high-quality upland areas adjacent to wetlands is a critical habitat component for several amphibians and reptiles. Some snakes and turtles migrate seasonally between wetlands and uplands (e.g., Eastern Massasauga Rattlesnake, Copper-bellied Water Snake, Blanding's Turtle). Several salamander and frog species require vernal pools for breeding and larval phases and the associated uplands for foraging during adult life stages.

Prioritize areas to protect – Overlaying maps of various features (e.g., land cover, topography, species distribution or home ranges) can reveal areas that are critical to ecological function, such as vernal pools and the adjacent uplands, which development plans should avoid. Construction, linkages (e.g., utilities and roads), and associated impacts should be planned to avoid or minimize impact to these areas. Also, corridors and areas that provide connectivity should be identified for protection to minimize barriers to movement. Use of a Geographic Information System (GIS) – spatial data analysis and mapping software - by a wildlife or environmental professional may be helpful in this process.

Several maps and GIS layers are available through various government and nonprofit organizations. The USDA NRCS Geospatial Data Gateway is a large, online database of spatial environmental and natural resource data provided through a partnership between the three Service Center Agencies (SCA); NRCS, Farm Service Agency (FSA), and Rural Development (RD). Ducks Unlimited provides the Conservation and Recreation Lands (CARL) database online, which maps and describes public and private lands involved in conservation or which are protected. These maps were developed to aid in the development of landscape and long-term planning perspectives for conservation activities. United States Geological Survey (USGS) supports Earth Explorer, an online database that allows the user to query and order or download satellite images, aerial photographs, and cartographic products. The State of Michigan provides public access to several online GIS databases (e.g., potential wetland restoration areas, land cover, aerial photographs, hydrologic and hydrographic mapping)

through The Geographic Data Library catalogs. All of this information can be used to develop models of where the optimal habitat for any given species is distributed. If field visits confirm the reliability of the model it can then be used to prioritize protection and restoration efforts(Gara and Micacchion 2010).

Plan to Maintain Ecologically Functional Landscapes

Land planning focused on maintaining the ecological function of a site can help to direct the smaller scale, site-design components and management activities. Ecosystem function defined as the interaction between organisms and the physical environment (e.g., nutrient cycling) is an important component to consider when restoring a site. Maintaining ecological function of a landscape can also benefit the conservation of amphibians and reptiles. Large-scale decisions and general guidelines about management activities, earth moving, siting developments, and construction materials can affect habitat quality and connectivity, hydrologic processes, and wildlife conservation.

1. Wetland restoration is complex, and contacting a wetland restoration specialist is recommended.

2. Protecting hydrologic connections between landscapes is critical for ecosystem health and maintaining viable herpetofauna populations.

Maintain natural drainage systems, hydrologic processes, and water quality - For most species of Michigan herpetofauna, the presence of high-quality water is imperative for survival. Amphibians are especially affected because their permeable skin requires moisture. Hydraulic connectivity can greatly influence herpetofauna population stability. Even the hydrologic connections through ditch systems can increase genetic diversity within amphibian communities (Reh and Seitz 1990), although creation of narrow corridors is not recommended as a conservation strategy, due to potential increased predation pressure (Mazanti 2003). However, this is a situation where working with the landowner to protect areas adjacent to the waterway through the Conservation Resource Program (CRP) may be a viable avenue.

Conservation Resource Alliance

Avoid wetland alterations/Maintain functional wetlands - Filling or draining wetlands displaces amphibians and reptiles and destroys their habitat. Displaced animals are less likely to find new home ranges and they experience increased predation pressure, risk of exposure, and possibly desiccation. Suitable habitat may not be nearby or if suitable habitat is available, other individuals may already have filled the same niche. The structure, hydroperiod, vegetative cover, microtopography, slope, and adjacent upland buffer areas of high-quality wetlands contribute to maintaining high-quality amphibian and reptile habitat and ecological function and should all be maintained

1. Fragmenting large contiguous habitat with roads as shown here can not only impact hydrology but also increase mortality of migrating wildlife.

(Semlitsch and Bodie 2003; Rittenhouse and Semlitsch 2007). Development and disturbances in wetlands, wetland critical zones and buffers, and habitats hydrologically and ecologically connected to wetlands should be avoided whenever possible.

Avoid critical habitat – Construction and management activities should be planned to preserve critical habitat for species potentially present on site and avoid possibly killing large numbers of amphibians and reptiles. Heavy equipment may also entomb salamanders in burrows and compact loose soils, negatively impacting diverse vegetation growth and invertebrate communities, which serve as a critical food source for herpetofauna.

Maintain watercourse function – Streams and rivers naturally move on the landscape and development and management activities should account for this natural process. Constructed features such as bridges, buildings, and roads should be located in areas where they will not restrict the flow of a waterway as it naturally changes its meander. Fluctuations in streambed topography, structure, stream flow dynamics, bank slope, and floodplain areas should be considered in determining where development can be placed. Planning for these natural processes can help avoid costly damage to constructed features and avoid degradation of wildlife habitat in riverine areas.

Reduce habitat fragmentation – Creating wildlife habitat corridors and buffers around critical habitat and reducing the number of roads, fences, or other barriers can help to increase and/or

Herpetofauna-safe Construction Along a Linear Corridor

Several ecological protections were implemented during the construction of a natural gas pipeline in Oakland County, Michigan in 2010. Since work was conducted through the active season for amphibians and reptiles, barrier fences were installed to reduce movement of herpetofauna into the construction site (2). Staff, contractors, and construction crews actively watched for wildlife, like Blanding's Turtles, that entered the construction site and relocated these animals to safer areas in nearby wetlands (3). To further reduce long term impacts to habitat, temporary log construction roads were constructed adjacent to the pipeline installation to reduce soil compaction by vehicles and equipment (4).

maintain genetic diversity and a more robust population of animals. Clearly defining the extent of disturbance around a building can preserve natural areas that are used by amphibians, reptiles, and other wildlife. By only disturbing the natural areas directly around a building within the areas actively used by people (e.g., the space between a house and garage and a small outdoor picnic area) the native flora and fauna and landscape connectivity for wildlife can be preserved (Thompson and Sorvig 2007). Preserving a greater proportion of natural areas also allows people to interact more closely with the ecosystem in which they live and become better stewards of their resources.

1.Artificial cover objects, as shown above, are used to attract snakes for surveys. Lizards and amphibians will also use these.

Maintain landscape mosaic – A diversity of natural communities including critical wetlands and associated uplands helps to sustain a diversity of species including those which rely on linkages between uplands and wetlands, such as Wood Frogs (*Rana sylvatica*), Blue-spotted Salamanders (*Ambystoma laterale*), Spotted Salamanders, and Marbled Salamanders (*Ambystoma opacum*). Maintenance of a contiguous landscape mosaic allows for several subpopulations to exchange individuals, which enhances genetic diversity and sustains the metapopulation in the event of the extinction of one subpopulation.

2-3. As part of construction projects, workers and staff should be trained to avoid and report herps like Eastern Fox Snakes. It is important to report all observations of Eastern Fox Snake and other herpetofauna to the Michigan Herp Atlas.

Cluster development and disturbances – Where possible, focusing work in areas far from wetlands and high-quality herpetofauna habitat minimizes habitat fragmentation. Clustering development and disturbances in lower quality habitat areas, which do not impact landscape connectivity can preserve ecological function and healthy herpetofauna communities, as well as other wildlife (Milder 2006; Baldwin, Bell et al. 2007; Milder 2007). These types of development conserve open space, reduce impervious surfaces, minimize habitat fragmentation by roads, reduce road mortality of amphibians and reptiles, and decrease road-related pollution. Clustering development is also economical. Some communities give incentives for clustering and allow for smaller lot sizes or greater unit density in certain areas that avoid impacting habitat (Bengston, Fletcher et al. 2004). Fewer roads and reduced infrastructure typically reduce the initial construction costs, increase the selling price, and reduce overall long-term maintenance (Arendt 1996; City of Novi 2012). Preserved green space is considered an asset by many potential property owners who are willing to

Conservation Resource Alliance

1. Synthetic soil erosion mesh can entangle amphibians and reptiles, leaving them exposed to the elements and predators.

2. This Blue Racer that was trapped in erosion material and would have likely died due to exposure or predation. Use of natural herp-friendly materials will significantly reduce mortality associated with these products.

3. Species like Eastern American Toads require multiple contiguous habitats for survival. Fragmenting these systems can result in species and population decline.

pay a higher price for this valuable amenity. This development strategy also reduces cleared areas which are susceptible to the establishment of invasive plants, and it reduces the movement of herpetofauna predators (e.g., raccoons) into forested areas.

Reduce impervious surface - Large-scale implementation of pervious surfaces or reductions in impervious surfaces can reduce surface flow and increase infiltration. Increases in water quality (on which several amphibians and reptiles rely) can result from increased infiltration. Techniques to reduce runoff and increase infiltration include use of porous paving, green roofs, vegetated swales, and rain gardens. Retaining and planting large street trees and other vegetation, reducing the width of residential streets, and clustering developments can also reduce the proportion of impervious surface covering the landscape.

Implement Herp-friendly Work

Development and management activities can have long-term impacts on wildlife communities and habitat and should be planned to conserve and promote herpetofauna and other wildlife.

Avoid indirect habitat alterations – Indirect alterations include activities such as removal of shade trees, which can affect the microclimate and change habitat suitability for herpetofauna, changes in topography that alters runoff inflows into a wetland, or the alteration of ground flow by creating ponds in uplands adjacent to spring fed wetlands.

Conduct work when risk to wildlife is less – By evaluating which species are present at and near a work site and their annual movements and habitat needs, specific construction tasks can be timed to reduce impacts to these animals. Construction should be timed to avoid migrations, and management activities such as herbicide application should be timed to avoid sensitive larval stages of amphibians in nearby wetlands.

Educate work crews - Work crews should also be alerted to the presence of listed and non-listed wildlife species on site that are to be the target of conservation efforts. Workers should be trained to identify these species and should be informed of protocol to follow upon observing one of these animals, including who to contact, their contact information, the place and time of a sighting, and whether or not positive identification was possible (to the best of worker abilities). When State or Federally Threatened or Endangered species are sighted, workers must stop all activities that could endanger the animal until it has cleared the area and is out of danger.

Avoid creation of wildlife traps – Synthetic soil erosion control mesh should never be used as it can fatally entangle herpetofauna and other wildlife. Photodegradable varieties do not degrade when shaded by newly sprouted vegetation and must also be avoided. Several natural products are available and should be used as the standard soil erosion control product.

Perc test holes, uncapped vertical pipes, drain pipes, stand-pipes, head gates, and other open holes also act as pitfall traps that collect herpetofauna and other small animals. Because these animals cannot climb vertical walls, they often perish within these unintentional traps. Pipes should be removed, capped, or covered with screen and holes should be filled in to grade after use. Other traps include the creation of areas that are attractive to herpetofauna but do not provide the resources for these animals to thrive (e.g., a small pool of water in the spring that will dry before eggs can hatch or larvae metamorphose).

Soil erosion control fences on construction sites are barriers for herpetofauna, sometimes trapping them on a construction site. These barriers should be removed immediately after the site has been vegetated to reduce mortality. Owners and owner representatives may choose to hold bond until these and other potentially hazardous soil erosion control measures have been removed.

1-2. Silt fences can be used to isolate habitat adjacent to construction sites in order to keep herps from wandering into harm's way during the duration of a project.

3. When conducting projects in aquatic habitats, heavier duty materials such as this "super silt" fence may be necessary to prevent animals from entering construction zones. It is important that these products be removed following construction activities as they can serve as a long term barrier to wildlife and contribute to landscape fragmentation.

7. Ecological Restoration and Mitigation and Habitat Design

This section highlights opportunities for planners, designers, and contractors to incorporate herpetofauna habitat in ecological restoration and mitigation projects. Several of the management and development techniques described in Section 6 are also applicable to restoration and mitigation projects. Consult Section 6 to minimize potential impacts to amphibians and reptiles at all phases of site development and management. There are also several voluntary programs available through NRCS and the USFWS that provide support for protection and restoration of wildlife habitat. These programs often provide technical and financial assistance and can help to enhance amphibian and reptile habitat. For more information on these programs, please contact NRCS about current Farm Bill, financial and technical assistance, easement, and landscape planning programs.

Planning Restoration and Mitigation

Regardless of whether the focus of an ecological restoration or mitigation project is amphibians and reptiles, a successful project will have more sustainable outcomes through good planning. To help a project to be most successful the following should be considered during the planning process.

1. It is important to engage stakeholders early and identify the needs, goals, and protection strategies necessary to maximize success. Education is a key component in effectively developing realistic and achievable project goals.

Identify restoration needs at large and small scales – Watershed assessments can be useful to identify which restoration activities will most benefit landscape processes. Large-scale natural resource mapping and species surveys help quantify the available resources, the status of herpetofauna and wildlife communities, and how large- and small-scale management decisions will affect local and regional ecosystems. This more holistic approach can help to guide restoration design to address the actual problems instead of attempting to create small-scale temporary solutions.

Involve stakeholders – Government, non-governmental, private sector, academic, and local citizen groups should be invited to contribute knowledge and resources needed to create

Large-scale Conservation Success for Lake Erie Water Snake

Population declines of Lake Erie Water Snakes (*Nerodia sipedon insularum*) had become so severe that this species was listed as Federally Threatened as of August 30, 1999. Local community members became involved in planning and conservation efforts to conserve their quickly disappearing snake. Some shorelines were permanently designated as natural areas to protect snake habitat, and new developments within the range of these snakes incorporated habitat features and reduced habitat loss. Through implementation and strong local support of a recovery plan to prioritize actions for snake survival, Lake Erie Water Snakes were delisted in 2011.

Kristen Stanford

1. Thanks to adaptive management and dedicated conservation efforts by herpetologists like Dr. Kristin Stanford and Dr. Rich King, this species was delisted as federally protected.

One such development (residential lots) included the establishment of a buffer area with no construction along each lot, allowing old stone foundations that the snakes would use as habitat structures to remain, construction of artificial hibernacula structures, closure of an existing access road in a kill zone, posting road signs to promote lower vehicle speeds and alerting community members to the presence of these snakes. Major earth moving was conducted between May 1 and November 1 to reduce mortality of hibernating snakes, and construction activities were conducted to maximize conserved habitat area. Activities such as these also facilitated research to aid in future recovery and management plans.

an ecologically, economically, and socially sustainable project. Involving these groups early on is often necessary to gain community support important in long-term success.

Set measurable goals – Goals can help to gain support for a project and provide direction for smaller decisions that will be made along the way. By clearly defining goals in a measurable way, the success of a project can be determined when the project is complete.

Consider long-term goals and outcomes – Most restoration or mitigation sites require some level of continued management to provide ecological function or accomplish other goals. Funding sources may not be apparent or available for long-term management needed for simple tasks like periodic removal of invasive plants. Long-term success may need to be supported by stable government or non-governmental organizations or have considerable local community support.

2-3. During a coastal wetland restoration project, fill and a bike path were removed and coastal wetland substrate and plants were restored. The restored coastal wetland naturally buffers wave action and provides amphibian and reptile habitat.

Kathy Evans

Kathy Evans

1-2. Salamanders, such as Small-mouthed Salamander and Northern Dusky Salamander, can only live in areas with high humidity, like under logs, and leaf litter and near wetlands. Maintaining moist, forested upland areas and creating wetlands can help maintain salamander populations.

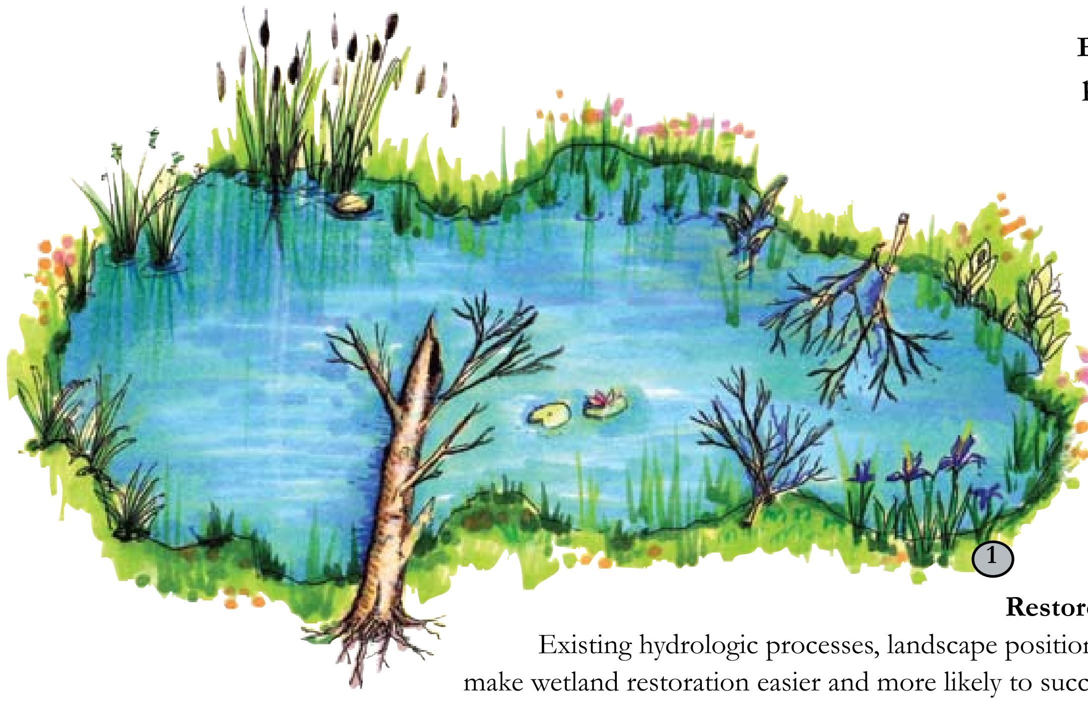
3. When practicing adaptive management, effects of climate change on species' seasonal habitat and natural history should be considered. Changes in hydroperiod can influence species and community success. Planning for such changes can impact overall success and utilization of a site as habitat.

Prioritize restoration elements - Identification of which elements will have the most impact or must be created first can be used to create a plan of construction and restoration activity phases. Phasing plans should also account for seasonal conditions, wildlife movements and life stages, economic feasibility, and regulatory conditions.

Practice adaptive management – For the project to be successful in the long term, it needs to be flexible to changing environmental, economic, and social conditions. Adaptive management uses a feedback cycle where setting goals and priorities lead to developing strategies. These strategies are realized by taking action, after which results are compared to the original goals and priorities to measure success and find ways to improve the project (The Nature Conservancy 2011). It is important to share the knowledge gained through adaptive management implementation with the broader community of restoration practitioners and land managers to advance restoration techniques.

Wetland Mitigation and Restoration

Over half of the wetlands in Michigan have been destroyed or degraded from their pre-settlement condition (Dahl, Johnson et al. 1991) (See Section 3). Wetland restoration and creation can have large-scale benefits – including improved social welfare, greenhouse gas mitigation, waterfowl recreation (Jenkins, Murray et al. 2010) and can enhance population sustainability and connectivity of wildlife habitat (Petranka, Harp et al. 2007). Although there are substantial gains associated with wetland restoration, the exact outcome of any wetland restoration is difficult to predict (Zedler 2000). Following some basic guidelines/principles in wetland restoration planning can help to ensure the restored wetland becomes a functional and valuable part of the ecosystem and provides habitat function and conservation value for herpetofauna and other wildlife.



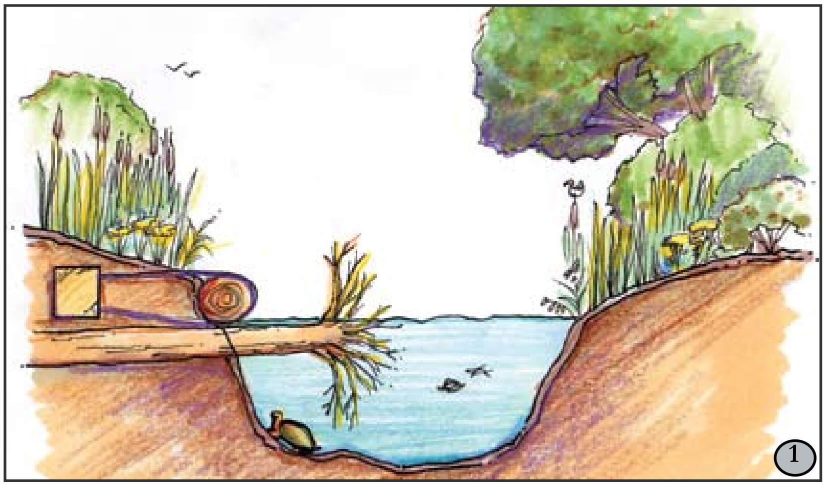
1. A diversity of vegetation and structure will contribute to habitat for amphibians and reptiles as well as other wildlife.

Ensure hydrologic processes can support the wetland - Siting wetland mitigation or restoration activities should take water inputs and outflows into consideration. A hydrogeomorphic approach to locating a wetland restoration project will greatly enhance the potential of its success.

Restore historical wetlands – Existing hydrologic processes, landscape position, and soil types usually make wetland restoration easier and more likely to succeed than a created wetland. Often native plant stock remains and high-quality wetland habitats can be established quicker and more cost effectively. A major problem often associated with this type of restoration is the establishment and domination of the site by invasive species. To counteract this, soil types should be tested and amended if they are lacking sufficient nutrients to support healthy native vegetation. Seeding and planting of desirable wetland plant species at high densities to establish a thicker native bed of vegetation that will be a strong deterrent to the establishment of invasive species.

Locate the restored or enhanced wetlands to increase connectivity – Several herpetofauna rely on a variety of wetlands in a complex. Restoring or creating a wetland complex with several wetlands of different configuration and depth within a few hundred feet of each other can

2. A wetland mosaic as shown here provides a variety of habitats which help meet the suite of landscape features required to support a healthy ecosystem.



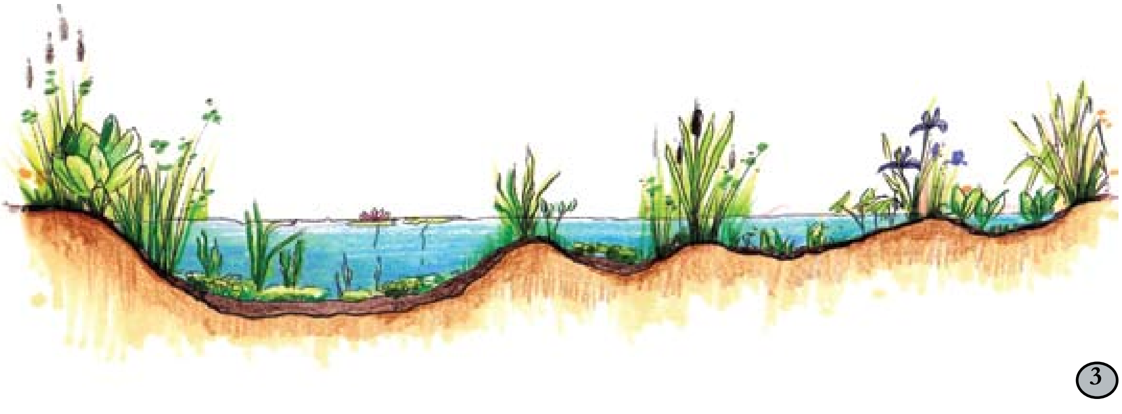
provide dispersal opportunities for juveniles, migratory adults, or herpetofauna displaced by drought (Mazanti 2003). For animals such as salamanders, terrestrial travel can be risky due to a high risk of desiccation and predation (Ash 1997). Many of these species have extremely small home ranges and do not migrate far in search of additional habitat. By creating a wetland within close proximity between two existing wetlands, the distance that herpetofauna must travel to reach the nearest wetland will be reduced, and assures the potential for natural repopulations of the restored wetlands, thus reducing risk to amphibians and reptiles.

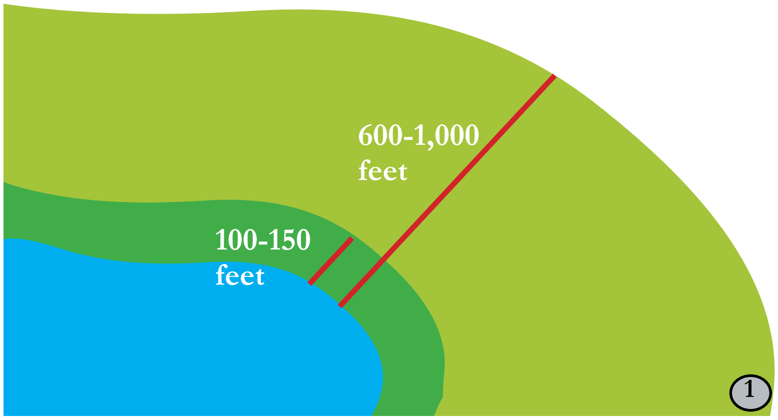
Create several wetlands with a variety of hydroperiods and conditions – The conditions created by depressions and pools of various depths and sizes can provide habitat suitable for several amphibians and reptiles during all seasons; however, they should provide similar conditions as nearby naturally occurring pools (Mazanti 2003). For example, within a body of water species such as Northern Map and Musk Turtles will utilize deeper waters while Midland Painted and Eastern Snapping Turtles occupy shallow zones. A diverse wetland complex or landscape matrix will have variable predator pressures, which is likely to provide long-term persistence of herpetofauna populations (Petranka and Holbrook 2006).

1. A variety of habitat structures serve multiple purposes, including basking logs which can also provide valuable cover for amphibians and reptiles.

2. Maintaining a mosaic of habitat within a wetland is critical for herpetofauna population viability.

3. Wetlands with several depths, even if only varying by a few inches, can provide habitat for a wider variety of species.





1. Disturbance within 1.25 miles of a wetland can impact amphibians and reptiles associated with the wetland, although the closest 500 feet surrounding a wetland provide the most critical habitat. It is important to protect an upland buffer around wetlands to preserve habitat integrity and quality.

Restore and protect a buffer around a wetland - Strive to protect the first 600-1,000 feet (depending on which species are present) of upland area adjacent to a wetland to protect core habitat areas for amphibians and reptiles (Semlitsch 1998; Mazanti 2003; Semlitsch and Bodie 2003; Calhoun, Miller et al. 2005). Management or development actions within this buffer should not impact greater than 25% of the area to reduce risk of local population declines (Calhoun and Klemens 2002). This 25% should also be selected based on relative quality and proximity to contiguous habitat. If this amount of buffer cannot be protected, at least the first 100-150 feet of upland area adjacent to a wetland should be preserved as buffer as this is where most pool breeding amphibians live their first year and where riverine turtles occur (Bodie 2001). Land conversion and habitat disturbances within 1.25 miles of a wetland can have a significant effect on the biodiversity of the respective wetland, and protection of this land should be included in wetland policies in "herp hot spots" and where critical habitat is present (Findlay and Houlahan 1997). If creating a wetland buffer, plant native species that provide cover, foraging and hunting areas, and safe breeding habitat for amphibians and reptiles while maintaining interstitial spaces for basking and herpetofauna movement. Establishment of dense vegetation and tall grasses should be avoided.

2. Time construction and operation of machinery for times when amphibians and reptiles are less likely to be present.

Design for a diversity of animals – Creation and restoration must take into consideration the needs of all wildlife including herpetofauna, birds, mammals, and macroinvertebrates. A diversity of native plants can contribute to habitat structure for several wildlife species. In general, a design based on herpetofauna and aquatic macroinvertebrates will have ecosystem benefits for other taxa (e.g., waterfowl, mammals, and fish).

Time construction and earth moving for the warm season – Grading and earthmoving should be conducted when animals are active during the warm seasons. Be aware that many amphibians and reptiles are slow-moving and may not be able to avoid equipment moving at seemingly slow speeds. Before beginning work, establish barrier fences around areas to minimize use of these areas by herpetofauna during construction activities and concurrently relocate animals out of construction zones. This should be done under the guidance of an experienced professional wildlife biologist with demonstrated expertise in working with amphibians and reptiles and experience in conducting translocations. Barrier fences should include one-way doors that allow any additional animals to move out of construction zones. When using large equipment, start work at a central point and move outwards from that point to allow any remaining animals to flee in all directions.

1. These large rocks provide useful habitat for snakes that bask at this site. However, at a site with valuable turtle nesting habitat on land, these rocks could be a barrier for females going ashore or hatchling turtles attempting to return to the water. Incorporating areas with small rocks which fill in gaps will help improve turtle movement and reduces risk of babies getting trapped in gaps.

Create gradual slopes - Studies have shown gradients as shallow as 1:15 (rise to run ratio) to 1:20 are much more ideal for supporting a variety of herpetofauna and their prey items. Whenever possible, wetland slopes should have no more than a 30% grade to support target species. Steep banks can prevent herpetofauna from coming ashore to bask, pursue prey, and nest (Reese 1986; Mack and Micacchion 2006).

Repurpose cleared vegetation as habitat structures – Trees, shrubs, stumps, rocks, and rubble removed as part of clearing and grading may be placed throughout the site to provide basking structure, cover, and hibernacula for herpetofauna (Mazanti 2003). This not only prevents much of this material from being landfilled, but can save a significant amount of money on the project while maximizing the habitat value.

Establish native emergent and submergent vegetation in the littoral zone and in pools – This vegetation will provide refuge for small amphibians and reptiles and for amphibians to attach egg masses (Mazanti 2003). These plants can also improve water quality, foraging sites, and help increase dissolved oxygen in the water.

Translocate animals from construction areas – Trapping and relocation efforts are important especially in restoration of existing wetlands where some herpetofauna may already live. This is not only at times a permitted requirement, but more importantly an opportunity to help minimize loss of populations. This activity should only be conducted under the guidance of a trained herpetologist with experience conducting such efforts and with appropriate permits. Further details on translocation are discussed later in this section.

Monitor to gauge success – Evaluation of project outcomes, including flora and fauna communities, can indicate which methods were the most successful and which can further be improved on to increase future project success. Measures of project success should include objective, quantitative, and repeatable data in order to provide reliable feedback. This feedback cycle helps to improve techniques used for sites with a specific set of conditions and drives better habitat restoration and management. Herpetofauna should be monitored during times when species are most active to accurately gauge restoration success. Ideally at a minimum sampling would be conducted in late spring and late summer/early fall to maximize species and life stage detection.

2. Branches and old logs provide important refugia following tree removal. These materials can also be repurposed as basking logs or substrate for amphibian eggs in ponds.

Nick Scobel

Nick Scobel

1. Species like Queen Snake (1), Northern Water Snake (2), and Northern Map Turtle (3) can benefit from installing a variety of habitat features during stream restoration. Materials removed during a project such as logs or large rocks can utilized for basking or cover. Reusing these materials can also reduce the cost of a project.

Stream and River Restoration and Mitigation

Many of Michigan's streams and rivers have been physically altered through channelization, bank stabilization, dredging, culverts, and impoundments. These alterations have reduced the habitat structures and niches that herpetofauna, such as Wood Turtles, Northern Map Turtles, and Queen Snakes (*Regina septemvittata*) use in the channel and riparian zones. Disturbances that contribute to the imbalance in stream function can be gradually removed, or in some cases, quickly removed in active restoration and mitigation activities. Due to the complex nature of stream restoration and the unique conditions surrounding each waterway, a stream restoration specialist, preferably one familiar with the Rosgen Natural Channel Design Method (e.g., (Rosgen 2011)) or George Palmeter river restoration techniques (e.g., (Herbkersman 1982)), should be contacted to lead restoration. The Natural Channel Design should be utilized when appropriate to allow for natural stream processes and biological lift, however this is not always possible due to infrastructure limitations. General guidelines to follow in planning for stream restorations that provide conservation value to herpetofauna are listed below.

Create a variety of habitat structures – Creation of sand and gravel bars, overhanging vegetation, and natural cutbanks provide cover and foraging grounds for a variety of species of herpetofauna and other wildlife. In-stream habitat structures for herpetofauna include woody debris, snags, leaf litter, boulders, clean sand, gravel, or cobble substrate. Small pools can also be excavated to the side of a river channel to provide additional protected areas to facilitate breeding, nesting, feeding, and basking.

Place culverts on straight parts of a stream or river – Straight stream sections can accommodate straight culverts or pipes and are less likely to dramatically move over time.

Culverts should be slightly wider than bankfull width – By placing a culvert wider than the bankfull width of a stream or river – the width a stream or river reaches just before spilling onto the floodplain - a flood-plain area can be created along the sides by placing rocks. It is important that if culverts larger than bankfull are installed that banks are created within the culvert that may not be mobilized out of the culvert. This is not only important for animal passage but it is necessary in order for the stream to continue to transport sediment through the system and allow for unimpeded

Figure 2

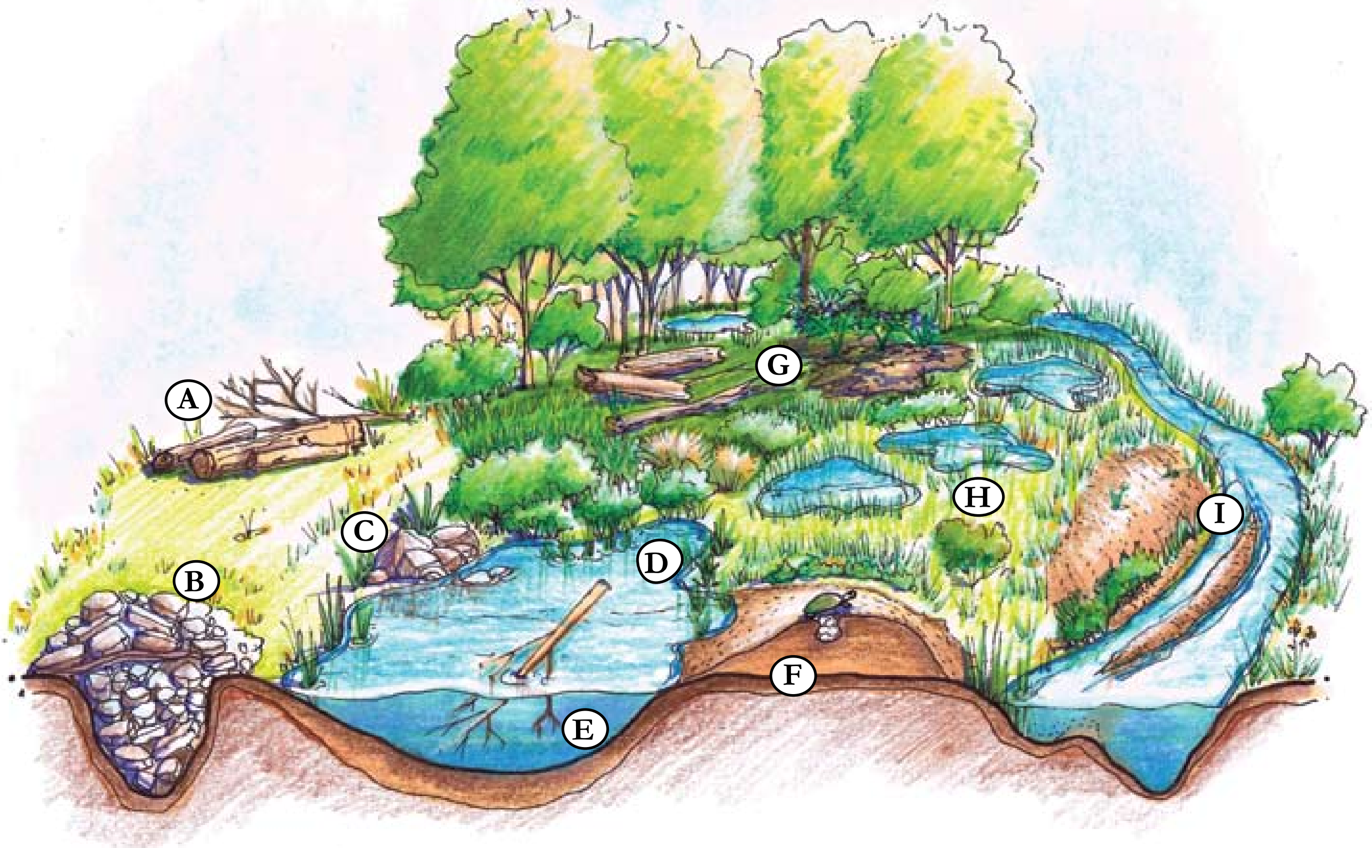


Figure 2. This figure illustrates an ideal landscape that can be managed or created to support herpetofauna richness and density

Logs in a sunny/partly sunny location. Cover, basking, nesting and hibernation (A).

Depression filled with rocks, rubble, and/or rootballs. Reptile basking and hibernation B).

Rocks along shoreline. Shelter and basking (C)

Emergent and submergent vegetation. Basking and foraging (D).

Finely branched brush and trees. Amphibian egg attachment and cover (E).

Sunny areas of loose, well drained soil. Turtle nesting and basking (F).

Logs and leaf litter in the forest understory. Salamander cover, nesting, foraging, and hibernation (G).

A variety of wetland types to support migrations, breeding, foraging, hibernation, and development of various amphibians and reptiles (H).

Sandy banks and sand bar. Turtle nesting and reptile basking (I).

fish passage. Sediment fills in between the rocks and creates an area that wildlife can also cross. Using a culvert to maintain bankfull width allows water, sediment, and debris to move downstream without blocking the culvert, creating scour pools, or perched culverts.

Select the appropriate type of stream crossing structures – Each stream crossing site varies but bridges are always the preferred alternative for animal passage and then typically are, in descending order of preference, open-bottom arch culverts, box culverts, elliptical culverts, and circular culverts. Larger culverts can provide more natural conditions - such as ambient light and temperature – which facilitate movement for a greater number of amphibians, reptiles, and other wildlife. Wing walls or barrier fences leading to both

Conservation Resource Alliance

1. This open-bottom arch culvert allows species like Wood Turtle to follow stream corridors safely while reducing the risk of road mortality. For an additional illustration of this structure, see figure 10 in development techniques.

openings of crossing structures can direct wildlife through a structure and prevent their movement onto a road. Consult a professional herpetologist or wildlife biologist to provide conditions the target species will need. Refer to Section 6 Road Crossing Structures for more information on implementing crossing structures that best accommodate amphibian and reptile movement.

Consider the flow of water when placing culverts – Typically, a culvert should be placed with the invert elevations of both ends of the culvert buried at 1/6th of the riffle bankfull width of the stream up to a maximum of two feet at the same slope as the streambed measured from a riddle upstream and downstreams of the existing culvert. If the upstream flowline – the general path that water follows - is raised, scour near the culvert could result, and if the downstream flowline is raised the water velocity could be reduced and reduce the downstream scour. Maintaining a continuous slope allows amphibians and reptiles to traverse culverts and access upstream and downstream river areas.

Incorporate floodplain shelves – Floodplains provide an area for a stream to dissipate energy during flood events. Flooding reduces the velocity of the water in the channel and prevents unnaturally severe erosion downstream. During flooding, sediment is deposited on the floodplain, enriching the soil. Rocks, branches, and vegetation in the floodplain also provide wildlife habitat structures near to the water. Seasonally, floodplains can provide important habitat for herpetofauna and serve as critical corridors between habitats. In culverts that are large enough, floodplain shelves should be constructed from material that is not mobile during high flow events. These shelves should be created at the bankfull elevation and meet the bankfull width upstream and downstream to the culvert. If culverts are too small to construct a floodplain bench, smaller diameter culverts should be installed higher than the channel culvert and at the bankfull elevation. Another method of floodplain maintenance includes the two-stage ditch developed by The Nature Conservancy. This design introduces

Figure 3

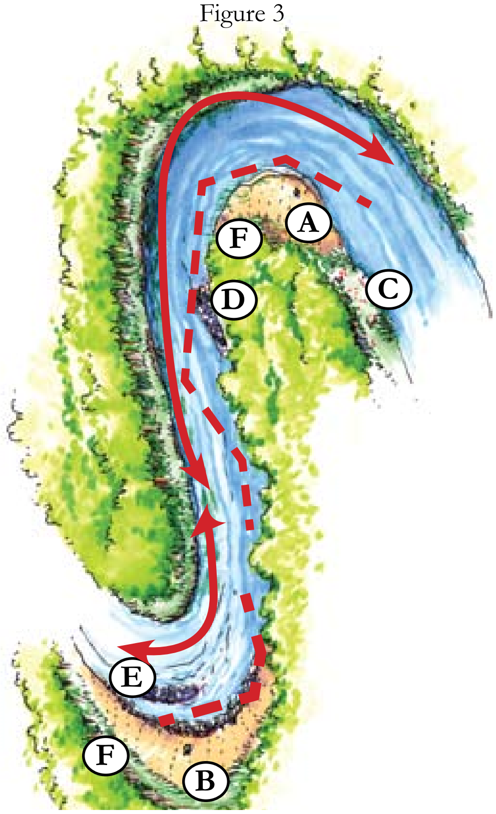


Figure 3. Sandy, sparsely vegetated banks along a river provide turtle nesting habitat (A and B).

Cutbanks which are prone to erosion (A) can be protected while maintaining access for turtle nesting. Rocks in the channel deflect stream velocity (C) and the toe of the slope is stabilized by small rocks filled-in with gravel or sand (D).

Sandbars prone to erosion (B) can be protected by rocks or riprap placed as a wing deflector (E).

Protect nest areas from predators by placing fencing (F). Predators following along this fence will be deflected away from the nesting area.

1. A professional herpetologist uncovers a recently constructed Wood Turtle nest in a river sandbar to prevent raccoon predation. Upon hatching, the turtles were safely returned. Such activities require permits by DNR.

2. A female Wood Turtle makes its way on land during the nesting season looking for nesting sites. This species can benefit from restoration activities that enhance riverine features and increase nesting opportunities. Education is also critical to discourage people from collecting this increasingly rare and long-lived turtle.

a floodplain zone called a bench into a ditch by removing the banks roughly 2-3 feet above the bottom for a width of about 10 feet on each side (The Nature Conservancy 2013). These various methods allow for improved hydraulics, reduced velocities, organism passage, woody debris transport, and reduced long-term maintenance costs.

Restore riffle, run, and pool sequences – These natural stream features are often degraded in streams with significant anthropogenic influence. These sequences also give rise to point bars, beaches, and bank habitats important to riverine herpetofauna. These features also help oxygenate the water while also providing deeper pools where many riverine turtle species and some amphibians overwinter. If changes are made in stream features to improve habitat it is important to consult a stream restoration specialist since perturbations in the system can have significant effects of stream geomorphology and stability.

Stabilize slopes - In areas prone to erosion, use of vegetation as bank and toe of slope stabilization may be the best option, as it allows for the stream to move over time without scouring effects from stone placement and also enhances water infiltration through root penetration. However, in areas where Wood Turtles potentially occur, exposed sandy areas provide critical breeding sites. Strategically placed vegetation, rock, and wood structure may be needed to protect these sandy areas in degraded systems where erosion threatens these features. Placing sand, clay stone, and riprap can be added to stream banks, but should not constrict the stream more than its natural bank-full width.

Depending on which species use an area, various techniques should be incorporated into slope stabilization. In areas where turtles nest, large gaps between rocks can trap female turtles attempting to nest on the banks or hatchlings emerging from a nest. These scenarios often result in death to the animal. Filling in the gaps with smaller gravel, sand or other stable materials will help reduce the risk in turtle nesting areas. However, in areas where turtles are unlikely to nest (e.g., a north facing bank), snakes will seek cover in large gaps between rocks. Identification of the target species and providing a mosaic of conditions can help enhance amphibian and reptile populations.

Figure 4

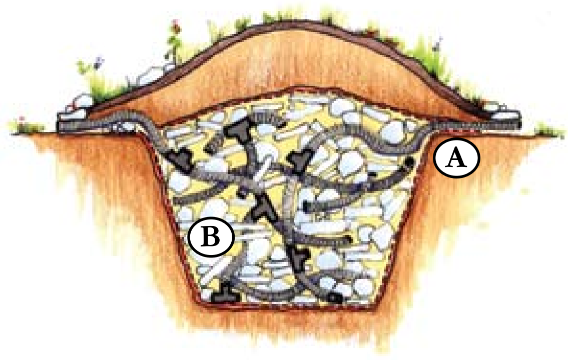
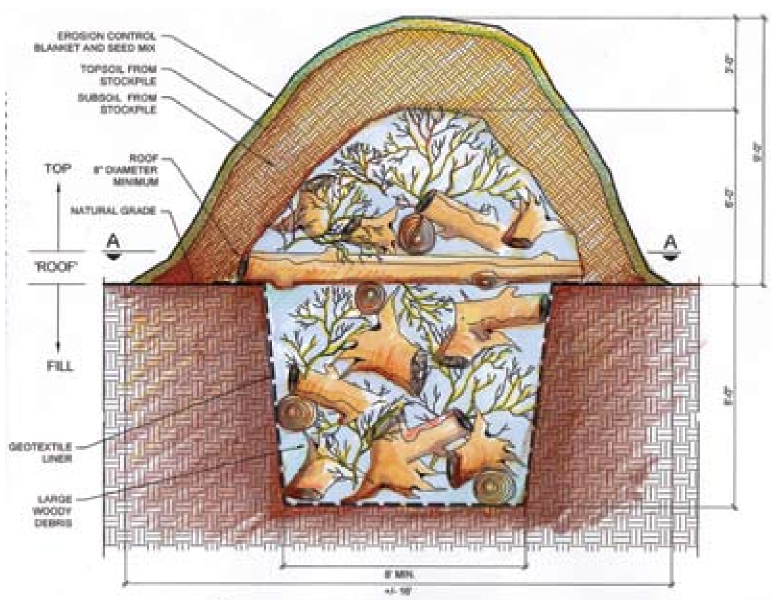


Figure 5



Habitat Design

Wildlife habitat is comprised of everything that contributes to the presence or abundance of wildlife (Cooperrider, Boyd et al. 1986; Hall, Krausman et al. 1997). This means that floral, faunal, physical and chemical components as well as the spatial and temporal interactions among these components contribute to wildlife habitat and should all be considered in a restoration plan. Ecological restoration and mitigation often focus on habitat quality, connectivity, and reduction of fragmentation as a means to benefit wildlife communities. Creation of features, such as breeding, nesting, or hibernation structures, further supports herpetofauna by providing them an opportunity to carry out necessary life processes (Gillingham and Carpenter 1978). These structures enhance herpetofauna habitat quality and population viability when integrated into a plan that also accounts for restoration of large-scale landscape process. Oftentimes, small changes to conventional designs can result in large wildlife habitat improvements and monetary savings. A certified wildlife biologist or professional herpetologist should be consulted to design herpetofauna habitat and to integrate these components into a master plan. They can help coordinate efforts in the best interest of wildlife species on site while helping construction and management plans move through regulatory approval. General amphibian and reptile habitat design considerations are listed below and followed by details about the creation of habitat structures that benefit specific groups of herpetofauna.

Figure 4.
Hibernacula structures containing pipes and tubes should have a "trap" (A) in the pipe to prevent cold air from traveling to the bottom of the hibernacula and freezing the hibernating animals in the winter. Several openings allow snakes and other animals to find an ideal niche in the hibernacula (B).

Figure 5.
Logs and stumps can be used to create a hibernaculum and provide tens or even hundreds of snakes and other wildlife protection from the cold. Both are reasonably priced and in many cases incorporating them can save money on projects.

Create complexes of wetlands connected by high quality upland areas – Several Michigan herpetofauna species rely on high-quality wetland and upland areas to complete their lifecycle (Harding 1997; Porej, Micacchion et al. 2004; Attum, Lee et al. 2008; Attum, Lee et al. 2009). Developing a mosaic of different vegetation types and providing connections between features of value enhances landscape connectivity for herpetofauna species. Creating ample upland corridors (>100 feet in width, e.g., (Mazanti 2003)) between high-quality wetland features may provide appropriate landscape connectivity.

Maintain a variety of hydroperiods – Create an uneven surface with both large (approximately 3 feet) and small (approximately 6 inches) depressions to provide a variety of hydroperiods that various herpetofauna can utilize

throughout the year. Larger pools within a wetland will make the system less vulnerable to drying, and combined with small pools that form in these microtopographic depressions can provide sources of water over a larger portion of the landscape and better accessibility for herpetofauna. The irregular topography also allows for greater variety in community types and allows for greater species colonization and densities.

Look for opportunities to incorporate features at low cost – Byproducts of site alterations or on-site resources may present opportunities to create no-cost or low-cost habitat features. Rebar free concrete, rocks, trees, stumps, and rubble, which would otherwise be removed from a site for a cost, may be reused in hibernacula, refuges, basking sites, or nesting sites. The money is saved when removal costs are eliminated and no materials are purchased to create habitat features. Care should be taken to reduce the amount of crushed concrete material that enters aquatic systems as pH can increase from concrete leachates (Van Dam, Smith et al. 2011).

Create habitat for prey species – Providing habitat for the food source of the target amphibians and reptiles is essential to supporting and maintaining a rich assemblage of herpetofauna at a site. This is often accomplished while creating habitat or landscape features intended for use by herpetofauna. These restoration features provide habitat for the macroinvertebrates, mussels, small mammals, fish, and the other fauna that herpetofauna eat. However, the food source and the habitat requirements of the food source of each target species should be identified and checked for inclusion in restoration plans. This 'double-check' can be especially important for species, such as Queen Snakes (*Regina septemvittata*), which have a specialized food source, feeding almost exclusively on crayfish (Wood 1949). In this case, meeting the habitat requirements for maintaining a healthy population of crayfish is necessary to ensure a food source for Queen Snakes.

1-3. Concrete/limestone rubble can be repurposed to provide critical reptile habitat such as hibernacula shown at these three project sites located throughout Michigan. When incorporating sand, these structures can also provide important nesting sites for reptiles. These systems are becoming increasingly used in Michigan are an inexpensive and effective way to create critical habitat while repurposing onsite resources.

1-2. This turtle nesting area is covered by a fenced structure designed to keep raccoons and other potential predators out. The fence attached to the sides of the structure is embedded in the ground. Turtles can access the nesting area under this structure from the water. This system has been successful, though each project is unique and consulting with a professional is encouraged.

Turtle Nesting

Nesting sites can be on a sunny riverbank or lakeshore, in a sandy field near a wetland, on an island or sandbar of a main channel, or even the dangerous gravel shoulder of a highway. Turtles typically nest between mid-May and early July, and species such as Blanding's Turtles will travel extensively (sometimes >1 mile) in upland areas to locate an acceptable nesting site (Standing, Herman et al. 1999; Mifsud 2004). Other turtles, like the Eastern Spiny Softshell, nest directly adjacent to the water, with most nests approximately 10-30 feet from the edge of the water. Always assess which turtle species are likely present and their nesting requirements when creating turtle nesting areas. Various turtle nesting area creation and maintenance techniques are listed below.

3. Sand bars such as this are critical nesting sites for many turtle species in northern Michigan. Armoring or stabilizing to encourage vegetation can eliminate this habitat locally.

Locate a site – Turtle nesting areas are typically on south facing slopes to warm the nest to an appropriate temperature for incubation. Turtles typically nest in areas of sandy or loose, friable soils. Nesting areas should be approximately 3 feet or more above summer water levels to reduce potential flood damage. When possible, locate nesting areas isolated from egg predators (e.g., raccoons, chipmunks, skunks) and human disturbance. Small islands without predator populations are ideal areas for nesting sites. If constructing turtle nesting sites along the shoreline of a lake or the banks of a river, space nesting areas at 1-2 mile intervals (Buech and Nelson 1991).

Place sand or wood chips – A pile of sand or wood chips or an excavation filled with sand near to the water on a south-facing slope can provide a turtle nesting area. Avoid creating nesting areas on steep slopes to minimize erosion. If placing sand, select washed sand to reduce vegetation colonization. These types of nesting areas can be easily and quickly created with earth-moving equipment. A caution about using wood chips: when fresh these produce heat through the decomposition process and when exposed to full sun can become hot enough to bake turtle eggs. Use old mulch or place mulch at site well before nesting season (e.g., the fall of the previous season) to allow for sufficient decomposition to take place. These areas can also provide snake nesting sites.

1. Sand can be used in restoration sites to create nesting areas. Knowing the species found locally will also guide what type of substrate is best.

2. Nesting areas should be maintained to reduce the growth of vegetation.

3. Protecting nests from predators will increase nest and hatchling success as observed with these emerging Wood Turtles.

Nesting area maintenance - Till sandy nesting sites in late spring after any potentially overwintering hatchling Painted Turtles have emerged, but well before nesting season begins. This method of maintenance is less time intensive than hand weeding, poses less threat of water contamination than herbicide treatment, and maintains loose soil ideal for nesting (Dowling, Hartwig et al. 2010).

Mitigate predator damage – In several areas throughout Michigan, artificially high populations of subsidized mesopredators (a medium size predator that often increases in abundance when larger predators are eliminated), like raccoons, can result in devastatingly high turtle nest mortality (See Section 3). Individual turtle nests can be protected, or fenced covers can be placed over an entire nesting area, to increase chances of nest and hatchling success; however, raccoons (and even chipmunks) have been known to destroy or dig under these covers to reach eggs (HRM 2011; HRM 2012). Use of techniques, such as electric fences or construction of islands (e.g., digging a moat at the base of a peninsula) may be implemented to protect ideal turtle nesting areas, as this has been a technique to successfully reduce mammalian predation on ground nesting birds and on sea turtles (Lokemoen, Doty et al. 1982; Bennett, Chaudhry et al. 2009). Control of these predators on islands where turtles nests has been effective at

Jan Storey

Chris Hoving

1-2. Thanks to their ability to withstand below freezing temperatures, Wood Frogs can overwinter on the soil surface. Eastern Box Turtles, however, burrow into the soft forest floor under leaf litter and debris to thermoregulate over winter.

reducing predation pressures (Garmestani and Percival 2005; Engeman, Duffiney et al. 2010) but to date there has been limited effort and success conducting similar control measures in inland areas.

Turtle Hibernacula

Some aquatic turtles remain semi-active during the winter, but most turtles in Michigan hibernate during cold seasons. As the weather begins to cool, the body temperature of turtles gradually decreases, preparing them for hibernation. During hibernation some species of hatchling turtles produce proteins that act like antifreeze and prevent ice crystals from forming in their cells which would cause death (Packard and Packard 1993). Aquatic turtles and terrestrial turtles have different hibernation requirements, both of which can be provided for in restoration projects.

Aquatic turtles - Aquatic turtles that hibernate use fine silts, mud, and detritus at the bottom of water bodies or in submerged banks. In areas where turtle species hibernate on the bottom, wetlands should be the appropriate depth to avoid the entire water column from freezing solid and to ensure that the water does not become anoxic as turtles and other submerged fauna consume dissolved oxygen in the water. Some species that spend the winter on the bottom, such as Blanding's Turtle, may not truly hibernate the entire winter and have been observed moving slowly on the bottom under the ice. Hibernacula structures can be created as hollowed out areas under the banks. These structures must remain submerged or at a constant water level from early fall until emergence in the spring.

Terrestrial turtles - Michigan's only truly terrestrial turtle, Eastern Box Turtle, hibernates in burrows in sandy or friable soil in forested areas. Hibernation of these turtles can be supported by ensuring that soils are not heavily compacted and that leaf litter and duff layer are maintained on the forest floor throughout the winter as these provide an important insulating layer. Providing areas of leaf litter at least one foot deep is ideal to ensure Eastern Box Turtle can survive the winter.

Turtle Basking

Several aquatic turtle species, such as Wood Turtles, Blanding's Turtles, and Spotted Turtles, need to bask to thermoregulate. These turtles climb out of the water to dry off and warm themselves in the sun. Basking helps fend off parasites, infections, and provides warmth and energy needed for digestion and other metabolic processes. They typically bask on logs or other structures in the water, as they are difficult for predators to access and can quickly dive

1. Logs and fallen trees already present at a site can be used to create basking structures. This helps reduce disposal costs while finding use for the material.

into the water at the first sign of danger. When adequate basking sites are not present, turtles will use shorelines and banks where the risk to predation is greater.

Basking Structures – Felling trees on site, using existing logs, or bringing in logs can provide basking habitat. These elements should be placed roughly horizontally and in shallow waters. The branching and irregular shape of trees allows some surfaces of the tree to be above water even during times of high water. They may or may not connect to the shore. In fast moving waters these structures may need to be anchored in place and angled to reduce drag. Snakes will use these structures for basking and, depending on locations, amphibians may attach their eggs to the submerged fine branching. These structures also serve as habitat for some fish species that can provide an important food source for amphibians and reptiles.

Snake Hibernacula

Michigan snakes hibernate during cold seasons in crevices, holes, abandoned animal burrows, and crayfish chimneys (Carpenter 1953; Gillingham and Carpenter 1978; Smith 2009). Snakes may hibernate in large groups due to the scarcity of ideal hibernation areas and the benefits of warmth and protection from predators derived from a large group.

Hibernacula Structures – Created hibernacula are typically mostly below grade. Hibernacula are prepared by excavating a pit to a depth of at least 8', and then rocks, logs, tubing, pipes, concrete rubble, and/or other objects are placed in the pit that create interstitial gaps. The snakes are able to traverse these gaps and are protected from cold and predation. Once filled, the pit is covered with soil with only small openings remaining as a 'door' to the structure below. The rock and/or log structure exposed in this 'door' can also provide a secondary basking site. If incorporating corrugated plastic tiles into the design, it is recommended that air traps be incorporated to prevent cold air from traveling to the bottom of the enclosure. For illustrations and additional details please refer to figures 4 and 5.

2-3. Logs along the edge of the forest can serve as important habitat for a variety of herpetofauna including Five-lined Skinks (right).

1. Northern Ribbon Snakes and other reptiles utilize branches and snags as basking sites.

2-3. Rock Structures such as this natural formation and created structure provide opportunities for thermoregulation as well as refugia, nesting, and overwintering habitat.

4. Rotting wood is utilized by Five-line Skinks and many snake species to lay their eggs.

Snake and Lizard Basking and Cover

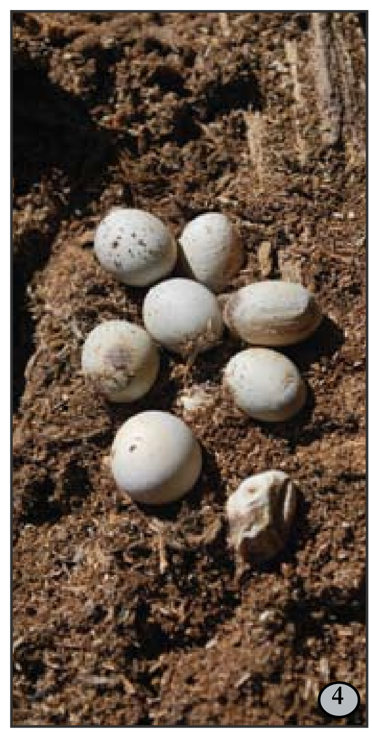
Like all herpetofauna, snakes and lizards are ectothermic and rely on the warmth of the sun to provide the heat energy needed for quick movements, digestion, and other metabolic activities. A suitable basking site is especially important during cooler periods in the spring, early fall, or on cool summer mornings. When snakes bask they are exposed to predators, including predatory birds, and prefer to have cover nearby if a quick get-away is necessary. Basking sites with a rough surface can help snakes shed their skins.

Snake Basking and Cover Structures – Basking structures are typically made of rock or wood. Gaps between stones and logs are important to provide places where snakes can quickly escape a predator. Hibernacula, as described above, can double as basking and cover areas. Stumps can also serve as cover and basking sites, as small snakes can hide under bark or in rotted holes in the stump.

Lizard Basking and Cover Structures – Similar to snakes, lizards will use logs and stumps for basking and cover. However, Five-lined Skinks prefer these structures along the edge of moist (not dry or wet) forests. Six-lined Racerunners (*Aspidoscelis sexlineata*), another Michigan lizard, prefer drier open forests and open fields, and will use woody debris, stones, logs, burrows, and leaf litter in these areas for cover and/or basking sites. Placement of these structures can attract and help support a healthy population of lizards if a nearby source population exists.

Snake and Lizard Nesting Sites

Some Michigan snakes give birth to live young, but other snakes and all lizards also lay eggs in a nest depression or a cavity that they excavate. Five-lined Skinks lay eggs in a cavity excavated in moist soil, sand, rotting wood, or leaf litter or under a log, rock, or other object (Harding 1997). Six-lined Racerunners lay eggs in burrows in the ground. Logs and rocks placed as hibernacula, cover, and basking structures for snakes and lizards can also provide ideal conditions for nesting. These structures may also provide the cover and protection from threats needed by a female snake giving birth to live young.



1. Finely branched limbs and trees dropped in the water can provide attachment sites for amphibian eggs and refugia from potential predators.

Amphibian Egg Laying Sites

The first step to create a successful amphibian egg laying site is to ensure a source of standing water in the spring that will last at least into early or mid-summer. Most species of salamanders and frogs and toads in Michigan (with the exception of the Eastern Red-backed Salamanders; *Plethodon cinereus*) lay their eggs in water or over water, and several species mate in water. Some amphibians deposit their eggs on sticks, branches, and plant leaves and stems in the water. These features can also help cover eggs and protect them from would-be predators. Once eggs hatch, the live and dead plant structures also offer protection to larvae.

Egg Laying Ponds – Ensure ponds hold areas of <30" water for at least four consecutive months. Irregular shorelines can help to increase the shoreline length, which provides greater habitat area. If areas of the pond are >30", these areas will not freeze solid and can provide hibernation opportunities for herpetofauna.

Amphibian Egg Laying Structures – Trees with fine branching can be felled into wetlands or brush removed from elsewhere on site can be placed in the water. The fine branching will decompose over a couple of years, and replacement structures will need to be placed. These sites can often double as reptile basking areas.

2. Spotted salamander egg masses attached to vegetation and branches in shallow water.

Plant Communities for Eggs and Larvae - Native, emergent and submergent wetland vegetation can provide ideal structure for amphibian egg placement, larvae foraging, and cover from predators. Protect this type of existing vegetation, or if conducting a wetland restoration, be sure to provide this vegetation as a component of wildlife habitat. Care should be made to limit the amount and type of plants within wetlands and allow for portions to remain as open water with sun exposure to help egg and larval development.

Frog and Toad Cover and Basking Sites

Frogs and toads need to bask to raise their body temperature above the ambient air temperature. Warmer body temperatures facilitate movement necessary for catching food and escaping predators. These amphibians are a desirable food source for many other animals and need cover nearby where they can hide from attack.

Vegetation - Sunny areas in shallow water or at the edge of a water body are ideal for basking. South facing slopes have more direct sun exposure, and the shadow pattern of nearby trees and vegetation should be considered when creating areas for frog and toad basking. The mottled

1. Queen Snakes rely on riverine areas to support their primary food source: crayfish. This species has declined in recent years due in part to habitat loss and presumably increase in invasive rusty crayfish which out-compete their native food source. It is listed as a species of Special Concern and observations of this species should be reported to the Michigan Herp Atlas.

shadow pattern of sparse herbaceous vegetation or deciduous trees in the spring can provide small areas of sun interspersed amongst shadows where frogs can quickly hide.

Logs and Submerged Objects - Logs and partially submerged vegetation also provide good thermoregulation areas where a frog can jump into the safety of water at the first sign of a threat.

Salamander Cover and Foraging Sites

Salamanders do not bask as their skin is highly permeable and they would quickly desiccate in the sun and wind. To prevent desiccation, most salamanders need cool, moist, shadowed areas to live and hunt. Providing cover and foraging sites in the water is important for salamanders. Most salamanders live in water during their larval stage and some species with gilled adult phases (neotenic salamanders), such as Mudpuppies and breeding phase Red-spotted Newts, live in the water during their adult life.

2. Simple structures such as these repurposed segments of sidewalk mimic natural Mudpuppy habitat.

Logs and Cover Objects - Areas near vernal pools or in moist forest areas are ideal for salamanders, and providing logs and leaf litter gives salamanders places to hide, attracts the invertebrates they eat, and helps retain moisture.

3. Species that vocalize to call mates often rely on darkness of night and vegetation to camouflage their location from potential predators.

Aquatic Structures – Providing submergent and emergent vegetation and/or finely branched brush in water can enhance cover opportunities for salamander larvae and provide conditions ideal for the invertebrates and vegetation that salamanders eat. Additionally, placing logs or rocks in shallow waters can provide gaps and spaces for neotenic salamanders to take cover and hunt for fish, mollusks, and other invertebrates. The creation of rocky shoals in rivers and lakes can provide excellent habitat for Mudpuppies.

1. Many species of amphibians and reptiles require a mosaic of habitat with intact uplands between wetlands. Maintaining such landscape allows for greater ecosystem resilience and overall community function and health.

Upland Conditions for Amphibians

Upland areas that are suitable for amphibians are generally shaded, cooler, moist environments. Promoting or preserving dense canopy cover, little understory vegetation, and a high amount of leaf litter and duff can provide suitable conditions for salamanders, frogs, and toads. If designing for salamanders, try to minimize the ratio of edge to area of forest. Vernal pools throughout upland areas can provide a water source valuable to many amphibian species as well as other wildlife.

Upland Conditions for Reptiles

Upland areas managed for reptiles or those suitable for reptiles are generally dry and relatively open with gaps in forest and shrub canopy. These open conditions can be maintained through tree thinning or occasional use of fire (Iowa NRCS 2005). Prior to engaging in any invasive

2-3. Reptiles like Northern Brown Snakes (2) and Blue Racers (3) require upland communities for survival. Incorporating techniques discussed in this BMP will benefit them and other regional herpetofauna.

1. Headstarting programs can benefit rare and declining long-lived species such as Wood Turtle and Blanding's Turtle. These activities should be conducted in coordination with the MDNR and a herpetologist with experience headstarting the target species.

2. Comparison in size between a natural Wood Turtle (left) at three years and a headstarted Wood Turtle (right) at one year. This can be an effective conservation strategy when conducted as part of an overall management approach.

species management always assess the species of amphibians and reptiles present. Wooded areas may also be enhanced by the establishment of fruiting plant species, such as strawberry, raspberry, and grapes, in areas where Eastern Box Turtles likely occur. When possible, encourage the development of healthy fungal colonies in woodland environments. Various mushrooms are an important food source for Eastern Box Turtles and for prey items of herpetofauna. They also help maintain healthy forest ecosystems.

Captive Breeding and Rare Species Headstarting

Establishment of an animal population can be part of the restoration process similar to the placement of plants from a nursery or dispersal of collected seeds from a reference site. Michigan turtle populations are in decline, with 40% of the native species listed as Species of Greatest Conservation Need (SGCN) in the MDNR Wildlife Action Plan and Special Concern or Threatened by the MDNR (Eagle, Hay-Chmielewski et al. 2005). The turtles listed as Species of Greatest Conservation Need, (Spotted Turtle, Blanding's Turtle, Wood Turtle, and Eastern Box Turtle) are all rare in Michigan and throughout their ranges. Given the current habitat conditions and population trends for these species in Michigan, human intervention is increasingly necessary to ensure populations of these species exist in perpetuity.


1

For rare species, pressure on populations can be offset through headstarting programs, where eggs are collected and the hatchlings are released once they have reached a larger, less vulnerable body size. Turtles are generally long-lived animals, with some species known to surpass the century mark, and must live long lives to successfully reproduce and replace themselves in the population. Longevity and reproductive opportunities are necessary to make up for the naturally high mortality of turtle eggs and hatchlings, as well as the typically long time periods needed for young turtles to reach sexual maturity.


2

Headstarting is a time intensive yet necessary part of turtle conservation to ensure these turtle species persist in Michigan. Although headstarting does not reduce threats from habitat destruction, road mortality, and unsustainable collection, headstarting does improve chances of hatchling survival to maturity. In fact, there is strong evidence to suggest that some northern Michigan Wood Turtle populations have only experienced recruitment through the release of head-started individuals over the last decade (Harding 2013). It can help prevent further declines of rare turtle populations while other challenges facing turtle populations are addressed through separate conservation actions. Headstarting increases the likelihood of hatchling turtles reaching sexual maturity, which is essential to maintaining the population while other conservation efforts advance. These efforts should

1-2. Relocation of herpetofauna can be a useful tool when conducting a restoration. During these activities it is vital to include a professional herpetologist to ensure the safety of the animals and the effectiveness of the movement. Permits are required to conduct any rescue and relocation activities.

only be conducted as part of a well thought and justified program by trained professionals with expertise in captive husbandry or headstarting turtles or other target organisms. Because of the potential risk of disease, these animals must be kept isolated from other animals and closely monitored.

Relocation, Translocation, and Rescue

When conducting a restoration or other conservation activity that may disturb or threaten wildlife communities temporarily or permanently, relocation or translocation should be considered. Relocation is defined as any movement of an animal, which can be within the same site; however translocation occurs when an animal is moved to an entirely new area usually some distance away from where it was found. Other situations where wildlife communities are imperiled may also require some level of 'rescue' to maintain viable populations, especially for rare or threatened species. Capture techniques, interim care, and release techniques should be appropriate to species' needs. This process requires that measures be taken to reduce the potential negative effects of donor and recipient sites. Do not attempt without consulting the proper authorities as rescue and translocation are regulated activities. A professional wildlife biologist with demonstrated experience and expertise in conducting these activities for amphibians and reptiles should be consulted to coordinate and conduct any effort that involves collecting, relocating, or holding an animal. Their skill and knowledge will help to ensure the safety of the animals and that all animals are moved and held legally and according to required permits. They also likely have knowledge of local areas and capture techniques that will make the rescue process more effective and rewarding. There is debate among biologists regarding the benefits and limitations of relocating herpetofauna, however research indicates that projects focused on amphibian and reptile translocations have shown increasing success in recent years (Griffiths and Pavajeau 2008; Germano and Bishop 2009; Bodinof 2010).

Receptor sites should be carefully selected and, if necessary, prepared for the wildlife to be released. Appropriate receptor sites depend largely upon the numbers of animals and the species to be released. The likelihood of long-term success of a relocation project is affected by the following criteria.

Location – The best options are sites that are close to the donor site and have good connections to other herpetofauna habitat. Because of the number of known and emerging diseases, care must be taken when considering a site. Potential pathogens should be evaluated when moving animals to new sites. Various veterinary labs and clinics can provide the necessary pathologic analysis to determine if a site is safe.

Habitat – The conditions should be similar to donor site and have features necessary to support all aspects of the relocated animals' life cycles. Prior to any work, a receptor site should be evaluated for quality, structure, and functional similarity. If a site does not meet these criteria it should not be considered.

1-2. Even relatively inconspicuous and easy to create microhabitat such as segments of a tree trunk can provide ideal conditions to support amphibians and reptiles. These salamanders represent the animals observed under just one log. Simple steps such as this can have lasting effects on presence and density of amphibians and reptiles at a site.

Size – Receptor sites should be at least equal if not larger than the donor site.

Season/Timing – Movement of animals should occur during the active season preferably in early spring to maximize the potential for adaptation and establishment. Alternatively if this is not possible, relocation can be done in late summer when conditions are cooler and when there is still sufficient warm weather to allow animals time to acclimate to new conditions and find suitable overwintering sites.

Pre-existing populations – If many animals are to be relocated, the receptor site should not already support those species to be relocated or an evaluation should be conducted to make sure the established population would not experience negative effects as a result of the relocation. If only a few animals are to be relocated, a pre-existing population of the species to be relocated should be present at the receptor site. This will incorporate relocated animals into a viable, breeding population. Pathological assessment is necessary when relocating animals to sites that support the same or similar species. In addition, the existing food chain dynamics should be taken into consideration. Releases should not occur at sites that have an abundance of predators or vulnerable prey populations.

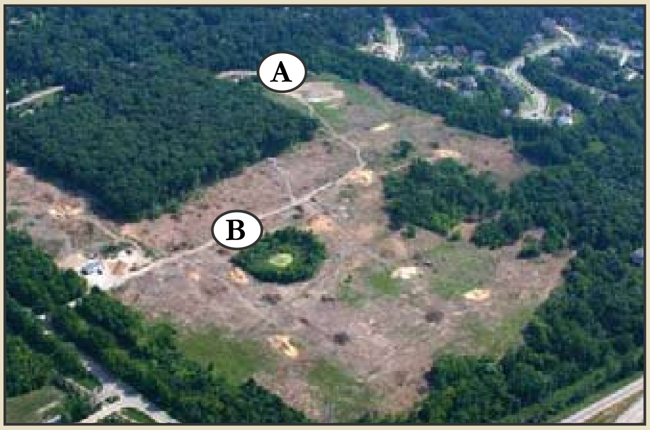
Founder population structure – The age structure, proportion of males and females, and size of a relocated population will contribute to the long-term viability of a population. These aspects should be included in analysis of the likelihood of long-term success.

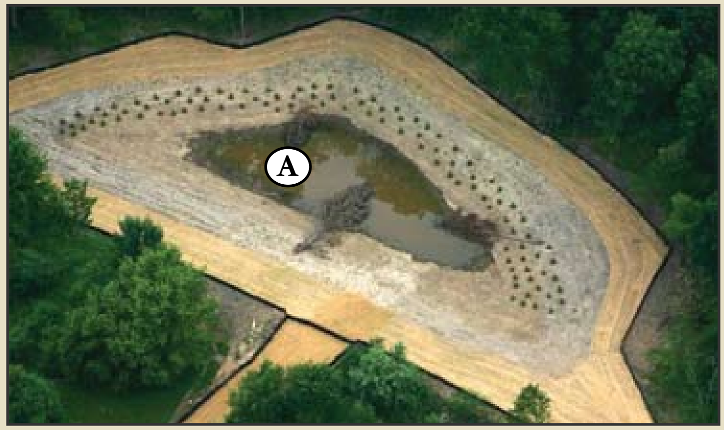
Prevent return to the donor site – Many herpetofauna have a 'homing' instinct and will return to a site after they have been moved (Farnsworth and Seigal 2012). Measures such as the placement of herpetofauna-proof fence may be necessary to contain relocated animals to the receptor site during an adjustment period. In the case of "homing species" additional measures including the use of soft release are necessary. These cases involve a process where animals are partially contained in the new environment before being fully released. Studies have shown increased success when animals are allowed to slowly acclimate to their new environment (Tuberville, Clark et al. 2005; Alberts 2007; Parker 2008; Attum, Farag et al. 2010).

Long-term management – After animals have been relocated, monitoring of the population and possible maintenance of habitat suitability may be necessary, depending on the site.

Multiple receptor sites – Having multiple sites that are linked may be useful in establishing a population. This can foster population connectivity and reduce the chance of a catastrophic event eliminating the entire relocated population.

Skyline High School Herpetofauna Rescue and Relocation





Ann Arbor Public Schools

In 2005, an intensive amphibian and reptile rescue was conducted in Ann Arbor, MI through a partnership between Ann Arbor Public Schools and City of Ann Arbor Natural Area Preservation (NAP). Important to the success of this effort was the involvement of a qualified herpetologist to approve mitigation design and placement, identification of recipient sites, as well as ensure that animals were handled appropriately. Translocation required permits and approval from the state.

Construction of the city's new Skyline High School resulted in the removal of the largest wetland on this site, a 0.5 acre vernal pool known as the "frog pond" (B) to neighbors. Located in an old field adjacent to an oak-hickory forest, this buttonbush dominated vernal wetland supported a diverse community of herpetofauna including at least nine amphibian species. A mitigation (A), designed to replace this wetland as best as possible and serve as a translocation site, was constructed prior to the rescue. Between March and August, approximately 5,000 reptiles and amphibians were moved from the impacted portion of the site to the mitigation, including common species which are often overlooked in conservation efforts. To date, the project has been successful as nearly all amphibian species known from the frog pond currently breed in the mitigation, and none were extirpated from the site.

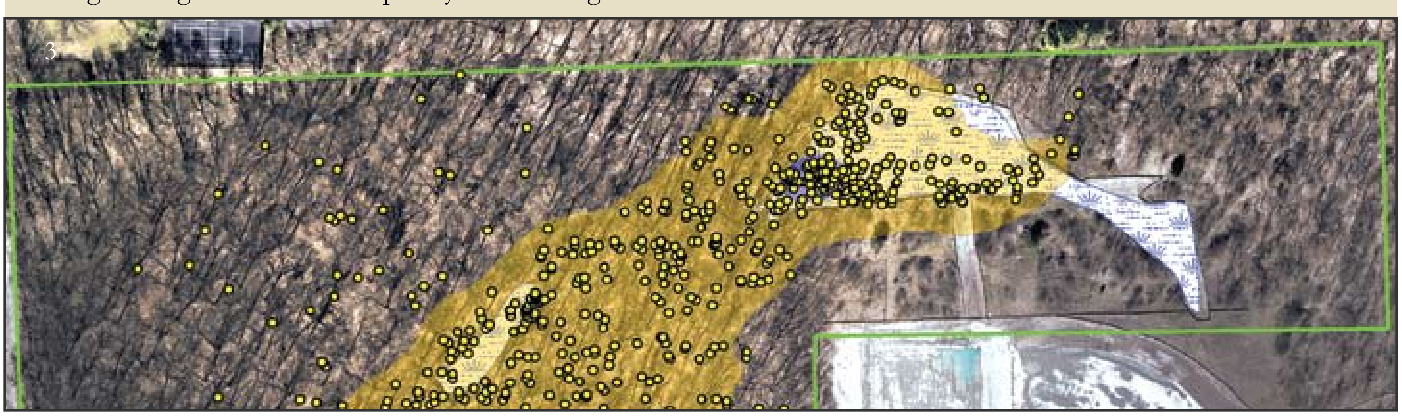
An important first step was installation of a wildlife barrier along the edge of the woodland, separating it and the mitigation from the frog pond to prevent herpetofauna from migrating to the frog pond in early spring. A three foot silt fence was used to maximize the likelihood of keeping amphibians and reptiles within the protected area and out of the construction zone, and was left in place and maintained for four years.

The mitigation was constructed in a section of old field immediately adjacent to the woodland. This allowed the species involved, which use forests for part or much of the year, to easily migrate to the new wetland without having to cross the lawns or roads being built on the rest of the site. Importantly, the mitigation was constructed before the frog pond was destroyed. This allowed for water to be pumped directly from the original wetland to the mitigation, resulting in the translocation and immediate establishment of macroinvertebrates and microscopic life. Mature buttonbushes (*Cephalanthus occidentalis*) were successfully transplanted from the frog pond as well. A seed bank was incidentally transferred along with the water and shrubs, and native plants established quickly. Since the water chemistry and food sources were identical to the source, the mitigation was immediately able to serve as a translocation site for breeding amphibians and their larvae.

Before translocation began, samples were collected and submitted for pathology testing to reduce the risk of disease transmission between the donor and recipient sites. The amphibians and reptiles rescued were released to the mitigated wetland or to the adjacent woodland, which included a much smaller vernal pool that was also a breeding site. Animals were collected from within the frog pond and elsewhere in the construction zone, but

also were removed from along the inside of the fence as they attempted to migrate. Breeding activity was noticed almost immediately among frogs and some salamanders released to the mitigation. Calling from translocated male frogs helped to draw others to the mitigation. Where large numbers of a species were translocated, a portion were released to other suitable habitats within the city. These sites were selected for the occurrence of appropriate habitat and data indicating the historical presence of the species.

Intensive monitoring was conducted for four years following translocation. Coverboards and pitfall traps were used in conjunction with frog call and visual encounter surveys. During the first year after the destruction of the frog pond, a large number of amphibians and reptiles continued to migrate to the barrier fence, attempting to return to their historical breeding site. Over several years migration activity shifted, with frogs and toads abandoning the original migration route completely and thriving in the mitigation. Even Western Chorus Frogs, few of which were translocated due to difficulties stemming from their natural history, slowly recovered. Due to many salamanders being long lived some continued to attempt to migrate toward the frog pond. A decision was made to replace the temporary barrier made of silt fence with a more permanent fence designed to prevent species (especially salamanders) from wandering out of appropriate habitat. Novel projects like Skyline which utilize a well-designed and monitored approach are good examples of how projects can be successful when incorporating baseline data and a planning team with demonstrated expertise.



8. Management Techniques

1. Rare and sensitive species, like Eastern Fox Snake, should be removed from areas being treated with chemicals during a species' active season.

This section provides information for land managers and those maintaining created and natural environments. This information can also be applied by others interested in conducting management that will minimize the negative impacts to herpetofauna. Several common land management techniques are harmful to amphibian and reptile communities, however, alternative strategies and practices and careful timing can be used to reduce negative impacts to herpetofauna and, in some cases, improve habitat quality for amphibians and reptiles.

Chemical Applications and Management

Chemicals are applied purposefully as well as unintentionally to a wide range of landscapes. Fertilizer, herbicide, and pesticide use is common in agricultural and residential areas. Accidental chemical spills or toxic contamination is associated with industrial land use, but due to the need to transport chemicals and the mobility of some chemicals in the environment, these events can even impact wilderness areas. Conventional management of agricultural lands, golf courses, swimming areas, and manicured landscapes often uses chemicals to control pests or weeds and in fertilizer applications (Ingram 1999). Additionally, the introduction of pharmaceutical byproducts into sewage water results in treated waste water discharge that contains hormones and other chemicals (Garric and Ferrari 2005; Gross, Montgomery-Brown et al. 2009). Chemical and hazardous spills and non-point discharge events can introduce harmful chemicals into aquatic and terrestrial biomes that can have public and wildlife health concerns (Andrews and Gibbons 2005). The introduction of chemicals to aquatic and terrestrial ecosystems can alter water chemistry, which can trigger physiological and morphological responses in organisms present (Hopkins, Winne et al. 2005; Brühl, Schmidt et al. 2013).

Pesticides, Nutrients, and Fertilizers

Herbicides, insecticides, pesticides, nutrients, and fertilizers contain chemical compounds that are meant to alter ecosystem function (e.g., kill pests, encourage growth). These chemicals can also have non-target impacts on amphibians and reptiles and should be avoided when used in proximity to these species whenever possible (See Section 3). Glyphosate based herbicides (e.g., Roundup®, Rodeo®, Accord®) that contain surfactants such as POEA (polyethoxylated tallowamine), which are commonly used to treat invasive plants, can severely impact amphibian species and cause population declines (Trumbo 2005; Howe, Berrill et al. 2009; Relyea and Jones 2009).

The fertilizers applied in agricultural fields and residential areas and the nutrients that are sometimes byproducts of industrial and urban areas can be carried via stormwater runoff to aquatic ecosystems, sometimes up to 4,000 meters away (Houlahan and Findlay 2004). Added nutrients, specifically the introduction of phosphorous and nitrogen, can result in eutrophication – the over-enrichment of water with nutrients that can stimulate excessive plant growth - of aquatic systems, which can facilitate shifts in plant and animal communities and decreased water quality (Smith 2003; Howarth, Chan et al. 2011; Chambers, McGoldrick et al. 2012). Such shifts in aquatic macroinvertebrate communities may lead to a rise in parasitic infections and malformations in amphibians (Johnson and Chase 2004). Elevated levels of nitrogen (N) can also result in deformities in amphibians (Rouse et al 1999), and increased levels of nitrogen (N) and phosphorous (P) may reduce hatching success, increase deformity rates, and lower survivorship of frogs and salamanders (De Solla, Pettit et al. 2002).

To reduce chemical applications, an ecosystem approach to management can be developed, which includes biopesticides, biological agents, integrated pest management, and site-specific cropping systems that limit pest influence (Lewis, Van Lenteren et al. 1997). Also, be sure necessary herbicide application permits are obtained, all other pertinent regulations are followed, and anyone who applies herbicides as part of their employment becomes a certified pesticide applicator before herbicide application. In addition, a permit from the Michigan Department of Environmental Quality is usually required to apply herbicide where standing water is present. Several strategies can be used to reduce chemical impacts on the environment. Recommendations to reduce the impact of these chemicals on herpetofauna are described below.

Figure. 6 Spot-treat invasive plants and problematic weeds with quickly degrading, low toxicity herbicides during dry times or in the fall or winter when amphibians and reptiles are hibernating (A).

A 100-400 foot (min.) no-mow buffer adjacent to water bodies will help intercept chemicals in runoff and reduce erosion (B).

Use low toxicity substances inside as well as outside (C).

A diversity of native plant species can encourage a variety of predatory insects and wildlife that will reduce the need for pesticides (D).

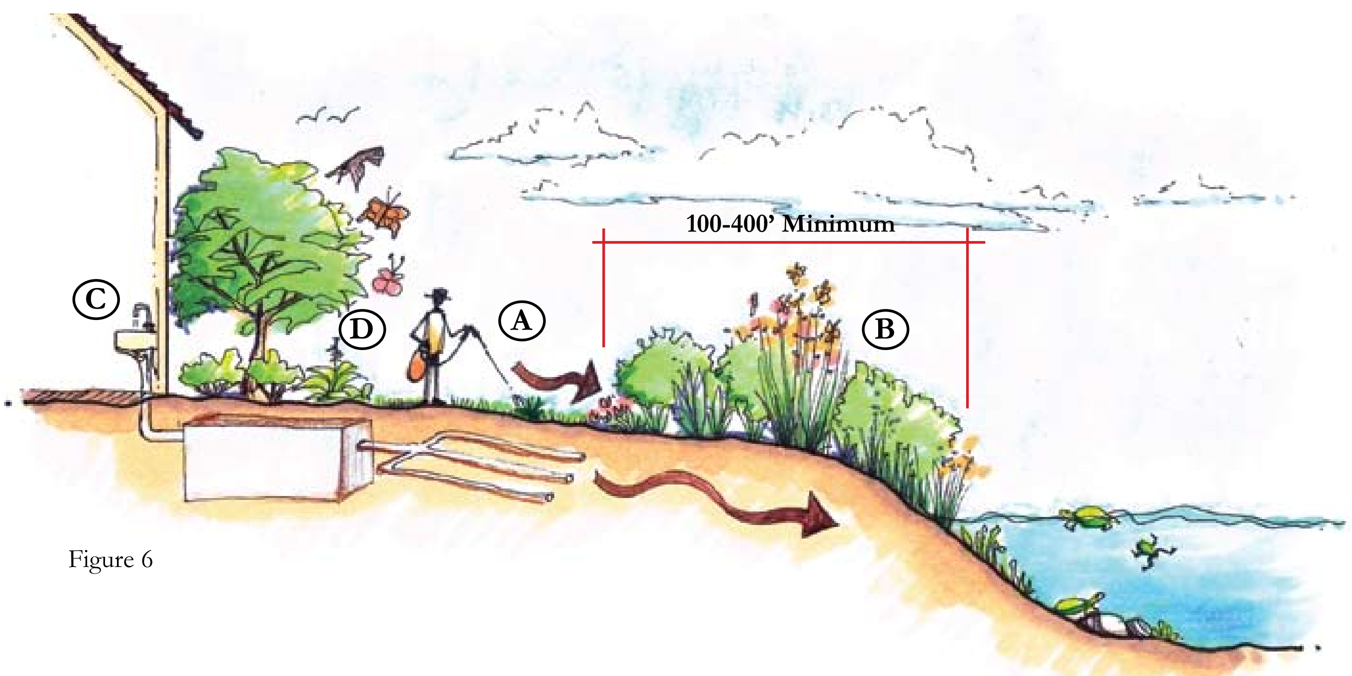


Figure 6

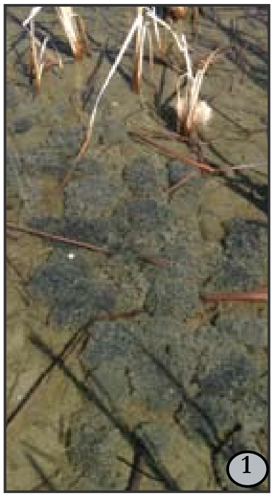
Sean Zera

1-4. Purple cone flower, bee-balm, arrowhead, and cardinal flower (clockwise from upper left) are native plants which can be used in buffer areas to enhance water quality and contribute to amphibian and reptile habitat.

Educate about techniques to reduce chemical, fertilizer, and nutrient inputs - Education about environmental side-effects of chemical applications, non-point sources of chemical contamination - such as stormwater runoff, lawn fertilization, and failing septic systems - and alternative practices can enable people to maintain their lands and homes in an environmentally responsible way. Simple, yet wide-reaching changes, such as reductions in lawn fertilization and the creation of unmowed buffers (or no-mow zones) near water bodies (e.g., ideally 600-1,000 feet from a wetland, but at least 100-150 feet (Semlitsch 1998; Bodie 2001; Semlitsch and Bodie 2003; Calhoun, Miller et al. 2005) can help to reduce impacts of chemicals on herpetofauna. Changes in attitudes can also be as simple as the adoption of a "mixed plant" lawn which reduces the need to treat "weeds" and insects with herbicide and pesticide.

Implement alternative strategies to prevent the need for chemical applications Prevention of weeds and other pests is the best and most effective strategy for eliminating the need for chemical applications. Changing maintenance practices to support a diversity of native plants and those that provide for beneficial insects and bugs (e.g., ladybugs, bees, dragonflies, predacious wasps, and spiders) can result in a diversity of birds, insects, reptiles, and amphibians to keep "pest" (e.g., aphids, slugs) populations in check. Also, use of companion planting (the ability of some plants to repel pests) can help to reduce pest populations. To prevent pest infestations, use barriers such as paper collars around the base of a plant to prevent burrowing pests, fine netting over plants, or sticky traps that deter and capture pests. Cutting, pulling, or digging up pest plants are often good alternatives to herbicide. Additionally, several amphibians and reptiles eat garden pests (e.g.., insects and rodents) and maintaining habitat that support these species can help control pest populations.

Use vegetated buffer zones between areas of chemical application and aquatic systems - Vegetated buffers, such as rain gardens, planted swales, and unmowed areas, can intercept chemical runoff. Once stormwater runoff is intercepted, chemicals can be adsorbed to soil particles, intercepted by plant roots, and degraded by soil microbes (Pivetz 2001; Nannipieri, Ascher et al. 2003). Some plant species also sequester chemicals and convert them into inert compounds, thus these plants may be beneficial to establish in these areas (Hinchman, Negri et al. 1996; Adesodun, Atayese et al. 2010; Díaz, Tapia et al. 2011; Murphy and Coats 2011). Wider buffer zones typically result in lower concentrations of herbicides entering the water. These lower chemical concentrations in the water bodies on which common and threatened amphibians and reptiles rely



1-3. Spraying herbicide on *Phragmites* in fall when larvae have completed metamorphosis and animals have begun hibernation reduces direct exposure of species like Northern Leopard Frog (1), Eastern Gray Treefrog (2), and Midland Painted Turtle (3) to herbicide.

result in healthier herpetofaunal communities. When used in close proximity to streams, a buffer zone, ideally 600-1,000 feet but at least 100-150 feet, with no chemical application, should be established to protect amphibian and reptile communities (Calhoun and Demaynadier 2004).

Apply chemicals during late summer and fall - If chemicals must be applied, application should be carefully timed to reduce contact with herpetofauna and other sensitive wildlife. Conduct management during times of the year when resident animals may not be present at the treatment location (i.e., treating a wetland when animals have seasonally migrated to upland areas) or when animals may be inactive (i.e., during times when they are burrowed in substrate, estivating, hibernating). Avoid application during times when amphibian larvae are present. Herbicides applied during times when amphibian eggs and larvae are not present will help to reduce negative side-effects to herpetofauna. However, tadpoles of frog species such as Bullfrogs (*Rana catesbeiana*) and Green Frogs (*Rana clamitans melanota*) overwinter and are still present as tadpoles in late summer and fall (Harding 1997). Applying chemical in late summer and fall application will reduce exposure and potential negative affects to herpetofauna.

Apply chemicals in upland areas during "dry-spells" - The length of time between chemical applications and the next rainfall event affects the amount of chemicals entering nearby water bodies (Battaglin, Rice et al. 2009). To reduce the concentration of chemicals being washed into nearby water sources, the application of herbicides, insecticides, and pesticides in upland systems should be timed for the beginning of a 'dry-spell' when rain is not predicted. Reputable weather prediction sources, such as the National Oceanic and Atmospheric Administration (NOAA) National Weather Service, should be consulted to determine when drier conditions occur.

Apply quickly degrading chemicals during hibernation or estivation – Generally, herpetofauna are inactive when the temperatures are quite cold or very hot. Application of chemicals is likely most suitable in early spring prior to emergence, during mid- to late summer when herpetofauna is estivating (Michigan Natural Feature Inventory 2012) or have moved to upland areas, or in late fall when herpetofauna has entered hibernacula (Michigan Natural Feature Inventory 2012). Be aware that some species do not follow these general patterns (e.g., salamanders are generally active in early spring). When selecting chemicals, refer to the information labeled on the product to determine how quickly it degrades. It is also important to keep in mind that degradation can vary based on weather and soil conditions.

Apply persistent chemicals earlier in the year, when possible – Early season application is preferable to late season applications because warmer temperatures increase soil microbial activity, which can increase the rate at which herbicides degrade (Helander, Saloniemi et al. 2012). Some herbicides, such as glyphosate, can persist in the environment for at least 4 months during cool temperatures (Edwards, Triplett et al. 1980), meaning that even when applied later in the season, herbicides will still be present in the spring when egg and larval abundance is highest. Other herbicides, such as triclopyr, can be detected in nearby aquatic systems up to 13 months after treatment (Battaglin, Rice et al. 2009). For chemicals with extended persistence, extreme care and consideration should be used to determine the necessity of use.

1. Using a hand-sprayer to spot-treat individual plants with herbicide is labor intensive but uses less herbicide. This reduces the cost of herbicide and the impacts on amphibians and reptiles.

Exclude or relocate rare species during times of greatest risk - If any rare species occur within a treatment area, a barrier fence to reduce movement into treatment areas during application should be undertaken. The temporary relocation of the animals from the treatment area should be considered.

Consider use of alternative, low-toxicity substances and biocontrols – Several alternative products - essential oils, soaps, low toxicity pesticides, surfactant-free herbicides - are available that reduce potential ecological degradation and reduce impact to herpetofauna communities. Direct contact with amphibians and reptiles should still be limited to reduce impacts to these sensitive communities; however, these substances generally do not persist for long periods of time and can be less toxic in the long-term. Use of biocontrols – other organisms to control pests – can also be an alternative to chemicals; however, extensive research and testing is necessary to determine the full range of consequences of introducing one species to control another. Although still potent chemicals, use of surfactant-free glyphosate-based herbicides (e.g., Accord, Rodeo) may reduce mortality of tadpoles and juvenile frogs that is commonly associated with use of glyphosate-based herbicides that contain surfactants (Trumbo 2005; Howe, Berrill et al. 2009; Relyea and Jones 2009). Always review if a product has been evaluated for amphibians and reptiles. Consult a professional herpetologist or certified wildlife biologist for recommendations.

2. This novel wetland system is comprised of a treatment wetland that mitigates the pH and temperature of stormwater runoff. The water is then outlet to this larger wetland area where herpetofauna and other wildlife thrive. Habitat features including projected nesting sites and basking logs were also placed to maximize site functionality.

Intercept runoff of chemicals before they reach aquatic systems - In areas where minimization of chemical application and strategic timing are not options or where particularly hazardous chemicals are applied, specifically designed bioremediation systems may be implemented. These systems work by retaining and treating contaminated runoff. Soil-based and biobed (tank enclosed) systems can degrade heavy loads of pesticides to acceptably low concentrations for discharge into groundwater and surface water systems (Rose, Basford et al. 2003) and prevent chemicals and pathogens from entering ground water. These systems generally consist of a multi-tank arrangement, including a tank enclosed pit in the ground, which contains a mixture of straw, soil and compost where the majority of treatment occurs (ADAS 2006). These systems are inexpensive and are able to degrade chemicals (Boivin and Guine 2011).

Glenn Barrett

1. When applying chemicals near sensitive habitat, measures should be taken to reduce harm to amphibians and reptiles.

2. Chemicals applied throughout the landscape along with residential and commercial debris often accumulate in nearby wetlands like the one this Bullfrog is occupying.

Apply chemicals sparingly – Only using the specific amount of chemicals to obtain a desired effect (pest control, plant growth) can save money and reduce ecological impacts by applying the smallest amount necessary. Application of herbicides through spot treatments – using an applicator (e.g., hand sprayer, sponge, glove, etc.)to apply herbicide to individual plants – may involve more labor compared to larger spray treatments using machinery but also uses less herbicide. Spot treatment targets a specific plant and reduces side effects to non-target organisms. Broadcast application should be avoided, as it indiscriminately affects target and non-target organisms over application and airborne drift is difficult to avoid. This method is not always possible as the type of invasive plant may require broadcast application to effectively eradicate. When chemical application is necessary, time applications to minimize impacts on species known or suspected to occur at a site. Use soil testing and plant nutrient uptake (i.e., integrated nutrient management) to determine how much fertilizer plants will be able to utilize. Avoiding over-application of fertilizers results in healthier plants, monetary savings, and fewer ecological impacts.

Identify and prevent non-point nutrient inputs – Industry, urban runoff, and residential runoff can input substantial nutrient loads. By following general principles of stormwater management (i.e., reduce volume, increase time, and increase quality before reaching surface waters), the concentration of nutrients in these sources can be significantly decreased.

Oil and Chemical Spill Response

Post-spill crude oil exposure has been related to lower egg fertility, hatching success, and hatchling abnormalities in Snapping Turtles and Painted Turtles (Bell 2005). Oil spills can cause loss or displacement of aquatic turtles at a site (Luiselli and Akani 2003) and chemical burns, sloughing of scutes, and respiratory problems can also result (personal observation). Preliminary data also indicates that turtles captured at a spill site and later released a large distance from the site may attempt to return to their original home range. To prevent any further harm due to exposure, turtles should not be released in the contiguous drainage unless their original capture sites are considered pollutant free and suitable for occupancy. When dealing with long-lived species such as turtles, it is important to address these issues as populations can be negatively affected by the loss of relatively few individuals.

1. Chemical spills can result in the direct loss of animals. Exposure can compromise immune systems as well as alter thermoregulation opportunities for reptiles.

2. It is critical to document long-term behavior and survival of animals affected by a chemical spill. This can be done through tagging animals and performing mark-recapture studies.

Timely Response - Rehabilitation of oil-exposed wildlife is time sensitive with the greatest results occurring from prompt action (Saba and Spotila 2003). The faster post-spill response and rehabilitation action is taken, the more individual animals may be rehabilitated and re-released into a restored or healthy habitat. Rescue of herpetofauna should be conducted in a humane and timely manner.

Provide appropriate conditions for recovering herpetofauna - Decontamination and rehabilitation facilities should provide appropriate shelter, controlled temperatures, high-quality food, clean water, and levels of cleanliness standard in zoological and animal husbandry settings.

Get professional assistance - A professional herpetologist and a qualified veterinarian or veterinary technician with expertise and experience with amphibians and reptiles should be contacted for assistance in planning and conducting herpetofauna rescue efforts.

Metal and Toxic Contamination

Industrial and municipal wastewater and other brownfield/contaminated sites can contain metals such as nickel (Ni), tin (Sn), zinc (Zn), cadmium (Cd), and selenium (Se). These metals can inhibit physiological response (Hopkins, Snodgrass et al. 2003), lead to deformities in amphibians (Rowe, Kinney et al. 1996; Rowe, Kinney et al. 1998), pose toxic effects to aquatic turtles, and accumulate in turtle eggs, which may lead to reduced hatchling success and life function (Tryfonas, Tucker et al. 2005). Because of the variety of contaminants and the range of contamination levels at each site, a site-specific decontamination plan is necessary in most situations. For more information, visit the MDEQ or EPA websites.

Stormwater Management and Soil Erosion Control

Land management and development influences what happens to precipitation that runs off a landscape as stormwater and can affect the rate of erosion. Several problems, such as downstream flooding, bank erosion,, increased sedimentation and turbidity, and associated contamination can result from improper stormwater management leading to impacts on water-dependent herpetofauna (Booth and C.R. 1997; United States Environmental Protection Agency 1999; Public Sector Consultants 2002; Murray and Hoing 2004; Massal, Snodgrass et al. 2007). These impacts can degrade amphibian and reptile use through fragmentation, and destruction of plant communities, and change the distribution of habitat features that support specific species (See Section 3).

1. The biodegradable natural fiber mesh used at the top of the slope prevents erosion and does not entangle amphibians, reptiles, and other wildlife. However, the lower portion of the slope is eroding and could benefit from erosion blankets.

2. Silt fences can be used to prevent herpetofauna from entering a construction site.

Stormwater management and soil erosion control (SEC) should be an essential part of any construction project and is required by the DEQ for activities that disturb one or more acres of land. Visit the DEQ Soil Erosion and Construction Stormwater webpage for more information on these requirements and the Michigan Department of Transportation (MDOT) SESC Manual for detailed information on commonly used techniques. Techniques to manage stormwater and control erosion help improve the quality of stormwater that enters surface and ground water sources as well as enhance and maintain the health of herpetofauna and other wildlife communities.

Create a stormwater management and erosion control plan – Develop a comprehensive plan that complies with current Michigan DEQ regulations and takes into account the presence of local herpetofauna. The planning stage is the optimal time to assess which stormwater management and SEC measures will be used and the potential benefits and risks these measures pose to herpetofauna. Consider techniques that create wildlife habitat and provide long-term stormwater management and erosion control.

Place construction and soil erosion fences to exclude herpetofauna from construction sites - Fences help deter herpetofauna from moving onto a construction site and should be placed early in construction (Farnsworth and Seigal 2012). Include excluder devices into silt fences to ensure amphibians and reptiles can move out of a construction site once fences have been placed. These devices or fence configurations act as one-way doors for herpetofauna to leave a construction site. Another option is to stagger silt fences every 20 feet so that erosion will be intercepted, but herpetofauna can pass. Erosion control berms made of compost and/or mulch should be used in sensitive areas (e.g., near vernal pools) where barriers to herpetofauna movement would be highly detrimental to population stability.

1

2

Use biodegradable, loosely woven, natural-fiber erosion control matting - These natural fiber products biodegrade over time and do not entangle wildlife. Although SEC measures are put in place to help maintain healthy ecosystems, conventional SEC matting/blankets contain plastic monofilament mesh, which does not readily break down and can entangle snakes and other wildlife (Barton and Kinkead 2005; Walley, King et al. 2005; Kapfer and Paloski 2011). Once entangled, a snake will thrash and twist in attempt to free itself; however, this only ensnares the snake further and often causes fatal cuts. A snake in this situation will quickly die as it is also exposed to the

1. This Eastern Garter Snake became entangled in synthetic erosion control mesh and as a result, died. Use of natural wildlife friendly products is preferred.

2. Reuse of concrete or rip-rap can help prevent erosion and create basking and cover areas for species like Eastern Fox Snake. Telemetry research of this species in Michigan has shown >90% of occurrences are associated with rocky shoreline habitat.

3. Smooth metal seawalls restrict movement of amphibians and reptiles between water and land by serving as physical barriers and should be avoided.

elements and is virtually defenseless against predators. This material can remain intact on site for more than seven years and can cause significant mortality within local snake populations: nearly 50 Northern Water Snakes (*Nerodia sipedon sipedon*) were tangled in the SEC mats at a local road construction project in Vermont (Slesar 2009).

Remove silt fence as soon as slopes have been stabilized - Silt fence can also create a barrier for herpetofauna (Kittredge Jr and Parker 1995; Calhoun, Miller et al. 2005; Glista, DeVault et al. 2009) and can reduce connectivity when it remains on the landscape after a construction project is completed. Owners and owner representatives may choose to hold bond until SEC measures have been removed. This will prevent herpetofauna from unnecessarily being excluded from an area after construction is complete.

Reduce impermeable surfaces – Where possible, impermeable surfaces should be removed or replaced with permeable materials (e.g., vegetation, permeable paving). These permeable materials allow stormwater to be absorbed and to replenish groundwater and surface waters via soil infiltration. The result is higher quality waters, which are healthier for humans and wildlife. A reduction in impermeable surfaces can reduce costs initially by simply reducing the area being covered. Although permeable pavement installations are similar to traditional paving materials (e.g., concrete and asphalt) in installation costs (i.e., $3-$15 per square foot; Foster et al 2011), it can contribute to long-term monetary savings. Permeable paving in urban areas can reduce the need for additional stormwater management infrastructure and salt application (Wise, Braden et al. 2010). This method can also reduce human health costs associated with inadequately managed stormwater (Gaffield 2003), and avoid property and infrastructure flood damage (Foster, Lowe et al. 2011). Substituting areas with native vegetation for pavement can also reduce long-term maintenance costs compared to non-native varieties, as native plants that are appropriate for the site condition require little care beyond establishment.

Avoid use of bank armoring – Bank and shoreline stabilization through vegetation establishment provides better structure for the support of herpetofauna. It may be possible to incorporate sandy nesting areas, areas of dense vegetation, or woody materials that would provide specific habitat requirements for several species. However, when the use of seawalls or other bank armoring materials is necessary, an attempt to avoid vertical structures and create a gradual connection between the water and land should be made. This may involve the addition of rocks, rip-rap material or logs on the water-side of a wall. Adding these structures can allow snakes, turtles, and amphibians to climb out of the water and bask, feed, or take cover along the armored wall.

1. Detention ponds allow stormwater to be filtered while providing habitat for amphibians and reptiles. Caution should be made regarding salt inputs from roads as over time increase in salinity can degrade habitat.

Stabilize slopes with native plants instead of turf grass to reduce long-term erosion - Often turf grass is planted as a means to stabilize a slope or to reduce long-term erosion. Turf grass is typically mowed and has greatly reduced root penetration compared with native vegetation (United States Environmental Protection Agency 2012). Root depth is directly related to the amount of water the vegetation allows the soil to absorb during a precipitation event, and thus related to the ability of the vegetation to prevent erosion. Turf grass maintained as lawn has limited value for native wildlife and provides little cover or food for herpetofauna. Unfortunately, turf grass seed mixtures typically contain non-native varieties, and require large quantities of water to maintain a lush, green appearance. These water inputs often times are from potable water sources (Kjelgren, Ruppi et al. 2000) or draw from local water tables during the summer when water levels are lower. Seeding or planting native plant species can help contribute to herpetofauna habitat by stabilizing slopes with plants having longer roots and by providing a diversity of niches (Ingram 1999). Native plants often require less water and maintenance, which can reduce pressure on water supplies and maintenance costs.

Retain and detain stormwater using detention and retention ponds, constructed wetlands, filter strips, swales, rain gardens, and green roofs – Where possible, construct or maintain vegetated areas where stormwater runoff can be directed. Detention and retention ponds vegetated with native plants, small constructed wetlands, planted filter strips, vegetated and bio-retention swales, rain gardens, and green roofs improve water quality (Friedlich, Lucas et al. 2007; Baltrenas and Kazlauskiene 2009). These features allow water from precipitation and runoff to be absorbed by plants and percolate slowly through the soil, thus reducing the amount of runoff entering surface waters, filtering the water, and gradually releasing water from melt and precipitation events into surface waters. This can reduce flooding and erosion, as well as ensure that the water entering the surface waters will be cooler, cleaner, and provide higher quality amphibian and reptile habitat.

2. Excess nutrients in runoff from agricultural areas can contribute to algal growth and poor habitat conditions for aquatic amphibians and reptiles.

Amphibians and reptiles as well as other wildlife can benefit from the creation of stormwater retention and detention features in sites that are connected to other areas of habitat. Place structures for nesting, basking, and hibernation within or adjacent to these features to avoid the creation of an ecological "sink" where herpetofauna may be drawn to nest, but are not able to successfully reproduce or carry out their life functions. Stormwater retention and detention features that function as natural systems with connectivity to other habitat areas can improve habitat functionality and often require less maintenance than manicured landscape areas.

Rain garden or vegetated or bio-retention swale – A vegetated, shallow ditch designed to move water and sediment slowly to increase infiltration. Side slopes should be less than 1:4. Common uses are around parking lots and along roads. Rain gardens are vegetated depressions that temporarily hold standing water and allow for water to infiltrate and pollutants to be filtered by the soil and plants. The water is directed to groundwater because of the permeable soils of this feature.

Retention and detention ponds – These ponds intercept surface runoff before it reaches an adjacent water body. Retention ponds can also be used to control flooding and permanently hold water. Detention ponds temporarily hold water and slowly release water to nearby water bodies. In some cases, the establishment of native vegetation may be beneficial in preventing erosion and increasing wildlife habitat and biodiversity.

Sean Zera

Sean Zera

Green roof or living roof – A vegetated roof with a variable depth of planting media. The vegetation and soil intercept rain and reduce the stormwater runoff from a roof.

Isolate detention and retention features that mitigate heavily polluted runoff – Pollution from roadways, chemicals applied to the landscape, contaminant spills, and other sources of pollution on the landscape are transported by stormwater runoff to nearby water bodies. Construction of detention and retention features can help filter and contain pollutants to prevent the contamination of natural water bodies. However, herpetofauna or other wildlife that travel to these polluted water bodies will be exposed to these contaminants through eating contaminated food sources and absorption through their skin (See Section 3 for a range of impacts of pollution on amphibians and reptiles). Locate detention and retention features that collect pollution in areas without hydrologic connectivity with sensitive wetlands. Some researchers recommend that retention and detention ponds be located at least 750 feet away from vernal pools or other sensitive wetland areas (Calhoun and Klemens 2002). Also, high levels of pollution may threaten the viability of herpetofauna that immigrate to a retention or detention feature and may warrant the creation of a barrier (e.g., permanent silt fence with one-way excluder gates) around the feature to reduce use by sensitive herpetofauna. These precautions will reduce the risk that these areas will become biological traps. Additionally, use of natural wetlands as retention or detention areas for potentially polluted stormwater runoff is not recommended.

If heavy metals (e.g., lead, chromium, cadmium) or other substances that do not readily degrade (e.g., arsenic) are present in runoff entering the area of filtration, the soil will accumulate these pollutants (Davis 2007; Muthanna, Viklander et al. 2007) and may need to be removed and replaced if the concentration reaches an unacceptable level or becomes toxic.

1-2. Woody debris from forest management can be repurposed as cover and basking objects for amphibians and reptiles.

1

Separate storm and sanitary sewer systems – Many urban areas have combined storm and sanitary sewers, which under typical circumstances drain to a water treatment facility. During severe – and sometimes also small - storm events, the overflow from these systems results in raw sewage entering rivers (United States Environmental Protection Agency 1999). The increase in thermal, chemical, and biological pollutants can degrade habitat quality for herpetofauna.

Balance withdrawals and discharge from water reservoirs – Water being withdrawn for irrigation, drinking water, industrial use, etc., should be balanced by water inputs and also consider the seasonal fluctuations in water level required by herpetofauna and other wildlife. Maintenance of the water level will avoid drawdowns and ensure the water necessary for herpetofauna at critical life stages (i.e., eggs, larvae, breeding adults).

Forest Management

Common forestry management practices can be important in maintaining healthy forest ecosystems however they involve activities that can also degrade habitat structure and be detrimental to amphibians and reptiles (Hansen, Spies et al. 1991; DeGregorio 2008). Machinery can cause direct mortality to forest herpetofauna such as Wood Turtles and Eastern Box Turtles (Erb and Jones 2011) as well as create pools in ruts, pits, and behind soil ridges, which block drainage. These created pools may provide water for breeding but dry too quickly to support metamorphosis of amphibian larvae (Calhoun and Demaynadier 2004). Tree removal in upland areas can result in less canopy cover, reduced woody material on the forest floor, and alterations in hydroperiod of forested wetlands (Calhoun and Demaynadier 2004). Since forest dwelling amphibians respond to these habitat characteristics (Feder 1983;

2

1. Maintaining canopy cover through various harvest techniques can help salamander populations persist. It is important to maintain woody debris as microhabitat during forestry management.

DeMaynadier and Hunter 1995; Demaynadier and Jr. 1998; DeMaynadier and Hunter Jr 1999; DiMauro and Hunter 2002) their populations can be significantly reduced as a result of these practices. Vernal pools – seasonal forest pools – are only seasonally inundated or may hold water year-round except in times of severe drought. Vernal pools that hold water year-round are shallow and freeze solid and/or become anoxic during the winter and kill off fish. Vernal pools are particularly sensitive to disturbance and are critical to the survival of several amphibian species that do not successfully reproduce or have low species richness in the presence of fish (Figiel Jr and Semlitsch 1990; Hecnar 1997; Snodgrass, Bryan et al. 2000).

Strategic planning of operations can lessen the impact forestry has on herpetofauna directly and indirectly through reduction of sediment and erosion near rivers, minimization of disturbances near vernal pools, and maintenance of amphibian and reptile habitat components (Dupuis and Steventon 1999). The MDNR manages state forest lands using an ecosystem-based approach (Michigan Department of Natural Resources 2013), and it is our intent that the following recommendations help to support this aim.

Vehicle Use

Use tracked vehicles – Tracked vehicles distribute the weight of the equipment over the surface of the entire track, which lowers the pressure applied to the ground and decreases soil compaction compared to wheeled vehicles (Bol 2007). This can minimize short and long-term impacts to the landscape and better maintain habitat quality for wildlife.

2. Ruts created by heavy equipment that collect water may attract breeding amphibians, but will likely dry out before the eggs and larvae metamorphose. These areas can serve as a sink for wildlife.

Use construction mats – Large landscape timbers connected together to form 10'x10' mats can be placed in a temporary road formation to convey construction equipment over wetlands while minimizing compaction of soil. Mat roads reduce the creation of ruts in sensitive wetland areas and maintain the quality of herpetofauna habitat throughout forested areas. Although these mats reduce long-term impacts to forest conditions, if not cleaned between uses they can be vectors for disease and introduce invasive plant species into areas that are currently not infested.

Clean equipment after use - Equipment that is not cleaned between uses at sites can introduce invasive plant seeds and roots from other sites. Although permits may not require equipment to be cleaned between uses at sites, this practice is advisable to maintain the ecological integrity of a site and to reduce impact to valuable herpetofauna habitat.

A timeline of amphibian and reptile and forest management actions. Consider which species are likely present and their life stages when planning management actions.

Reduce use of vehicles off-road – Restricting vehicle traffic (machinery and all-terrain vehicles – ATVs) to roads will reduce the damage to wildlife habitat and reduce direct herpetofauna mortality by crushing or collision in forested areas (Congdon and Keinath 2006). Tire ruts can hold water and may appear as suitable nesting areas for vernal pool breeding amphibians but may not hold water long enough for eggs to metamorphose into adults (Calhoun and Demaynadier 2004). If these ruts do not exist, adults will likely continue onward to a vernal pool with a suitable hydroperiod to support larval amphibians. Reducing habitat disturbances from vehicle traffic can also reduce the introduction of invasive plant and animal species.

Season	Soil Condition	Amphibian and Reptile Actions	Management Actions
Spring	Saturated	Migrations between uplands and wetlands. Breeding in wetlands.	Minimize harvest or machinery use. Place branches over roads in early spring.
Summer	Dry	Adult movements into uplands to forage.	Minimize harvest or machinery use. Survey areas on foot for herpetofauna.
Fall	Partially Saturated	Juveniles migrate upland and some overwinter in pools. Begin hibernation.	Begin harvest with light machinery in late fall.
Winter	Frozen	Hibernation underground and in areas with heavy litter layer.	Use equipment in least sensitive areas and restrict movements to roads as much as possible.

Conduct excavation, fill, and grading during warm weather – Amphibians and reptiles are active during warmer seasons and are less likely to be burrowed in the soil. They are better able to escape disturbance during warm weather; however, most amphibians and reptiles are relatively slow-moving and an effort to relocate individuals from sensitive or at-risk populations may be necessary to avoid significant mortalities.

1. Earthwork conducted during warm weather gives slow-moving amphibians and reptiles a chance to evacuate a disturbed area. Work outwards from a single point to better allow these animals to escape. When possible conduct a rescue and relocation to avoid mortality especially with rare and declining species.

2. Eastern Box Turtles are susceptible to crushing by heavy equipment.

3. Water gathering in the tire tracks indicates that this road was placed in too wet of an area. This artificial pool may attract breeding amphibians and trap larvae.

Use heavy equipment or off-road vehicles when the ground is frozen - Forest-dwelling amphibians and reptiles, such as Eastern Box Turtles, are particularly susceptible to crushing from motorized vehicles during timber harvest and clearing from ground thaw until ground freeze. With the onset of colder weather, these animals hibernate underground. The frozen ground is better able to support heavy machinery and vehicles without rutting the soil and crushing herpetofauna (Bol 2007). Depending on the extent of vehicle use and compaction caused by the equipment, hibernating animals may also be crushed during the winter. Using heavy machinery that uses treads instead of tires and working at the coldest times of the year when ice roads can be used can reduce soil compaction and crushing of animals burrowed in the ground, but avoidance of high-quality habitat is the best option. Restrict motorized vehicle use on wood roads, skid roads, and staging areas to times of year when the ground is frozen (i.e., December 1st to March 30th).

Place logging roads in low impact areas - The creation of any road will result in direct road mortality as well as habitat fragmentation and degradation. Logging roads should be located in areas not likely to impact forested wetlands, vernal pools, or hydrologic processes. Road placement should also take into consideration species-specific habitat requirements, such as Wood Turtles nesting areas, and avoid bisecting other valuable habitat areas.

Seasonally close roads and place structure over roads – Some forest-dwelling amphibians, such as salamanders and Wood Frogs, seasonally migrate between wetland and upland areas. These migrations typically occur during some of the first warm, rainy spring nights of the year and closing roads in key migration areas during these times can reduce mortality of amphibians (Timm, McGarigal et al. 2007). This management practice is utilized successfully in Shawnee National Forest in southern Illinois. Additionally, closing roads during the rainy times in spring can reduce compaction of soil, erosion, and creation of ruts which can fill with water and become an ecological trap for amphibians looking for a place to breed. These ruts will likely dry out before the eggs metamorphose and reduce the number of surviving amphibian offspring. Boughs and branches should be placed over access roads that are not actively being used. This cover can help to reduce the impact of the road as a physical barrier to herpetofauna by providing suitable habitat conditions to facilitate their movement across the landscape.

1. Branches placed across inactive seasonal roads can provide refugia and necessary microclimate to facilitate movement of herpetofauna across the landscape.

Harvest Techniques

Harvest during late fall to early winter – Harvest and general forest management should occur from late fall to early winter or when temperatures are cold and animals are inactive. Also, operating heavy machinery on frozen ground reduces crushing animals and disturbances (e.g., reduces soil compaction and rutting), which would create unsuitable conditions for herpetofauna like salamanders that burrow into the soft soil and litter layer of the forest floor.

Consider various tree harvest techniques – Using shelterwood (removing taller trees while maintaining shorter trees to protect seedlings and the forest floor), group selection (small-scale clearcut), or single-tree selection (removal of individual trees) cuts can help maintain various levels of canopy and understory cover, which are beneficial for herpetofauna while meeting forest management objectives. These techniques may reduce the relative abundance of salamanders, but since these techniques maintain more canopy cover than clearcuts or seed tree cuts, they may better facilitate the persistence of salamander populations (Brooks 1999; Harpole and Haas 1999). Timing of tree removal for winter when the ground is frozen and use of smaller equipment can minimize habitat disturbance. By only removing some of the trees, canopy cover and understory cover can be maintained which can help preserve landscape connectivity for some salamander species.

2. To avoid causing harm to the herpetofauna occupying a site, various tree harvesting techniques including selective cutting should be utilized. Timing activities to minimize harm to herpetofauna is encouraged.

Avoid clearcutting large areas - Strategic clearcuts and seed tree cuts (cutting all trees except a select few to remain to provide seeds for forest regeneration) can be used to create habitat features for some wildlife (i.e., snowshoe hare, Kirtland's warbler) and can be conducted in accord with regard for biodiversity (Conroy, Gysel et al. 1979). However, clearcutting can be detrimental to Michigan amphibians, specifically salamander communities, which have been shown to have significant reductions in abundance compared to non-clearcut control sites (DeMaynadier and Hunter 1995; Semlitsch, Todd et al. 2009) and can take decades to rebound (Petranka, Eldridge et al. 1993). Seed tree cuts also reduce most canopy cover, which can reduce landscape connectivity and relative abundance for salamanders (Harpole and Haas 1999).

Consider the wildlife habitat value of the resulting landscape pattern – When conducting forest management, whether clearcutting or simply removing a few select trees, fragmentation and resulting landscape pattern should be considered to minimize negative effects on amphibians and reptiles that rely on forest (i.e., those that use forest surrounding vernal pools) (Hansen, Spies et al. 1991). Maintaining corridors of high-quality upland habitat among wetlands can help to maintain landscape connectivity for amphibians and reptiles. Also, tree community types contribute various levels of herpetofauna habitat and landscape connectivity (Degraaf and Rudis 1990), and several species of Michigan herpetofauna rely on conditions provided by hardwood stands (e.g., oak-hickory and beach-maple) (Harding 1997; Mitchell, Rinehart et al. 1997). Removal of softwoods, such as poplars, contribute to herpetofauna habitat to a lesser degree and their removal will likely have little impact on herpetofauna.

Use coarse woody debris to create simple habitat structures - It is not uncommon for woody debris to be cleared from an area after timber harvest, thus reducing ground cover and shade necessary for forest floor amphibians and reptiles. To provide structure and conditions beneficial for salamanders, frogs, snakes, and the Eastern Box Turtle, some snags, fallen trees, and treetops should be left in clearcut areas (Hansen, Spies et al. 1991; Ash 1997; Bol 2007). For details of these structures see Section 5. In addition, fallen logs may already provide vital structure for wildlife and should not be disturbed.

Maintain the litter layer and understory vegetation to provide appropriate microclimate conditions – Understory vegetation and the litter layer of fallen leaves and decomposing materials on the forest floor helps to maintain moisture levels and cool temperatures needed to support a diversity of herpetofauna (Dupuis, Smith et al. 1995; Baldwin, Calhoun et al. 2006; Semlitsch, Todd et al. 2009).

1-2. Vernal pools typically hold water in the spring and fall, but may dry completely for part of the year. These habitats are obligate breeding sites for a number of amphibians and important seasonal habitat for many species of herpetofauna and other wildlife.

Rotate cuts – Rotating cutting to allow 20-70 years between harvests, depending on flora and fauna present, will likely allow for the re-establishment of herpetofauna populations after a cut (Petranka et al. 1993; Ash 1997). The presence of an established population will also provide individuals to colonize other nearby clearcut areas that regenerate and provide suitable herpetofauna habitat. Cuts should also be rotated in a manner to maintain forested corridors between wetlands and to avoid cutting near vernal pools and other forested wetlands.

Vernal Pool Protection and Conservation

Vernal pools provide specialized breeding habitat for several sensitive amphibians that take advantage of the low-disturbance and predatory fish-free conditions. These wetlands also act as stepping stones through uplands for wetland-dependent wildlife and provide refuge for amphibians and reptiles during migration. Several salamanders and frogs use vernal pools for breeding and larval life stages, however, most species spend most of their lives in the surrounding upland areas (Semlitsch 1981; Vasconcelos and Calhoun 2004; Petranka, Harp

1-5. Northern Spring Peeper, Spotted Salamander, Blue-spotted Salamander, Blanding's Turtle, and Wood Frog are some of the species that rely on vernal pools.

et al. 2007; Holman 2012). Many of these amphibians will return to the same vernal pool where they developed to breed and lay eggs (Sinsch 1990; Semlitsch 2008). If these pools are destroyed or degraded, entire populations of amphibians can be lost. Some vernal pools are critical breeding pools (contains sufficient water to support breeding in most years) and are the primary sites where annual reproduction occurs for vernal pool dependent amphibians and other amphibians and reptiles that use them opportunistically.

Conditions at vernal pools can be sensitive to land use changes affecting hydrologic processes, pollution inputs, and vegetation cover. Forestry and other forest disturbances should aim to avoid vernal pools and the surrounding upland areas where amphibians and reptiles live. However, in some cases protecting the highest quality habitat at the expense of larger contiguous habitat may not be the most prudent decision as these ecosystems and their herpetofauna are dependent on the balanced proximity of aquatic and terrestrial habitats. These decisions should be based on thoughtful evaluation of the landscape and future uses and impacts. Suggestions for how to incorporate these unique habitat requirements into forestry management are detailed below.

Do not impact the pool depression or core buffer area within minimum of 600-1,000 feet – These areas should be protected from any management or development actions. If this buffer area cannot be protected, at least 100 feet must be protected as the amphibian species using vernal pools are often extirpated (locally extinct) when this area is impacted (Calhoun and Klemens 2002).

Protect a wide buffer - The distance from vernal pools that amphibians occupy varies by species (some salamander populations have up to 95% of individuals within 550 feet surrounding vernal pools (Semlitsch and Bodie 1998); Wood Frogs disperse as far as 1,500 feet from vernal pools (Berven and Grudzien 1990)). However, protecting the terrestrial buffer 600-1,000 feet from the pool will protect core habitat and most first year pool-breeding amphibians (Semlitsch 1998; Semlitsch and Bodie 2003; Calhoun, Miller et al. 2005). Management or development actions within this buffer should not impact greater than 25% of the area to reduce risk of local population declines (Calhoun and Klemens 2002). This 25% should also be selected based on relative quality and proximity to contiguous habitat. This buffer should be clearly marked in the field prior to any disturbance. Consult a professional herpetologist or Certified Wildlife Biologist for recommendations specific to the wildlife communities present at a site.

1-2. Vernal pools in forested areas are sensitive and important breeding and foraging grounds for several species of salamanders and frogs. Turtles and snakes may also feed and breed near these pools. Protecting these small wetlands is vital to maintaining population connectivity.

Maintain forest canopy – Forest canopy cover helps to retain moisture on the forest floor which is necessary for amphibians and reptiles to stay cool and/or moist. Forest canopy cover in and near vernal pools influences the presence and abundance of salamander and frog species (Skelly, Werner et al. 1999; Skelly, Freidenburg et al. 2002). Maintaining a similar forest canopy cover in and near a vernal pool can help to continue to provide habitat for the species present. When conducting timber harvest near vernal pools, canopy closure should not be reduced to less than 70% to minimize the affect of sun and wind (Michigan Department of Natural Resources and Michigan Department of Environmental Quality 2009).

Maintain habitat corridors - In addition to buffers and canopy cover, corridors that allow for salamanders and frogs to colonize and recolonize pools should be preserved (Semlitsch 1998; Vasconcelos and Calhoun 2004). These corridors will help ensure long-term viability for salamander and frog populations. Consult a professional herpetologist or certified wildlife biologist for recommendations specific to the wildlife communities present at a site.

Carefully restore and create vernal pools - Vernal pools can be restored and created if constructed and sited correctly. These pools should reference nearby pools with similar hydrologic conditions. Pool design criteria, including objectives addressing hydrologic processes, provision of woody materials for egg attachment, establishment of native vegetation, and presence of herpetofauna, should be established at the onset of pool planning to improve likelihood of success and to better provide for a diversity of herpetofauna (Lichko and Calhoun 2003). Seek professional assistance from a wildlife biologist, wetland ecologist, restoration ecologist or other experienced individual to ensure successful pool restoration and creation that is responsive to specified criteria. Restored and created pools can provide important ecosystem services, however creation of pools through normal harvesting activities (i.e., vehicle tracks) is not recommended. Ruts from vehicles may temporarily provide water required for egg laying but do not provide adequate water throughout the season, canopy shade, or appropriate soil conditions for amphibian and reptile survival (DiMauro and Hunter 2002; Calhoun and Demaynadier 2004).

1. This wetland acts as a potential habitat corridor among an area of agricultural fields.

2. Clearing of vegetation around wetlands particularly forested sections can significantly impact system function and breeding success.

Streamside/Riparian Zone Harvest

Avoid disturbing riparian zones and adjacent terrestrial areas– Harvest of trees along riparian areas can reduce channel stability, tree canopy, and large woody debris (Murphy, Heifetz et al. 1986), which reduce herpetofauna habitat suitability. Streamside harvest also can reduce tadpole density and tadpole habitat quality for stream and river dwelling frogs(Dupuis and Steventon 1999). Depending on the herpetofauna and other wildlife species present, consideration should be given to protect 600 – 1,000 feet from the edge of the water (Semlitsch 1998; Semlitsch and Bodie 2003; Calhoun, Miller et al. 2005). Maintenance of a terrestrial buffer at least 100 feet from the water with no harvest is recommended for ecological and stream stability (Steinblums, Froehlich et al. 1984; Semlitsch and Bodie 2003; Lee, Smyth et al. 2004). Eliminating disturbance in these areas can provide habitat for a greater diversity of species and better protect water quality. An experienced wildlife biologist or herpetologist should be consulted to determine an appropriate buffer width. Clearly mark the outer edge of the buffer using tree marking tape or staking prior to any harvest activities.

If riparian harvest is necessary, maintain understory and place temporary erosion control measures – Where trees are removed within potential buffer zones (approximately 1,000 feet or closer to a waterway) include logs and woody debris to provide structure and habitat. Understory vegetation will help hold the bank in place, prevent severe erosion, and reduce colonization by invasive plant species. Temporary erosion control measures, such as silt fence and natural fiber mesh can prevent sedimentation from entering surface waters until the bank has re-stabilized.

Prescribed Burns

Fire has historically played an important role in maintaining and restoring open prairie or savanna ecosystems in the Midwest, and can be a useful tool to manage vegetation structure of native and invasive plants. Prescribed fire can be used to restore native plant communities and can be valuable for increasing suitable habitat (e.g., maintain open areas, which can facilitate basking) for some Michigan herpetofauna (Mushinsky 1985; Setser and Cavitt 2003; Harner and Geluso 2011). Fire can be useful to reduce mid-story canopy – such as that created by thickets of invasive plant species - which can restrict movement of herpetofauna through the landscape (Bury 2004; Wilgers and Horne 2006). Open, sunny areas created post-burn can enhance opportunities for connectivity and migration of herpetofauna to restored habitats.

Although various amphibians and reptiles respond differently to burn regimes (Cavitt 2000; Wilgers and Horne 2006; Kaufmann, Smith et al. 2007), most Michigan herpetofauna is not adapted to frequent and intense burns. Although fire as a management tool has been shown to directly and

Tom Beauvais

1. Fires that occur before Green Snakes emerge from hibernation in the spring lessen the impacts on this and other sensitive amphibian and reptile species.

2. Burning during dry late fall or winter days when amphibians and reptiles are still inactive and many are underground reduces their exposure to fire.

indirectly impact rare and common herpetofauna, the full impact of fire on herpetofauna is yet unknown (Pilliod, Bury et al. 2003). Populations of vulnerable, rare, or threatened species can be negatively impacted by burns (Cross 2009; Gibson 2009; Woodley and Kingsbury 2011). However, loss of herpetofauna diversity in small burned areas may be offset by greater diversity on a larger scale (McCleod and Gates 1998). If a controlled burn is to be conducted as part of restoration or land management, the following points can help to reduce negative effects to herpetofauna and other wildlife.

Restrict burning frequency– By restricting the frequency of burns, unnecessary mortality of herpetofauna can be avoided. Also, some species (e.g., autumn olive; multiflora rose; and raspberry, *Rubus* spp.) respond to fire by vigorously re-sprouting (Michigan Natural Features Inventory 2012). For these species, several burns or a fire with the heat needed to kill the stems and roots may result in death of buried or burrowed herpetofauna. Some sites should avoid use of fire as a management tool if the impacts outweigh the benefits to the target wildlife.

Conduct pre-burn inventories - It is important to identify which herpetofauna occur (or may occur) and to conduct baseline inventories to determine the presence of rare species within areas proposed for management. This is critical for effective holistic land management and to evaluate the overall success of management strategies.

Know the natural history and life cycles of herpetofauna present – Annual and daily cycles and the response of various amphibians and reptiles to temperature, moisture, food sources, nesting, etc., can aid in planning fire to reduce negative impacts. Many herpetofauna have extremely limited mobility, and most exhibit life history characteristics that make them particularly vulnerable to even minor losses due to rapid and high-impact management techniques such as burning (See Section 3). Some species, such as Northern Ring-necked Snakes (*Diadophis punctatus*), have a higher abundance in areas with a longer fire return interval (Wilgers and Horne 2006). The vegetation structure in unburned areas likely provides increased moisture levels in soils and an abundance of earthworms (a primary food source), which makes these sites more suitable for Northern Ring-necked Snakes. Information regarding the life traits of some sensitive species can be found on the MNFI Rare Species Explorer webpage.

Account for undetected rare species - Rare herpetofauna populations can be difficult to detect and particularly sensitive to burns as they are not likely to recover quickly and generally do not have characteristics that help them withstand fire. The loss of individuals can be particularly devastating for species with a long time until sexual maturity. The loss of only a few adults within select species can dramatically affect population viability. Incorporating these considerations into plans can reduce losses. Prior to burning (or the use of other high-impact management methods such as mowing) in known rare or sensitive herpetofauna habitats, managers should carefully consider whether the result will benefit population viability and whether the actions can be modified or timed to reduce or eliminate mortality. Any management plan that threatens the local or large-scale destruction of vulnerable native animal populations should be reassessed.

1. This Eastern Box Turtle has been severely wounded and lost about half of its scutes in a prescribed burn. Due to the extent of injuries, it is unlikely that this turtle survived.

2. Northern Ring-necked Snake have a higher abundance in areas of long-term, unburned treatments than in areas burned with a higher frequency.

Conduct burns during seasons when herpetofauna are at less risk - Herpetofauna within the Midwest are generally inactive in late fall through winter. During these times, they remain underground or underwater, reducing their vulnerability to predation and the elements as well as to the impacts of fire. Understanding the ecological requirements and life cycles of the herpetofauna of a site is important to avoid mortality and to enhance biodiversity. Conduct burns during the very early spring before emergence from hibernation (typically, before April 1), summer after turtle nesting and spring migrations, and very late fall after hibernation has begun (Congdon and Keinath 2006; MWPARC 2009). Conduct spring and fall burns only after an extended cool spell (<50°F) when animals are less active and have a greater likelihood of being underground in burrows or hibernacula (MWPARC 2009). Spring burns in forests may harm Eastern Box Turtles, salamanders, and Wood Frogs emerging from hibernation. As the duff layer and woody debris on the forest floor are burned, so are these amphibians and reptiles that take cover there. Late spring and early summer burns in grasslands can impact nesting sites and staging female turtles, as well as snakes using these habitats seasonally. When burning must be conducted in the active season, actions should be taken to avoid impacts whenever possible. For example, conducting a warm season burn in July rather than June can have a significant impact on nesting turtle survival and maintain population viability.

Chris Woodley

Monitor herpetofauna and wildlife communities pre- and post-burn - Incorporate wildlife monitoring as a metric for measuring restoration success. This will provide a more comprehensive approach to understanding the benefits and timing of prescribed burns and minimize future impacts to amphibians, reptiles and other sensitive wildlife.

Avoid burning near wetlands – Burning the understory in wooded areas near wetlands reduces the leaf litter and woody debris layer where salamanders, Wood Frogs, and Eastern Box Turtles take cover. Burning here creates unsuitable habitat conditions for these species and exposes them to risk of direct mortality. If wetland or adjacent upland communities adapted to periodic burning and fire is deemed necessary for management, conduct burns during the hottest summer periods when many species have either migrated to shaded upland areas, are estivating underground, or can more easily escape. In areas where amphibians and reptiles are present in the spring, or remain throughout the summer, burning during or directly following warm weather can result in high herpetofauna mortality (Frese 2003; Woodley 2013).

1-2. Burning around logs should be avoided due to the high number of herpetofauna that use these structures for protection including this Eastern Garter Snake. Burn breaks are an effective way to minimize impact to these fire refugia.

Create refuge areas – Creating brush piles, snags, or other small areas with vegetative cover which will not be burned can provide herpetofauna with a safe place to flee to during a fire (Cross 2009). These features can often be created at no additional cost as these materials are often already on site.

Create fire breaks or protect critical herpetofauna habitat features from fire – Salamanders, some frogs, snakes, and Eastern Box Turtles hide under cover objects and duff on the forest floor. By not burning these critical habitat components, these animals are given some protection from fire. There are both natural and mechanical methods for establishing breaks though we encourage natural breaks as these do not result in greater landscape disturbance.

Avoid burning brush and leaf piles or logs – These features can provide cover during the active season and during hibernation for reptiles and amphibians. Animals will likely seek out refuge in these features during pre-burn site preparation, and burning these features will likely cause needless mortality (Cross 2009). Create fire breaks around these features, soak them with water, or create burn patterns to avoid their ignition. If brush and leaf piles are not desired features a management unit or project area, they should be thoroughly checked for amphibians and reptiles before burning or before removal to a different location.

Burn small areas infrequently - Burning various small areas at a 3-7 year frequency - as opposed to a typical 2-3 year burn frequency - can avoid reduction of amphibian diversity while maintaining a diverse native plant community (Schurbon and Fauth 2003). As various wildlife species respond differently to areas that have been burned and to the time since burning, a burn schedule should create a matrix of differently aged burned areas (Fuhlendorf and Engle 2004; Wilgers and Horne 2006).

In areas with herpetofauna that may be able to escape the site create slow-moving fires – Although most herpetofauna is not fast moving, some species, such as frogs, have been known to flee from the sound of fire (Grafe, Dobler et al. 2002) and may benefit from slow-moving burns, which they may be able to 'out-run'. The use of ring fires should be avoided or used in conjunction where refugia are present.

In areas with herpetofauna that cannot escape the site create fast moving fires– Fast moving fires are more likely to leave logs, cover objects, and parts of the duff layer unharmed. These objects can protect herpetofauna that is not able to quickly flee an area. However, fire can be especially detrimental to the Eastern Box Turtle. These turtles are not able to burrow quickly and are often exposed directly to fire during a burn, resulting in life threatening injuries if not outright mortality. Alternatives to fire should be considered in areas where the Eastern Box Turtle is present or are likely present (MWPARC 2009).

Chris Hoving

Matt Smar

1-2. Burning small areas allows for amphibians and reptiles to take refuge in nearby unburned areas.

Create a burn intensity that is appropriate for conditions reduces fire severity – Fire severity is generally described as the condition of the ground and amount of organic matter lost after a burn (Keeley 2009). Depending on the type of burn conducted and current conditions of a site, the severity of a fire can vary. Since most herpetofauna is not fast-moving, fires should be executed to burn at cooler temperatures (MWPARC 2009). Slow moving, low intensity fires may give some herpetofauna the chance to escape, however they can have a large effect on the remaining soil because they burn over a longer period of time. Fast moving, high intensity fires cause higher flames and temperatures but if conducted during times when the soil and forest floor are moist, the severity of the burn is less. When conducting a burn, evaluate which type will be most effective while minimizing direct and indirect impacts to herpetofauna.

Avoid use of fire retardant chemicals near wetlands – Use of fire retardants to create fire breaks releases sodium ferrocyanide into wetland environments. This chemical is highly toxic to amphibians even in dilute concentrations (Pilliod, Bury et al. 2003). Instead, use leaf blowers or rakes to create fire breaks (MWPARC 2009).

Documentation of findings – It is imperative that data both on dead and living amphibians and reptiles be recorded as part of any burn management activities. Historically most groups have not documented wildlife response. Groups Like Oakland County Parks and Recreation and the City of Ann Arbor are model organizations which commonly document the presence (live and dead) of herpetofauna post burns. This data should be contributed to the Michigan Herp Atlas program.

Fisheries Sampling and Management

Fisheries management can provide structure that contributes to habitat and a source of prey for amphibians and reptiles. High-quality headwater and riparian areas can provide amphibian habitat and ensure high-quality fish habitat (Naiman and Latterell 2005). Small, floodplain pools can provide essential habitat for fish and amphibians (Hoover and Killgore 2002). Turtles will often retreat to backwater pools or oxbows to mate in spring to avoid the strong current of rivers. Native fish, amphibian and reptile species also likely benefit from the control of aquatic invasive species, as the invasion of exotic species can degrade local ecosystems (Patel, Glassner-Shwayder et al. 2010; Strayer 2010) and high-quality waters (Naiman and Latterell 2005). Despite the overlap in the end goal of habitat management for both groups, some commonly used fisheries sampling and management techniques (i.e., electroshocking, fyke net surveys, use of rotenone) can be harmful to aquatic amphibians and reptiles.

1. Eastern American Toad larvae can co-occur in habitat that support fish. This amphibian is toxic to most fish species.

Hook and line fishing

Snakes, Mudpuppies, and turtles have been impaled on hooks that were intended for catching fish or other game species. When these animals are not able to be removed from hooks, these hooks are sometimes left in the flesh indefinitely and can affect the survival of the individual. To reduce the risk of causing additional harm to a non-target amphibian or reptile, hooks should not be forcibly removed when it is difficult to do so. Mudpuppies are killed when caught by anglers due to the assumption that they are predators of some game fish species, however this is not true and the unnecessary killing of these animals should be discouraged. Use of salamanders and frogs as bait is also strongly discouraged. Commonly used species such as the Tiger Salamander, Spotted Salamander, Northern Leopard Frog, Pickerel Frog, and Mink Frog, are experiencing population declines. Suitable artificial baits are available that provide a similar function without need of harm to herpetofauna.

Sean Zera

2. This Midland Painted Turtle has suffered permanent damage from a fishing hook.

Electroshocking/Electrofishing

Although electrofishing has been documented as a safe way to sample aquatic salamander communities (Williams, Gates et al. 1981), this technique does cause temporary paralysis in herpetofauna, much the same as it does in fish. One species frequently reported in bycatch during electroshocking is Mudpuppies. When catching and releasing these and other herpetofauna, surveyors should be aware that shocked and stunned herpetofauna is subject to potential predation and it is recommended that these species be carefully released as quickly as possible to an area with adequate submerged cover to reduce chances of predation.

3. When conducting electrofishing, be aware of the short term effects that nearby herpetofauna may experience.

Chemical Fish Control and Sampling

Chemical control, mainly through use of rotenone, is used to remove diseased fish populations or non-native and native fish with unbalanced populations (Ball 1948; Turner, Jacobson et al. 2007). Since Rotenone kills all fish (i.e., is a broad-spectrum poison), it can also be used in fish hatcheries to remove fish not caught before stocking new fry. This natural compound is lethal to fish and degrades quickly in the environment, thus it is also used as a tool to sample fish in small areas (Turner, Jacobson et al. 2007). Rotenone affects fish and wildlife, including amphibians, at the cellular level (Bradbury 1986). Rotenone has been related to mortality of turtles, larval and adult frogs, sirens, and other salamanders (Haag 1931; Bradbury 1986; Fontenot 1994; McCoid and Bettoli 1996; Billman,

U.S. Fish and Wildlife Service


National Geographic


Dick Bartlett


U.S. Fish and Wildlife Service

1-3. To avoid direct mortality of aquatic salamanders including the Mudpuppy (1) and Western Lesser Siren (2), lampricides and similar chemicals should be applied in the winter.

St-Hilaire et al. 2011). Larval stage and adult amphibians have a high sensitivity to rotenone, likely due to the ability of their skin and gills to readily absorb water and any compounds in the water (Turner, Jacobson et al. 2007). Despite the potential negative impacts of rotenone on amphibians, use of rotenone to remove fish from ponds can improve amphibian reproductive success (Walston and Mullin 2007). The following recommendations can help to reduce impacts of rotenone application on amphibians and reptiles.

Apply rotenone or other chemicals to control fish late in the year– Applying rotenone in the fall or winter after larval amphibians have lost their gills and move between the water and land will reduce the potential contact amphibians have with rotenone (Turner, Jacobson et al. 2007). However, Mudpuppies, Sirens, non-metamorphosed tadpoles, and aquatic turtles occupy aquatic areas year-round and are prone to impacts. Also, better results are produced during this time of year as rotenone is more persistent in cold water. Research should be conducted to determine effects of rotenone on overwintering turtles as this might be an issue during cold weather application.

Do not apply rotenone in areas with rare herpetofauna –There is a high likelihood that any amphibians and reptiles which come in contact with rotenone will die. Taking rare amphibians and reptiles will only further reduce their populations and their chances of survival.

Lamprey Control

TFM (3-trifluoromethyl-4-nitrophenol) is a poison used to control fish but has also traditionally been the chief control method for sea lamprey, an aquatic invasive species in the Great Lakes which significantly affects native fisheries, such as lake trout. Rotenone (as discussed in the previous section) is also utilized as a lampricide, however it is not used as frequently as TFM. Unfortunately, lampricides also impact non-target species, including amphibians and possibly reptiles (Boogaard, Bills et al. 2003; Dawson 2003; Hubert 2003; McDonald and Kolar 2007). More recently, alternative treatments including use of pheromones, sterilization, trapping, and use of barriers have successfully reduced local sea lamprey populations (Lavis, Hallett et al. 2003; Johnson, Siefkes et al. 2005; Bergstedt and Twohey 2007; Johnson, Muhammad et al. 2012).

Avoid use of lampricides - While these treatments effectively kill most sea lamprey and are generally considered safe for most adult amphibians and reptiles when applied at normal concentrations to kill target species (Farringer 1972), they can be lethal for gill-breathing larval amphibians and adult amphibians, particularly Mudpuppies (Gilderhus and Johnson 1980;

USDA-Forest Service

1. Due to their harmful effects on amphibians, Rotenone treatments should be avoided whenever possible. If necessary, removal of sensitive and rare herpetofauna should be conducted.

2. In general fish hatchery ponds can make good amphibian and reptile habitat with little to no impact on fish.

Boogaard, Bills et al. 2003; State of Vermont 2011) Also, long-term accumulation of lampricides in Mudpuppies may result in shortened lifespans and decrease reproductive ability (Parren and Hart 2012). Reports of hundreds of Mudpuppies dying after treatment are not uncommon (www.miherpatlas.org). Since lampricide applications are repetitive (i.e., reapplied every 3-5 years), this high level of mortality for this imperiled species, which is also the obligate host to State Endangered Salamander Mussels, is likely highly unsustainable.

Use alternatives, such as pheromones, trapping, and sterile male release - Alternative lamprey management includes use of pheromones to attract and trap lampreys (Wagner, Jones et al. 2006), injury-released chemical alarm cues which are chemosensory repellents (Imre, Brown et al. 2010), and sterile male release (Bergstedt and Twohey 2007). These techniques can successfully control lamprey populations and have potential to reduce the lamprey population throughout the Great Lakes without damaging herpetofauna.

If lampricide use is necessary, target areas and seasons with reduced amphibian presence or inactivity - When alternatives to lampricide are not a viable option, application of lampricide chemicals should be targeted to lamprey habitat, avoid Mudpuppy habitat, and application timing should avoid the presence of amphibian larvae. This compound has been shown to have high lethality to Mudpuppies and in some cases hundreds have died in a single application along single sections of streams in Michigan. Though efforts have been made to refine such impacts consideration of the system as a whole in use of such compounds is encouraged. Incorporating use of pheromones and other techniques to concentrate sea lamprey into small areas can reduce the area to be treated with lampricides and the extent of negative effects on wildlife. This can also reduce the cost of lampricide and can potentially increase percentage of successfully culled sea lamprey. To achieve these application standards, a professional herpetologist or professional wildlife biologist with demonstrated expertise in herpetofauna should be consulted.

Kurtz Fish Hatchery

Fish Hatchery Rearing Ponds

Most fish hatchery and rearing ponds are earthen dikes and can help support healthy amphibian and reptile communities while also addressing the needs of the fisheries community. Turtles and frogs are some of the animals that may be beneficial in or around rearing ponds. Most of their prey is weak, diseased, or dead fish. These feeding habits help to maintain overall higher quality fish stock and prevent the spread of disease in rearing ponds.

Although amphibians and reptiles can help maintain health and ecological balance in a rearing pond, occasionally rotenone may need to be used to cull a group of diseased fish or to "clean" the water between fish harvest and the


1. Eastern Tiger Salamander larvae are particularly sensitive to Rotenone and other chemicals as they can take multiple years to metamorphose into adults. If treated prior to metamorphosis the entire generation of species recruited could be lost.

introduction of a new batch of fish. Rotenone treatments will not only kill unwanted pathogens, they will also kill developing salamander larvae. Eastern Tiger Salamander larvae in particular can be impacted by rotenone treatments as they can take multiple years to metamorphose into adults. If rotenone or other chemicals must be used, first translocate all herpetofauna to a nearby wetland with similar conditions to that of the rearing pond. Then place excluder fences (i.e., soil erosion control fence or other similar barrier) to prevent herpetofauna from entering rearing ponds and becoming subject to poisoning by rotenone.

Net Sampling

Some fish sampling is conducted by using nets submerged as much as three feet below the water surface. These nets can safely hold fish hours or days until a sampling technician checks the trap. However, turtles are also captured in these nets and die because they cannot rise to the surface to breathe (Barko, Briggler et al. 2004; Dorcas, Willson et al. 2007). In some circumstances, even nets placed with "breathing room" (e.g., a milk jug float) can still result in significant turtle mortalities (Larocque, Colotelo et al. 2011). A turtle that has taken decades to reach sexual maturity can die in a matter of minutes because it cannot reach the surface.

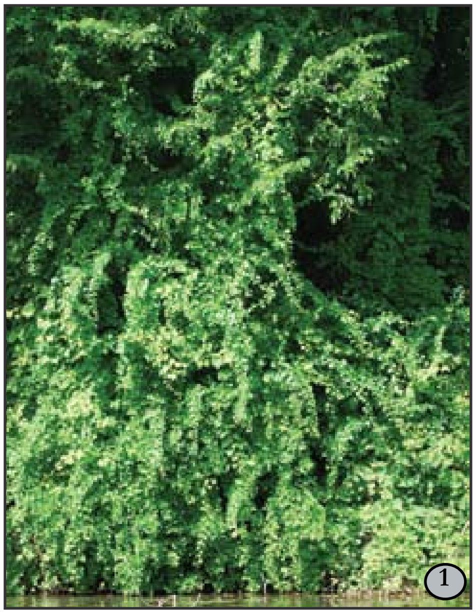
Place traps that have turtle escape routes or allow turtles to breathe - Turtles and other non-gilled amphibians and reptiles must occasionally rise to the surface of the water to breathe. Do not set traps at depths where turtles cannot reach the surface and avoid placing traps at times of year when turtles are active and likely to be caught in traps (i.e., late spring to early fall) (Larocque, Colotelo et al. 2011). Incorporating devices such as turtle excluders or turtle chimneys can prevent turtle mortality from drowning (Epperly 2002; Fratto, Barko et al. 2008). Turtle chimneys allow turtles to rise to the surface to breathe but prevent fish from escaping, and turtle excluders allow turtle to escape nets. These features and special floats to provide air spaces can be incorporated into net construction to reduce turtle mortality (Larocque, Cooke et al. 2012).


Dr. Don Uzarski - CMU

2. This fish sampling net has been properly placed in order to reduce harm to any amphibian or reptile that is caught. When placing traps in open water habitat, leave room within the device for animals to reach the surface to breath.

Do not set traps in warm water – Set traps in water ranging 40-50°F (Ultsch, Herbert et al. 1984; Herbert and Jackson 1985). Higher water temperatures increase the metabolic rate of turtles and require them to breathe more often to maintain suitable oxygen levels in their blood (Herbert and Jackson 1985). Higher temperatures also decrease the dissolved oxygen in the water, making intake of oxygen increasingly difficult. Because turtles have extrapulmonary gas exchange (breathe in part through their skin), lower dissolved oxygen levels can decrease

1. Even native plant species can become invasive and choke out other wetland vegetation on which amphibians and reptiles rely.



turtle survival when trapped under water (Ultsch, Herbert et al. 1984; Herbert and Jackson 1985). In addition, when turtles are stuck in traps they cannot move to a cooler location to thermoregulate and maintain a body temperature required for survival.

Avoid setting traps in marsh habitats – Placement of nets in most cases most commonly occur in the open portion of lakes and are aimed at sampling open water fish communities. Sometimes nets are set randomly or within a variety of habitats including marshes. Sampling in these habitats often yield high quantities of turtle by-catch. To minimize impacts to turtles these locations should be avoided or traps should be set shallow enough that animals can reach the surface. Whenever trapping results in an amphibian or reptile by-catch, observations should be submitted to the MI Herp Atlas website.

Invasive Species Management

The presence of invasive species (non-native and native species that are facilitated by anthropogenic forces) can reduce biodiversity, compromise ecological function, and reduce abundance and species richness of amphibian and reptile communities (See Section 2). The most effective way to reduce these impacts is by preventing the establishment of invasive species by maintaining healthy ecosystems and minimizing introductions of non-native organisms.

2. Decontaminate equipment between visiting sites. Use a 3-10% bleach solution for 30 minutes to reduce the spread of invasive plant and animal species and pathogens.

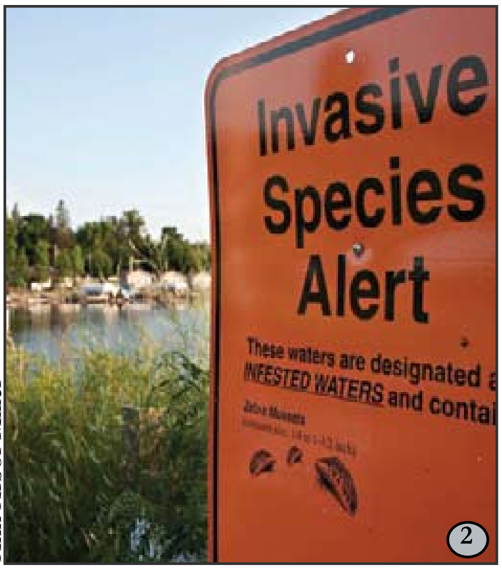
Decontaminate clothes and equipment - Since many invasive species are unknowingly introduced (See Section 2), decontamination of clothing, equipment, vehicles, and pets that have been in the field is essential to stop the movement of invasive species and disease. Boots and field equipment should be dried for three days or, if needed sooner, they should be cleaned with a 3-10% bleach solution for 30 minutes, and field clothing should be laundered or dried (DAPTF 1991; Coscarelli and Bankard 1999; Young, Berger et al. 2007; MWPARC 2012). Alternatively, equipment can be rinsed with hot water >110°F or frozen at 0°F for at least 24 hours (Coscarelli and Bankard 1999). Larger aquatic equipment – such as boats - should be drained of water and dried before moving to another location to minimize the transmission and establishment of invasive species (The Green Marina Education and Outreach Project 2012). Terrestrial passenger and recreational vehicles as well as equipment used for construction, agriculture, forestry, land management, and road work should be inspected and cleaned to remove all invasive plant and animals (Halloran 2013). Inspections should be conducted before entering a new area, especially one that may not have invasive species established, and after exiting an area where invasive species may have been present. Any vehicle or equipment that has operated in muddy conditions should be inspected and cleaned as seeds of invasive plants are easily embedded in mud. Inspections should include the underside

of the vehicle where plant material or mud may adhere. As part of cleaning, vacuum the inside of a vehicle and wash the outside in an area at least 100 feet away from a water body (Halloran 2013).

Place educational signs - Education about the impacts of invasive species and how to prevent their spread can also be effective tools in prevention and developing a greater understanding of the extent of this problem (The Green Marina Education and Outreach Project 2012).

Limit human access to sensitive or high-quality wetland areas – This will reduce the threat of introduction of invasive plant seeds, pathogens, and disturbance.

Monitor sites for long-term success - Long-term monitoring and removal programs can prevent invasive species from becoming established. Strategies to prevent invasions include holding bonds for construction jobs until native species are established and involving community or conservation groups in long-term monitoring and removal of any invasive individuals.



Ann Arbor Miller

1. Invasive plants including *Phragmites* and flowering rush quickly colonize disturbed and degraded areas. Due to the dominance and density of such plants, these areas are seldom used by herpetofauna.

2. Educational signs can be an effective tool in preventing the spread of invasive species.

Unfortunately, the introduction of some invasive species is inevitable; however, preventative measures and control techniques can limit the effect these invaders have on ecosystems that include herpetofauna. Although amphibians and reptiles can be impacted by the presence and expansion of invasive species, some techniques used to control invasive species can also harm native herpetofauna. Control techniques specific to invasive plants and animals are detailed below and concur with recommendations by Partners in Amphibian and Reptile Conservation (PARC) and align with goals set forth in the 2013 Michigan's Aquatic Invasive Species State Management Plan, Michigan Natural Features Inventory (MNFI), and Sea Grant's Aquatic Invasive Species-Hazard Analysis and Critical Control Point (Gunderson, Kinnunen et al. 2004; Michigan Department of Environmental Quality, Michigan Department of Natural Resources et al. 2013).

For additional information regarding identification of invasive plants and animals and the planning and implementation process for their prevention and control see the list of Recommended References in Appendix C. If planning to implement an aggressive invasive species control program, agencies such as the Michigan DEQ, DNR, or USDA Wildlife Services can provide the most recent information regarding specific invasive control techniques and programs.

Plant Invaders

There are several invasive plant species that are common throughout Michigan's aquatic and terrestrial communities (e.g., aquatic invaders: exotic *Phragmites*; narrow-leaved cattail, reed canary-grass; Eurasian watermilfoil; purple loosestrife; Terrestrial invaders: autumn olive; glossy

Controlling *Phragmites*

Exotic *Phragmites* is a highly invasive plant, which has dominated several wetland and coastal ecosystems throughout Michigan. As *Phragmites* dominates wetlands, these areas become unsuitable for most herpetofauna and contribute to habitat degradation and fragmentation for these animals. Since *Phragmites* is a highly resilient invader, control of established stands of *Phragmites* requires a multi-phase approach over several years to successfully eradicate a local population. As researchers continue to study *Phragmites* and explore alternative avenues for control, the ideal control methods will likely be updated for more effective, cost-efficient, and environmentally sustainable techniques. At the current time, general *Phragmites* control that accounts for conservation of local herpetofauna follows these steps:

1. Conduct baseline surveys to better understand the amphibian and reptile community composition to best minimize negative effects. These surveys will also provide a baseline for establishing restoration metrics.

2. Chemical Treatment – Use Glyphosate and/or Imazapyr herbicides in **late summer**/early fall when herpetofauna have migrated from wetland areas (Hokanson ; Michigan Department of Environmental Quality 2007).

3. Mechanical Treatment - Prescribed fire should be conducted the year following herbicide treatment, either in late summer (mid-July through August) or winter (January until prior to spring green-up). Use of fire in winter is preferable, as herpetofauna will be in hibernation at this time and at less risk (Hokanson; Michigan Department of Environmental Quality 2007). Alternatively, mowing using weed whips, small mowers, brush hogs, and flail mowers or hand-cutting of stems and seed heads can be used in late summer.

Flooding can also be used in systems with water control structures after initial chemical treatment and either prescribed fire or mowing. Areas should be flooded immediately after burning or mowing if conducted in late summer. If burning or mowing is conducted in winter, flooding should be conducted in the spring after hibernating herpetofauna has emerged. Areas should remain flooded (≥6" of water) for at least one year. Draw downs should be conducted in late summer (late July) to maintain and promote native vegetation and to avoid reestablishment of *Phragmites* and avoid disruption of herpetofauna during hibernation.

4. Follow-Up Spot Treatment and Monitoring – Monitoring and spot control should be planned for several years following the initial herbicide and mechanical treatments. *Phragmites* can re-grow quickly and off-site areas may continue to be a source of seeds. The presence of other opportunistic invasive species, which often occurs following treatment (invasive cattail, reed canary-grass, etc.) should also be monitored and spot treated.

1. The above wetland is populated with invasive plant species: flowering rush, purple loosestrife, reed canary, European frogbit and autumn olive. Though invaded by multiple non-native species, this particular wetland supported a relatively rich amphibian and reptile community in part because no one species dominated. Control of invasive species is important, but also considering location and current use by wildlife is important when deciding on how and when to restore.

buckthorn; honeysuckle; multiflora rose; oriental bittersweet, *Celastrus orbiculatus*) that can negatively impact ecosystems and reduce amphibian and reptile communities. These plants were originally introduced from Europe, Asia, South America, and other locations in North America.

Removal of invasive plants and concurrent restoration of native plant communities is a time-intensive process, typically requiring years of dedication to support the native plant community while invasive plants are controlled and drop out of the local seed bank. Even after restoration is 'complete', there is constant threat of invasion as invasive seeds may remain in the seed bank much longer than native seeds (D'Antonio and Meyerson 2002). Seeds of invasive species transported from nearby populations may sprout and become established if regular maintenance (i.e., hand-pulling, herbicide application) is not continued. Management plans without a long-term outlook can allow 'restored' areas to revert back to their previously disturbed state, which does not provide vegetation structure appropriate for herpetofauna. Short-term plans may also introduce toxins (herbicide) and/or cause mortality through mowing, thus reducing the herpetofauna community without providing an appropriate plant community structure required for the herpetofauna community to rebound (i.e., the herpetofauna community experiences stress from management activities and the continued presence of invasive species) (D'Antonio and Meyerson 2002). Methods of control may need to be integrated for successful management (Dodici, Kubiak et al. 2004). Recommendations for control of invasive plants are detailed below.

Weigh the need for non-native plant removal – Non-native plants can also provide ecological services, such as erosion control. In this situation, the stabilization provided by non-native plants may be more important than the removal of these plants at the risk of increasing erosion.

Consider and integrate multiple treatment methods – Controlled burns, use of herbicides, alteration of water levels, mowing, and other emerging management techniques should be considered when controlling invasive species. Selecting a combination of methods that optimizes control of invasive species while reducing impacts to herpetofauna and other native wildlife will help to restore ecosystem function. The plant species being treated will also help to determine which treatment methods to select, as various plant species may differ in response to mowing, fire, submersion, and chemicals. Mowing invasive plant species, such as *Phragmites*, can stimulate root growth and actually increase the severity of the infestation. In some cases, mowing may be used as a temporary measure to establish openings in the landscape, which can allow light to reach native plants. Consult the resources regarding invasive plants found in Appendix C to determine the likely response of invasive and native species to mowing before conducting control. For more information about mowing, burning, and chemical application techniques, refer to prior information presented in this section.

1. Bare soil can quickly become colonized by invasive plants.

2. Management techniques should be conducted during times of the year that herpetofauna is less likely to be impacted.

Cover or treat freshly graded soil – Earthwork creates disturbed conditions, which allow invasive plants to easily become established. Cover bare soil with mulch or plant non-invasive cover crops or native plants to prevent invasive plant establishment and soil erosion.

Monitor and spot-treat for individual plant growth – Since invasive plants can quickly become established, vigilant monitoring can identify and eliminate individual plants that could otherwise spread.

Do not plant invasive plants - Do not buy or plant seed mixtures and nursery plants that are invasive species. Select plants that are native species and varieties. Information to help consumers identify which plants to avoid is available from the MDEQ, the Midwest Invasive Plant Network (MIPN), in the Invasive Plant Atlas of the United States supported in part by the National Park Service.

Conduct management techniques during times when wildlife is least likely to be harmed - Regardless of which management technique is selected, timing is of the utmost importance both for a successful outcome and the minimization of potential negative impacts on herpetofauna. If possible conduct management actions during times of the year when resident animals may not be present at the treatment location (i.e., treating a wetland when animals have migrated to upland areas) or when animals may be inactive (i.e., during times when they are burrowed in the substrate, estivating, hibernating). To determine when animals are inactive, an inventory of species present will need to be conducted (See Section 4). Consult a professional herpetologist or wildlife biologist with demonstrated amphibian and reptile experience for recommendations specific to the wildlife communities present at your site.

Consider use of biological control – Use of host-specific insect herbivores can control invasive plants. Control of purple loosestrife by the introduced black-margined loosestrife beetle (*Galerucella calmariensis*) and golden loosestrife beetle (*Galerucella pusilla*) has eliminated up to 95% of purple loosestrife in some areas without the beetles shifting host to other native plants (Blossey, Casagrande et al. 2001). However, use of biological controls is *highly cautioned* as the successful implementation of a biological control program requires extensive research and testing to determine the full range of consequences of introducing one non-native species to control another.

1. Nitrile Gloves should be worn to reduce exposure of chemicals to amphibian skin and the potential spread of disease.

2. Encouraging healthy populations of Northern Water Snakes can help reduce round goby abundance.

Animal Invaders

Several invasive animal species throughout Michigan's aquatic and terrestrial communities (e.g., mute swan, emerald ash borer, rusty crayfish, zebra mussel, quagga mussels, sea lamprey, round goby, Eurasian ruffe, and spiny and fishhook waterfleas) have negative impacts on ecosystem function and on herpetofauna (See Section 2). Although a number of Michigan's amphibians and reptiles have begun to feed on these species, which reduces their overall success, continued efforts to reduce the spread or introduction of new species are necessary. Specific recommendations for control of invasive animals are detailed below.

Wear gloves to reduce spread of disease - Gloves should be worn when handling animals to reduce the potential spread of disease between sites and animal populations (MWPARC 2012).

Do not move animals or **vegetation** – Moving animals or vegetation from the water body or upland area where they were found to a different area can spread invasive species (e.g., moving firewood between counties has increased the rate of spread of emerald ash borer).

Do not release pets - The release of pets and non-natives can introduce disease to which native species are susceptible and increase competition for resources. Some species released, which are tolerant of Michigan's weather conditions may become established, leading to changes in species composition and shifts in community dominance towards the introduced animal. At popular "release" areas, such as public parks and ponds, large communities of common pet species like goldfish can be seen at high densities, which can impact ecosystem balance. Make sure you learn about the time and resource commitment of keeping and having a pet before bringing it home. In the event you are unable to care for your pet any longer, many organizations will take unwanted pets and should be consulted.

Encourage native biological control – Certain native species have begun to recognize some invasive species as a food source (e.g., Mudpuppies and Northern Water Snakes eat round gobies and Northern Map Turtles will eat zebra mussels). Encouraging healthy populations of native species may help control and minimize invasive fauna species.

Restore site conditions for native species – Create conditions that are beneficial for native herpetofauna and other native wildlife species. Invasive species often become established in disturbed areas that do not provide food, shelter, and reproductive opportunities for native species. By restoring vegetation and other structural and functional components (e.g., branches, logs,

1. Trapping can be an effective tool when dealing with invasive animal populations.

snags, or mounds of loose gravel and sand) suitable for native species, habitat suitability for invasive species may decrease.

Consider trapping and culling programs–Trapping and euthanizing can be very effective at reducing invasive populations (e.g., mute swan, feral swine, raccoon). However, public education and acceptance are critical to the success of any control program.

Only use toxicants/poisons if non-target species have a low probability of impact – When toxicants and poisons are used to control invasive species (e.g., European Starling, feral swine) (Campbell and Long 2009), measures should be taken to minimize risk to non-target species. In aquatic environments this method may not be acceptable, as it is difficult to control which organisms come into contact with chemicals released into a water body.

Avoid chemical controls – Chemicals used to control sea lamprey, zebra mussels, and invasive fish can be harmful to non-target species, including larval amphibians and Mudpuppies (Gilderhus and Johnson 1980; Kane, Day et al. 1993; Waller, Rach et al. 1993; Boogaard, Bills et al. 2003; Dawson 2003; McDonald and Kolar 2007; Billman, St-Hilaire et al. 2011). If applied, target sea lamprey populations and avoid locations and times of year when larval amphibians and Mudpuppies are present. Applications should be conducted near the beginning of the winter (i.e., December-January) to prevent residual rotenone effecting amphibians as they come out of hibernation.

2. Where invasive bird populations are an issue, fertility control including egg addling can be used. However, this technique can be time and labor intensive.

Consider fertility control – Methods of fertility control are dependent on the species in question and have variable levels of success (e.g., variable successes controlling sea lamprey and feral swine populations). However, these methods may enhance success in a multi-faceted invasive management plan. Since fertility control requires a considerable amount of research and field trials, we recommend consultation of the Michigan DNR or USDA Wildlife Services if considering fertility control measures. Egg addling and nest destruction are labor intensive methods to control invasive bird species (e.g., mute swan). Egg addling entails removing eggs from the nest, then terminating embryo development by shaking or greasing eggs. The eggs are then placed back in the nest, thus misleading the parent into not laying additional viable eggs. Sterilization in sea lamprey and birth control in nuisance mammalian wildlife species (Cooper and Larsen 2006; Bergstedt and Twohey 2007) have been used, but at the present time

1. Raccoon populations often are subsidized by available food sources and a lack of top tier predators in urban environments.

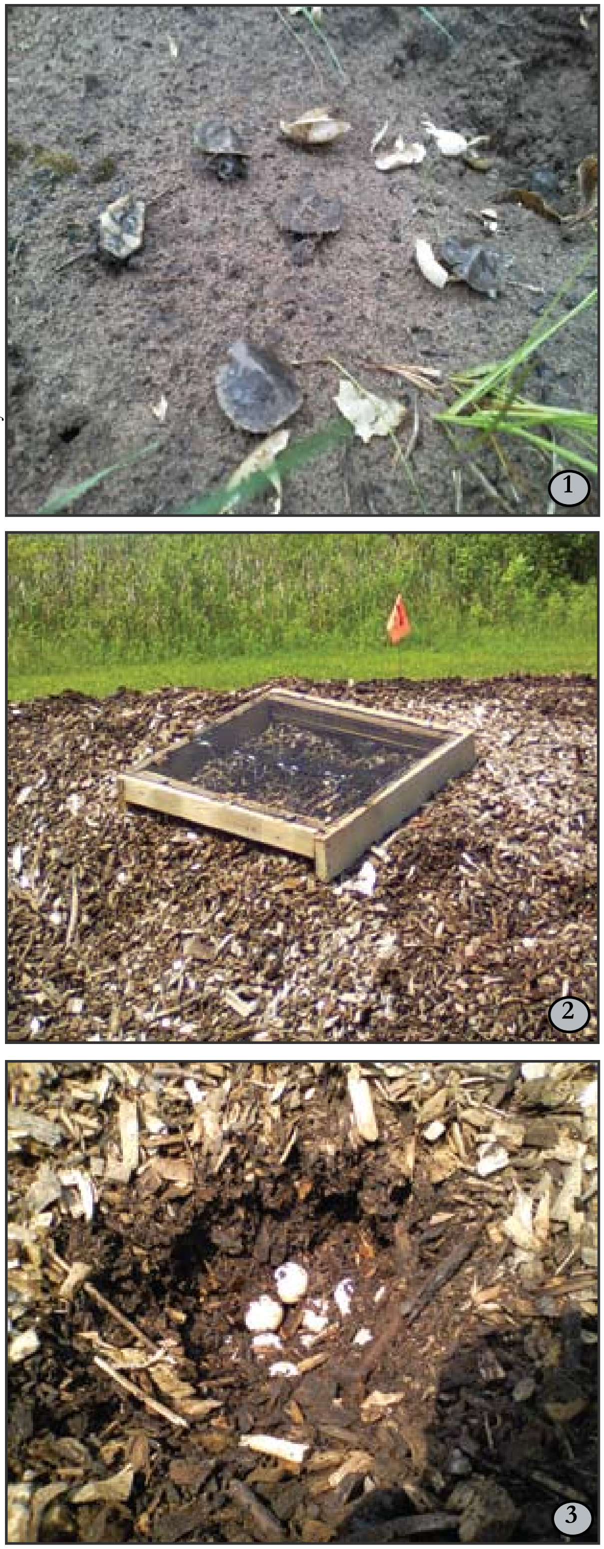
2. Turtle nests are frequently predated by raccoons, sometimes resulting in almost 100% nest mortality at some sites. This trend is unsustainable and if it continues will likely result in impacts to population viability.

these techniques are not effective solutions for large scale invasive eradication. Use of pheromones to attract sea lamprey can help to increase efficacy of other control measures (e.g., lampricide or collection for sterilization) without effect on non-target species. This method also allows for the invasive species to be trapped and removed without significantly impacting herpetofauna.

Subsidized Predator Management

Urbanization and human actions often help to subsidize mesopredator species like raccoons, opossums, and feral cats by increasing food availability (e.g., trash cans, agricultural leavings, intentional feeding) and by creating urban environments with a lack of larger, top-tier predators (e.g., large cats or wolves) (Prugh, Stoner et al. 2009) Urbanization also leads to a creation of roads, sidewalks, open lawn and park areas which fragment herpetofauna habitat but are easily navigated by raccoons or other urban-adapted wildlife, which disperse widely across the landscape. These conditions have helped to facilitate dense populations of raccoons in urban and suburban landscapes (Prange, Gehrt et al. 2003) Unfortunately, raccoons and other mesopredators are savvy predators of turtle nests (Standing, Herman et al. 1999; Burke, Schneider et al. 2005) often eliminating all turtle reproduction in an area – and also prey on adult and juvenile turtles (Seigel 1980; Seabrook 1989; Harding 1997; Browne and Hecnar 2007; MWPARC 2009; HRM 2011). Although turtles have relatively good defenses (ability to hide in their shells, swiftly swim away, or deliver a 'snapping' bite), raccoons' intelligence and well-adapted hands allow them to dig up turtle nests and catch and eat turtles as well as many other reptiles and amphibians.

The general survival strategy of turtles as a group is high adult survival to offset naturally high juvenile mortality. Because many turtle species are long lived with a slow rate to maturity and low reproductive rate, mortality exceeding the normal rate of loss could lead to population declines and possible long-term population/species extirpation. However, predation from raccoons and other mesopredators frequently leads to complete nest and juvenile mortality and significantly reduces adult survival (Christiansen and Gallaway 1984). The lack of recruitment of younger age classes paired with the loss of long-lived adults can lead to turtle population declines and local extirpations of rare and especially sensitive species (Congdon 2001; Browne and Hecnar 2007). Help restore natural population densities of these subsidized mesopredators through species control, education and outreach regarding the ecological and human safety concerns, and improved regulations and enforcement. For turtles and other sensitive herpetofauna and wildlife to be sustained in Michigan, populations of raccoons and other problematic mesopredators must decrease substantially through preventative and control measures.



Carl May

1-3. Protecting turtle nests from predation by an artificial cover (2) will increase the chances of egg and hatchling survival.

Discourage feeding of raccoons and other mesopredators – Further increases in populations of problematic mesopredators should be prevented by eliminating access to food sources, such as trash cans, and by discontinuing fostering, rehabilitation, and trap and release of these animals.

Implement control measures - In many places with established raccoon populations, lethal control methods can reduce pressure on turtles and other wildlife (Garmestani and Percival 2005; Engeman, Martin et al. 2006). Michigan allows raccoon trapping year round, and developing a relationship with a local trapper may also provide a viable and inexpensive option for raccoon control (MWPARC 2009). Control methods should always be conducted humanely and comply with state regulations.

Educate the public – Also, public education is necessary to support and implement these measures with long-term success and benefits for turtles and other sensitive wildlife populations impacted by raccoons. Explaining the importance of balanced ecosystems and the necessity for selective management strategies, such as mesopredator control in urban and suburban areas, can help the public to accept management strategies. Public education can also include simple strategies, such as placing signs to inform the public about local species conservation needs.

Protect turtle nests – Using fencing and other covers to exclude predators from turtle nests can help to increase turtle nest and hatchling survival (Brown and Macdonald 1995; Ratnaswamy, Warren et al. 1997; Smith, Steen et al. 2012), especially in areas where lethal control is not a viable option. It should be noted that this technique is labor and time intensive and does not remove predation pressure on adult turtles and by mesopredators.

Do not allow outdoor cats – Cats, whether beloved pets or feral, are an invasive species that alters the composition and abundance of small mammal, bird, amphibian, and reptile communities (Woods, McDonald et al. 2003; Baker, Bentley et al. 2005; Beckerman, Boots et al. 2007; Dauphine and Cooper 2011). It is estimated that domestic cats kill 1.4-3.7 billion birds and 6.9-20.7 billion mammals annually in the United States (Loss, Will et al. 2013). Keeping cats indoors prevents herpetofauna and other wildlife from being harmed by cats.

9. Development Techniques

This section describes approaches that should be taken during development activities with in natural, urban, and rural areas. These recommendations can be utilized by land developers, consultants, landscape architects, and those interested in minimizing disturbance to herpetofauna. Several common development practices are known to have negative effects on amphibian and reptile populations, however by practicing these strategies the impacts can be mitigated. The goal is to minimize impacts to the natural resources while still addressing the development goals and objectives.

Site Grading and Topography

Topography can determine how wildlife traverse a site, how water flows over or through a site, and what niches are available for flora and fauna. In areas where the original topography has been altered, historical maps, soil maps, and water table depth may give clues about the original community types that were present on the site. Such an analysis may help to determine the appropriate trajectory for restoration efforts.

1. Railroads can also inhibit animal movements. This Eastern Garter Snake was found alive along the inside of a pair of railroad tracks. Often turtles will get stuck between the rails and die. Working with rail operators to find solutions to reduce fragmentation is a good first step to addressing this issue.

2. Placing roads away from high quality amphibian and reptile habitat can help to preserve these critical natural areas.

Any site grading should preserve intact areas of wildlife habitat to prevent further degradation during construction. Additional recommendations are listed below.

Create gradual slopes in wetlands - Site grading should be gradual, especially along the banks and shoreline of wetland areas. Slopes in wetlands and uplands should be less than 1:10 and 1:3, respectively, with gradients as shallow as 1:15 to 1:20 preferable to support a greater variety of amphibians and reptiles and their prey items. These gentle slopes are

1.Western Painted Turtles and other reptiles and amphibians are at risk as they cross roads during their seasonal migrations to breeding or nesting sites.

easily traversed by amphibians and reptiles as well as equipment used to create various habitat structures. These slopes should be maintained along the banks of wetlands with deeper pockets in the center to avoid overgrowth of vegetation including reed canary grass, *Phragmites*, and hybrid cattail.

Create islands in constructed wetlands or lakes – Islands provide a place with reduced mammalian predator pressures on amphibians and reptiles.

Develop microtopography features - Microtopography is critical in wetland areas and some upland areas as it provides a variety of niches with unique hydroperiods, which can accommodate a rich variety of animals. Fine grading should be used to develop microtopography features (<6" deep) (Wisconsin NRCS 2010).

Figure 7

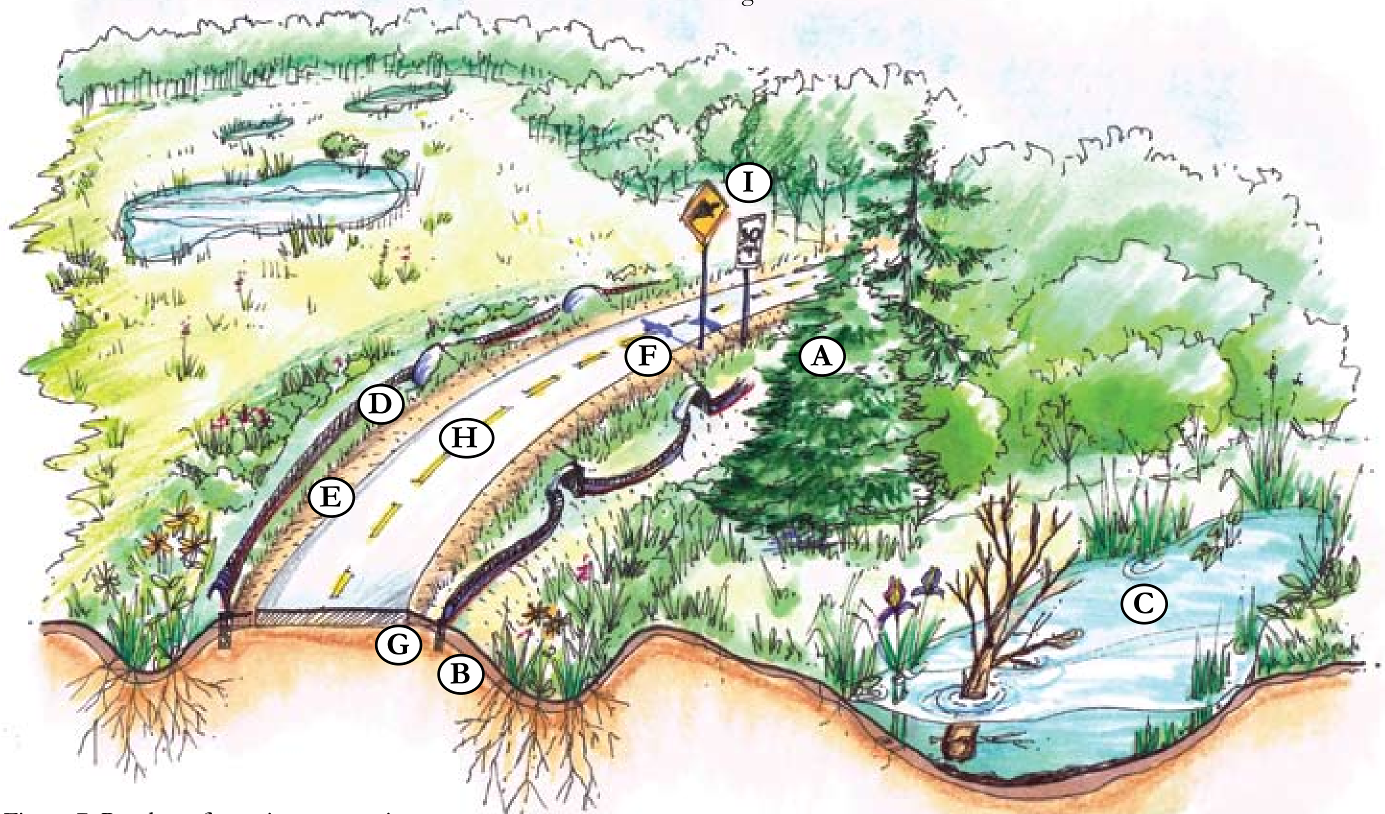


Figure 7. Road configuration, vegetation planted to block salt spray (A), and pollution-catching vegetated buffers (B) preserves high quality wetlands (C).

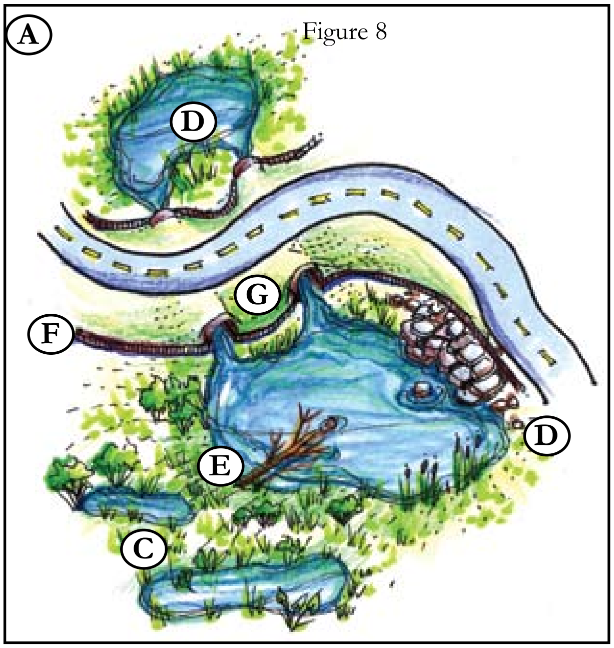
Do not mow along the shoulder in the spring during turtle nesting season (D).

No curb and gutter system to trap amphibians and reptiles on the road (E).

Road crossing structures maintain connectivity between amphibian and reptile habitat (F). An embedded barrier with curved top directs animals toward the crossing structures and restricts their movement into the road (G).

Reduced salt application in the winter reduces water salinity (H).

Wildlife crossing signs and lower speed limits at kill zones raise driver awareness and reduce road mortality (I).



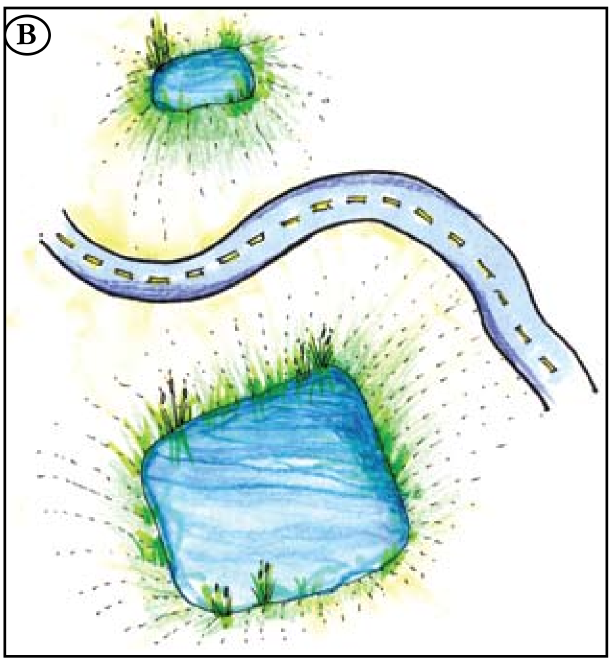


Figure 8. Landscapes which maintain hydrology, a variety of wetland types, and animal movements (A) provide habitat for a greater variety of amphibians and reptiles than do simplified landscapes with disconnected hydrology (B).

Fishless wetlands (C), rock retaining walls with crevices suitable for reptile cover (D), native vegetation and woody debris (E), herpetofauna barriers (F), and road crossing structures (G) support a variety of amphibian and reptile species.

Create compaction on the lower edge of wetland areas – During grading, vehicle tracks will compact the soil. These paths should be minimized, in general, but can be located on the lower side of wetland areas where soils need to be less permeable to water.

Stockpile and use sand, clay, topsoil, and high organic matter soils judiciously – Various soil types vary in texture and permeability and can be used to create a variety of wetland features and structure. Sand can be used to create well-drained areas, such as turtle nesting structures; clay can be used to create berms or slopes on the lower side of wetlands; and organic soils and topsoil can be used to topdress terrestrial areas for plant establishment (Biebighauser 2011). Organic soils should be combined with mineral soils with a high capacity for holding water to prevent loss before dense vegetation can be established.

Roads

Roads (including railroads) present several types of threats to amphibians and reptiles including habitat replacement, habitat degradation through decreased water quality, barriers to movement across the landscape, road mortality, and functioning as an attractive hazard for basking and travel corridors (Trombulak and Frissell 2000; Gibbs 2004; Andrews and Gibbons 2005; Rowe, Coval et al. 2005; Patrick, Gibbs et al. 2011) (See Section 3). Despite the many threats to herpetofauna associated with roads, road placement, construction techniques, and maintenance, public education can be used to lessen the impact of roads on herpetofauna.

Placement

Road placement relative to herpetofauna habitat can greatly affect the level of mortality along a road (Gunson et al. 2012) and create a barrier for movement of herpetofauna across the landscape (Gibbs 1998). Roads that do not conflict with seasonal migratory routes and herpetofauna habitat are less likely to have herpetofauna "kill zones". Also, road salt, petroleum, hydrocarbons and heavy metals are typical pollutants associated with roadways. Roadway design also dictates how road maintenance and vehicle use will impact water quality and the herpetofauna in those habitats. Prevention of pollutants from entering wetlands via the roadway is the best option.

Avoid herpetofauna habitat – Locating roadways away from critical herpetofauna habitats can minimize the impact on herpetofauna. Plan for roads to circumvent all habitat areas when possible; however, if this is not feasible, critical or high-quality communities should be avoided at a minimum. The Michigan Herp Atlas is a useful tool for determining known occurrences of herpetofauna and road-related mortality (if available). If placing a road near a critical habitat feature (e.g., a vernal pool), a landscape buffer should be used to mitigate impact to that feature and the herpetofauna using it (e.g., (Calhoun and Klemens 2002). Unmowed buffers (sometimes referred to as "grow zones"), rain gardens, and vegetated swales placed along roads can reduce erosion, intercept chemical and sediment adsorbed (non-point) pollution, and degrade pollutants before discharge of the water into herpetofauna habitat. Finally, if a wetland area cannot be avoided entirely, the road should be placed so that wetland is only on one side of the road to reduce mortality of amphibians and reptiles crossing between the wetlands (e.g., (Langen, Ogden et al. 2009).

Consider seasonal routes of movement for amphibians and reptiles – Roads should be placed to avoid or lessen impacts on local herpetofauna during their seasonal movements and migrations. Some Michigan herpetofauna use migratory routes that differ only slightly in location among years (Russell, Bauer et al. 2005; Jenkins, McGarigal et al. 2006); however, most movements across the landscape are tied to animals' life histories and long-term ecological conditions (Russell, Bauer et al. 2005; Semlitsch 2008). Annual migrations often are dependent on habitat features, such as the distribution of suitable areas for mating, egg laying, feeding, hibernation, and basking (Shine, Elphick et al. 2001; Jenkins, McGarigal et al. 2006). Weather conditions, such as temperatures and precipitation, can trigger migrations between upland and wetland areas for mating, egg laying, post emergence dispersal, and hibernation (Sexton, Phillips et al. 1990; Russell, Bauer et al. 2005).

Road Crossing Structures

If a road must be placed in or near areas of frequent herpetofauna movements or suitable habitat, under-road crossings and directional barriers greatly reduce habitat fragmentation and

Figure 9. Culverts historically have been undersized (left). This can create an impoundment upstream (A) and incise the channel downstream (B). This restricts hydrology and natural stream meanders as well as wildlife crossing in the culvert. Oversized culverts and overflow culverts (right) accommodate natural hydrology and provide more light and air circulation in culverts. Wingwalls or barrier fences (C) directing animals towards culverts can further decrease road mortality. Grates (D) in the top of culverts let in natural light.

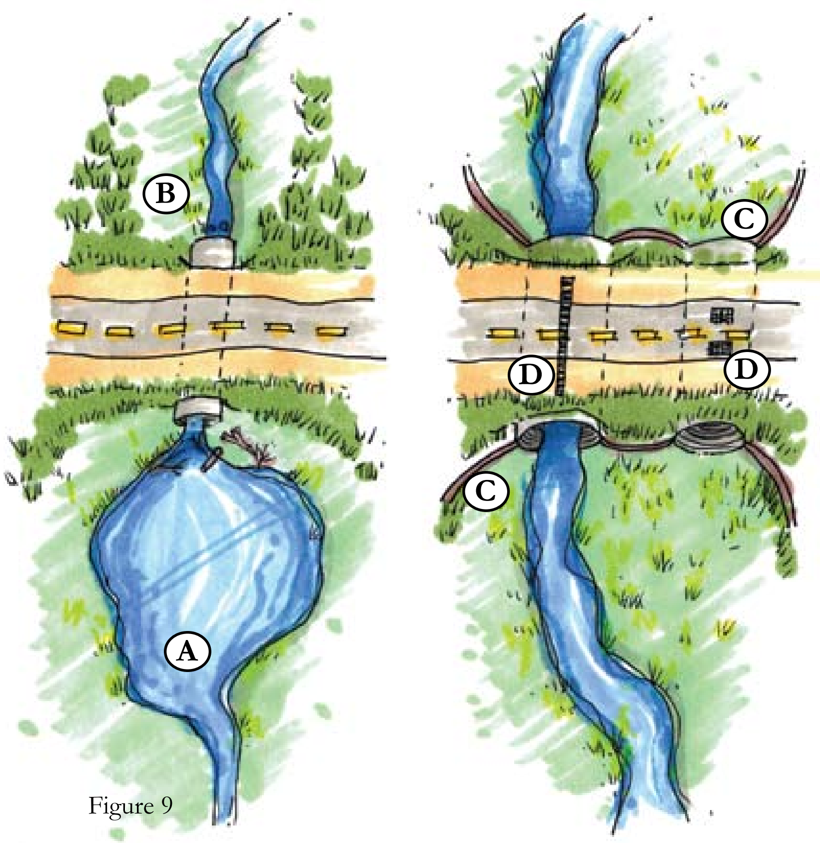


Figure 9

1. Wildlife culvert systems like this one can have a large impact on reducing road mortality.

1. Under-road culverts allow amphibians and reptiles to move over the landscape without entering dangerous roadways.

2. Incorporating barrier walls help guide wildlife into culverts and reduce road mortality.

3. Amphibians and reptiles, like this Eastern Snapping Turtle, may cross roads during migrations or bask on the warm surface

4-5. Dead-on-road amphibians and reptiles, like this Blanding's Turtle (4) and Eastern Fox Snake (5), are a common sight. This is most common during spring emergence, turtle nesting season, and fall migration.

herpetofauna mortality (Bassel 2002; Dodd, Barichivich et al. 2004; Pelletier, Nein et al. 2005; Rees, Roe et al. 2009). Turtle, snake, frog, and salamander species have all been observed crossing through under-road passages (Yanes, Velasco et al. 1995; Jackson 1996; Schrag 2003; Gartshore, Purchase et al. 2005; Kaye, Walsh et al. 2005). A professional designer or engineer should be consulted on the design of these structures to ensure public safety.

Document "kill zones" – Understanding where amphibians and reptiles cross roads and have the greatest risk is necessary to effectively and efficiently reduce mortality. Data collection can begin with anecdotal accounts but there is no substitute for conducting a "road-cruising" survey throughout the active season to clearly define the extent of "kill zones". A herpetologist or professional wildlife biologist that has demonstrated experience with herpetofauna can provide assistance conducting these surveys. It is important that observations of all amphibian and reptile data – dead or alive – be contributed to the Michigan Herpetological Atlas to help document these areas and help managers mitigate the negative impacts.

Install barriers and crossing structures at "kill zones" – Barriers will prevent most amphibians and reptiles from entering the roadway and are reported to be some of the most effective measures to decrease movement of wildlife onto roads (Glista, DeVault et al. 2009). A silt fence or drift fence can be used as a temporary, low cost solution to help move reptiles and amphibians safely across roads (Glista, DeVault et al. 2009). However, several manufacturers produce plastic, metal, and concrete wildlife barrier products that are more aesthetically pleasing and durable. Barriers should be embedded at least 6" into the ground to prevent "burrowers" (e.g. Mole Salamanders, *Ambystoma* spp.) from gaining access to the road. The top of these barriers should curve or angle away from the road to prevent "climbers" from going over. This type of barrier has reduced road mortality for herpetofauna and other wildlife (Bassel 2002; FHWA 2003; Dodd, Barichivich et al. 2004). Barriers should be placed to funnel herpetofauna directly into the entrances of an existing culvert, or bridge or a new crossing structure designed specifically to provide passage.

Maintain barriers and road crossings to ensure animal use – Overhanging vegetation can provide a path for herpetofauna over barriers and into the road, particularly for excellent climbers like Cope's Gray Treefrogs (*Hyla chrysoscelis*) and Eastern Gray Treefrogs (*H. versicolor*) (Dodd, Barichivich et al. 2004). Vegetation next to barriers should be maintained to ensure that none is overhanging or leaning on barriers. Road crossing structures that also convey water may occasionally need to be cleared of vegetation to ensure animals are not blocked from crossing through the structure.

Place crossing structures no more than 150 feet apart – More crossing structures spaced close together will decrease the barrier effect created by a road. However, crossing structures placed 150 feet apart appear to be suitable for several species (Ryser and Grossenbacher 1989). Even small herpetofauna, like the Spotted Salamander, have been observed successfully traveling to and crossing through road crossing structures placed over 90 feet apart (Jackson 1996).

1-2. Wildlife barriers which are anchored into the ground prevent amphibians and reptiles from burrowing under or crawling over into roadways or other hazardous areas.

Shorter crossing structures are better – Amphibians have been documented traveling over 130 feet through an under-road structure, but herpetofauna typically respond better to shorter crossing structures, crossing faster and with less hesitation (Krikowski 1989). Amphibians and reptiles using crossing structures potentially have a greater susceptibility to predation while using the structure since a predator could more easily corner or trap its prey in a confined area. A shorter crossing structure reduces the time for crossing and minimizes predation risk.

Oversize culverts for wildlife - Oversized culverts are favorable as they can be easier for herpetofauna to find and negotiate. This type of structure can also reduce maintenance and repair costs that result from large flood events, which are increasing due to climate change. Culverts should have a **minimum** of 1 foot of vertical clearance inside, and 2 feet of horizontal clearance. Some research suggests that tunnels >1.6 feet will likely accommodate the passage of the greatest number of amphibian and reptile species (Woltz, Gibbs et al. 2008). If a wildlife crossing structure contains a stream or river, the design recommendations in Section 5 should be consulted.

3. Oversized culverts with metal grated tops and soil bottoms let more light in and create conditions that are more natural and easier for amphibians and reptiles to navigate.

Carefully select culvert materials – Investigate potential impacts from the culvert material. Galvanized metals and some plastics may leach chemicals, and concrete retains moisture. Metals are excellent conductors, and air in tunnels may remain colder longer than the surrounding air. Current engineering guidelines should be consulted before a new structure is installed however, when possible select products

Kim Barrett

Kim Barrett

1-2. Wildlife crossing structures are becoming increasingly used throughout the U.S., Canada, and Europe.

with low-impact manufacturing processes, such as those that meet or exceed the American Green Building Council's LEED (Leadership in Energy and Environmental Design) standards. All work should also be in accordance with Federal and State engineering standards for roads, culverts, and bridges. Passage structures and materials used should be selected based on target species and their habitat needs present on each side of a roadway.

Mimic natural conditions - Crossing structures which are largely open to ambient light and conditions most closely mimic natural conditions typically encountered by wildlife, and are more suitable for herpetofauna to cross (Dexel 1989; Jackson 1996). This can be accomplished by creating larger tunnels or installing grates or slotted tops on culverts. Culverts with an open bottom allow amphibians and reptiles to cross on natural substrates and may be better suited for amphibian and reptile crossings than culverts with a metal or concrete bottom (Mazanti 2003). Also, planting native herbaceous plant species near culverts (as opposed to the turf grass typically planted along roads) can increase microclimate suitability for herpetofauna and increase the likelihood of culvert use (Mazanti 2003). Avoid using rip-rap or other stone placement near culverts. If rocks must be used, use as little as possible. Rock should be placed with gaps planted with native herbaceous vegetation to provide better access and cover for amphibians and reptiles (Yanes, Velasco et al. 1995; Mazanti 2003).

Size culverts and crossing structures to accommodate seasonal water levels – Pre-construction hydrologic processes should not be restricted by the crossing structure. Depending on the site, one or many culverts may be necessary to facilitate hydrologic processes without altering the ecosystem on both sides of the road. Spring amphibian migrations to breeding pools often coincide with snowmelt runoff and spring rains, creating treacherous flood conditions in culverts (Patrick, Schalk et al. 2010). Creation of dry ledges along the inside edges of a culvert or small bridge that is seasonally inundated can provide areas of refuge for smaller species to pass safely during periods of peak flow.

Examine the potential for predation at crossing structures – Raccoons and other predators are known to use culverts (Land and Lotz 1996; LaPoint, Kays et al. 2003). In areas of high predator densities, barrier fences and crossing structures may provide "easy pickings" for predators. Incorporation of grates on culvert ends can help reduce such predation pressures though it limits passage for larger herpetofauna such as turtles. No benefit would be gained by placing a crossing structure if predation would cause as much mortality as road-kills.

Provide habitat structures on both sides of a road – If creating a crossing structure is not feasible, creating features, such as turtle nesting sites or suitable breeding pools, away from the road surface. When possible, placement on both sides of the road may reduce or avoid the need to cross.

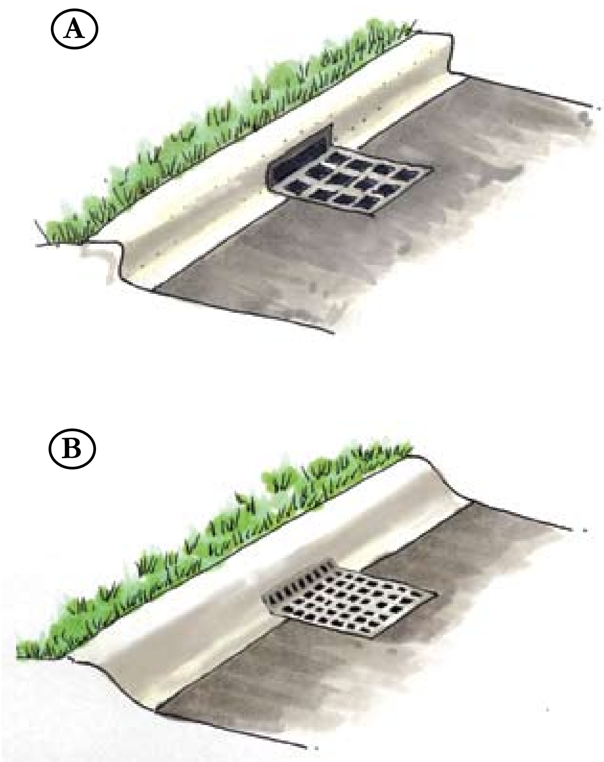
Figure 10. Section of a culvert with dry ledges to accommodate amphibian and reptile passage even when water levels are high.

Figure 10

Curbs, Gutters, and Drains

Vertical curbs trap small herpetofauna which have crawled, slithered, or hopped onto a road and try to exit on the opposite side. Once trapped by the curb, these animals are either killed by a vehicle or have to travel the length of the curb to find a traversable exit point. If an animal encounters a drain with typical-sized grate holes while traveling along a curb, they are likely to fall in and not be able to escape. This unfortunate fate is all too common for hatchling turtles or small frogs (personal observation ; Harding 1997; Piepgras, Sajwaj et al. 1998). Recommendations to avoid this unnecessary road mortality are described below.

Figure 11



Avoid placing or remove standard 6" vertical curb and gutter - A vertical 6" standard curb can trap small herpetofauna in the road. By not placing or by removing a standard 6" curb and gutter, they can more quickly cross the road thereby lessening the time in a 'danger zone'. Also, the lack of a curb and gutter allows for sheet drainage to the side of the road, and drains which can pose a threat to herpetofauna become unnecessary. Gutters often redirect runoff away from wetlands and can lead to altered wetland hydrologic processes.

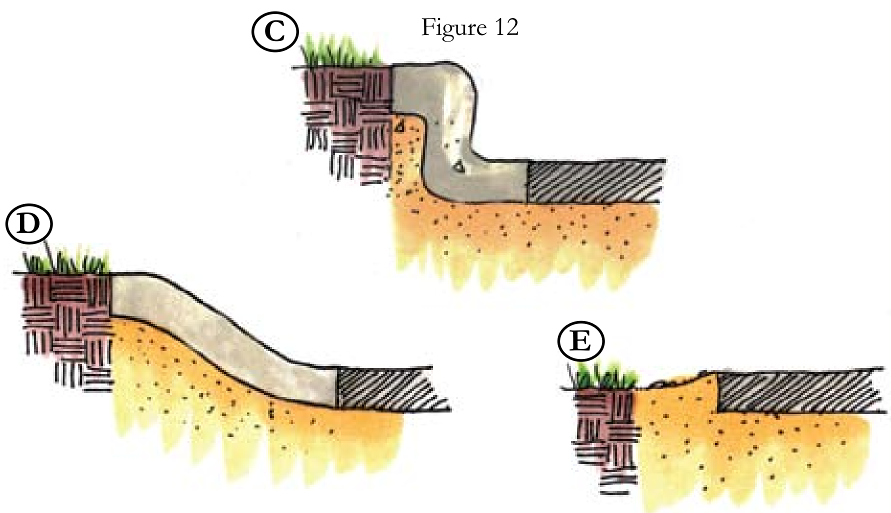
Place rolled curb - In instances where a curb is still needed to direct stormwater, a rolled curb with a <45° angle to the road will allow herpetofauna to climb over the curb (Piepgras, Sajwaj et al. 1998).

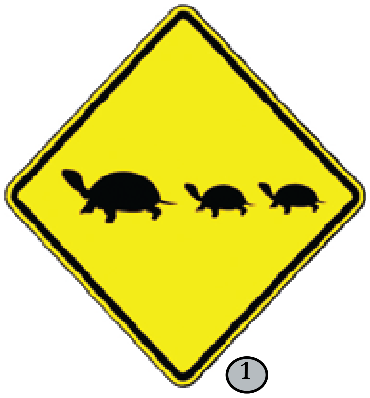
Fit drains with excluding grates - All drains should be fitted with grates with openings no larger than 1" x 1". This smaller size hole can ensure that even hatchling turtles are able to cross safely. These grates are sometimes advertised as "bicycle-safe" drains with small openings that prevent bicycle tires from becoming wedged in grates.

Figure 11. Typical drain grate (A) and wildlife friendly (a.k.a., bicycle safe) grates (B). Grates with smaller openings and grating along the curb prevent amphibians and reptiles from falling through.

Figures 12. Standard 6" curbs (C) can trap small amphibians and reptiles in roadways. Rolled curbs with a gentle slope (D) or no curb (E) can help small animals move to safety.

Figure 12





Marvin Blaine

1. Within Kensington Metropark, the installation of turtle and snake crossing signs at appropriate locations along the road appear to have helped decrease herpetofauna road mortality. Park patrons also have become more aware of the rich herpetofauna communities within the park and the need to protect these species. It is important to report observations of amphibians and reptiles on roads (both live and dead) to help document areas of high density to the Michigan Herp Atlas. Do not put yourself in danger by using extreme caution and always adhering to traffic laws.

Maintain Amphibian and Reptile Friendly Roadways

While road and culvert construction play a large role in the reduction of herpetofauna road mortality, post-construction measures can preserve water quality of nearby wetlands, further reduce fragmentation, and prevent road mortality to help maintain populations of herpetofauna.

Minimize salt and de-icer application - Use of salt should be avoided or reduced on roads, especially near wetlands, as increased salt concentrations can decrease survival of pollution-sensitive amphibians such as Spotted Salamanders, Wood Frogs, Northern Spring Peepers (*Pseudacris crucifer crucifer*), and Green Frogs (Karraker, Gibbs et al. 2008; Collins and Russell 2009), and are linked to increases of malformation in amphibians (Karraker and Ruthig 2009). Reductions in road salt application can also reduce the cost of purchasing and applying salt.

Buffer roads with vegetation - Where road salt is applied, the use of vegetated ditches can help infiltrate water to reduce runoff. As polluted water infiltrates the soil, plant roots and soil microbes can sequester harmful compounds or degrade them into inert compounds (Baltrenas and Kazlauskiene 2009).

Educate the public and motorists – Given the overwhelming evidence that use of salts as road de-icers increases the salinity of drinking water supplies and ecosystems (Jackson and Jobbágy 2005; Kaushal, Groffman et al. 2005), the public should be informed of how salt reduction policies can increase the quality of their community. Other local public education efforts can make the community aware of the need to protect and slow down for amphibians and reptiles as they move across the landscape where humans have built roads.

Time maintenance to avoid herpetofauna - Curb and shoulder maintenance can be scheduled to avoid activities during breeding and nesting seasons (typically April-June), migrations, or peak foraging times in areas where there are important herpetofauna populations. During these times, several species of herpetofauna migrate overland to look for mates and nesting areas, and turtles use the warm, dry substrate at the edges of roads for nesting.

Install wildlife crossing signs - Wildlife crossing signs may decrease road mortality through public awareness (Gunson and Schueler 2012). Signs should be implemented in documented or potential areas of high road mortality (i.e., between two wetlands), and sign type and graphics should be consistent at a regional scale (Gunson and Schueler 2012). These efforts should focus on migratory and breeding seasons of local amphibian and reptile species when they are most susceptible to road mortality.

Temporarily close roads – In rural areas with mass migrations of herpetofauna or other wildlife, a temporary road closure may prevent mass mortality and benefit local herpetofauna populations (Gibbs and Shriver 2005; Timm, McGarigal et al. 2007). These road closures have been successful in Europe, Canada, and parts of the U.S. (Seigel 1986; Jochimsen, Peterson et al. 2004).

Engage the public to move animals – Movement of animals across roads during migration events can be a viable option to reduce mortality, especially if locally supported in the community (Minnesota Herpetological Society 2010). These programs are only a temporary solution as they are incredibly labor intensive (they require catching animals using drift fences) and have inherent risks to participants. These events should only be conducted if an acceptable level of safety can be maintained for participants.

Slow traffic – Reduced speed limits and speed bumps can reduce traffic speeds which also reduces road mortality. This may be an option in residential or rural areas (Walston 2010).

Maintained Landscapes and Park Open Space

1.Grass maintained at <2” in height will deter amphibians and reptiles from inhabiting lawns and subsequently reduce mortality during mowing.

Figure 13. Alternately letting grass grow to >6” will provide cover and prey for amphibians and reptiles.

Simple steps in landscape maintenance can improve habitat quality, connectivity, and save money. By reducing or finding “herpetofauna-friendly” alternatives to the chemicals and pesticides used for management, herpetofauna diversity and abundance can be maintained or increased. Encouraging the presence of frog and snake species which eat pests can decrease the need for additional treatment.

Mowing

Although mowing can also be an effective management tool for reducing woody plant growth, it can cause direct mortality (Mitchell 1988; Durbian 2006; Meshaka Jr, Huff et al. 2008; Humbert, Ghazoul et al. 2009) and severely injure amphibians and reptiles as well as discourage use of sites by amphibians and reptiles and have significant negative impacts (Saumure, Herman et al. 2007). Mowing also affects habitat structure, temperature, humidity, and exposure to predation and desiccation.

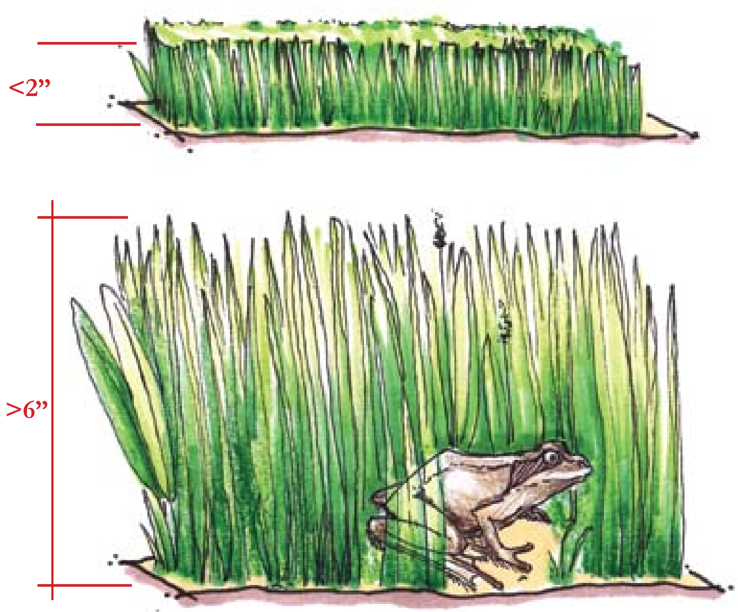
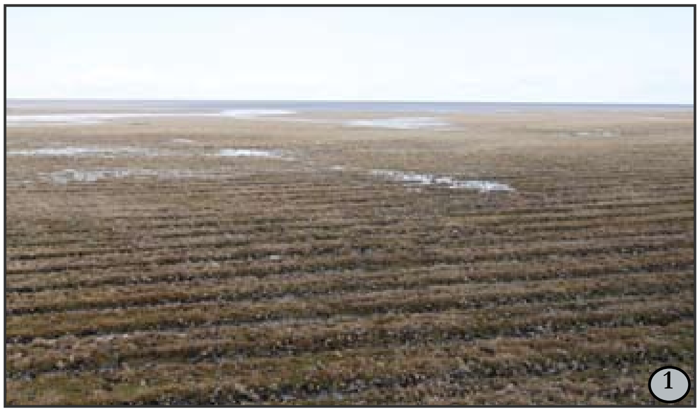


Figure 13

Mow infrequently and during the hottest times of the year – Less frequent mowing results in fewer mower-related mortalities of herpetofauna and other wildlife. Also, mowing less frequently also costs less and reduces carbon emissions. The best time to mow is during the hottest time of year, which in Michigan is generally July, when animals can flee or in late fall to early winter when animals are inactive. Turtles use edges of lakes and ponds and even grasslands of sandy upland areas for nesting. These turtles are slow-moving and sometimes require several hours to dig a nest and deposit their eggs. To avoid hitting turtles with



mowers, mow prior to or preferably after turtle nesting season (i.e., after early June). Mowing should be timed to avoid the turtle nesting season and the peak foraging and migration seasons of other amphibians and reptiles.

Set mower decks high (>6") or low (<2") – Setting mower blades 6" or more from the ground can help to avoid ground-dwelling wildlife. Additionally, by beginning in the center of the area to be mowed, herpetofauna may escape in all directions (Iowa NRCS 2005). Alternatively, if the presence of herpetofauna is not compatible with a landscape (e.g., discouraging Eastern Massasauga Rattlesnakes in public areas), mowing grass short (<2") can discourage the movement of herpetofauna into mowed areas and will reduce mower-mortality. This can be particularly effective for areas of known Massasauga encounters.

1. Beach grooming that includes tilling and mowing reduces the wildlife value and is often a continuous battle to maintain an artificial sandy beach area. This tilled and mowed costal area has become rutted and compacted, making it unsuitable for people in search of a sandy beach and herpetofauna in search of cover, food, and nesting areas.

2. Light fixtures that reduce spillage into the surrounding landscape are less likely to disrupt the natural cycles of amphibians and reptiles that are triggered by light cues.

Light Pollution

The intrusion of artificial light into wildlife habitat at night affects a diversity of wildlife species (Calhoun and Klemens 2002) and can alter the foraging, reproductive, and defensive behaviors of amphibians (Buchanan 1993; Wise and Buchanan 2006). Herpetofauna respond to artificial light in much the same way they do to natural light (Yorks and Sievert 2012). Herpetofauna use light as a cue for movement related to their need to thermoregulate (Sievert and Hutchison 1991), food availability, distribution, and movement between landscape features, as well as egg and breeding ground suitability (Halverson, Skelly et al. 2003). Additionally, disruptions to a natural photoperiod may cue seasonal changes (Buchanan 2006).

Apply 'dark-skies' principles - To avoid disruption of movement patterns and timing of life processes, low-lighting strategies should be used, especially near herpetofauna habitat (e.g., closer than 750 feet of a vernal pool; (Calhoun and Klemens 2002). Use low-spillage lights (lights that direct light downwards) and avoid use of fluorescent and mercury vapor lights(Calhoun and Klemens 2002). For further information and lighting recommendations, go to the International Dark Sky Association website.

1. The Shiawassee National Wildlife Refuge contains several diked wetlands which are drawn down in such a way and rate that the herpetofauna are able to migrate to suitable areas. Incorporating best management practices like this not only achieve the desired goals, but also reduce unnecessary risk to wildlife.

Controlling Access

Contact with nature can provide health benefits for people and enhance their appreciation and subsequent and protection of the environment (Maller, Townsend et al. 2008). Unfortunately, human access to natural areas can result in degraded wildlife habitat (Leung and Marion 1999; Marion and Farrell 2002). Areas of high-quality wildlife habitat or areas which support rare species should be protected from human disturbance and maintained as uninterrupted contiguous landscapes. Human disturbances such as trails, picnic areas, campgrounds, and hunting and fishing activity can facilitate the introduction of invasive species, create conditions suitable for opportunistic predators (e.g., raccoon, skunk, crow), increase erosion, and decrease water quality (Simberloff and Cox 1987; Simberloff, Farr et al. 1992; Hess 1994). They also fragment landscapes and increase potential for negative human interaction and persecution.

Lakes, Ponds, and Rivers

Lakes and ponds are often managed for multiple reasons including, aesthetics, recreation, wildlife viewing, waterfowl hunting, fishing, transportation, and the protection of human health. Management often includes control of aquatic plants (weeds) for aesthetics, ease of boating, and the promotion of native plant communities geared to game fish. Although these management objectives are not generally focused on wildlife, in most cases a few simple modifications to timing and technique of maintenance activities can benefit herpetofauna.

2. Spiny Softshell Turtles are particularly susceptible to draw downs on account of their soft, leathery skin and dependence on an aquatic environment. Timing such activities with consideration for their physiology and natural history can reduce mortality.

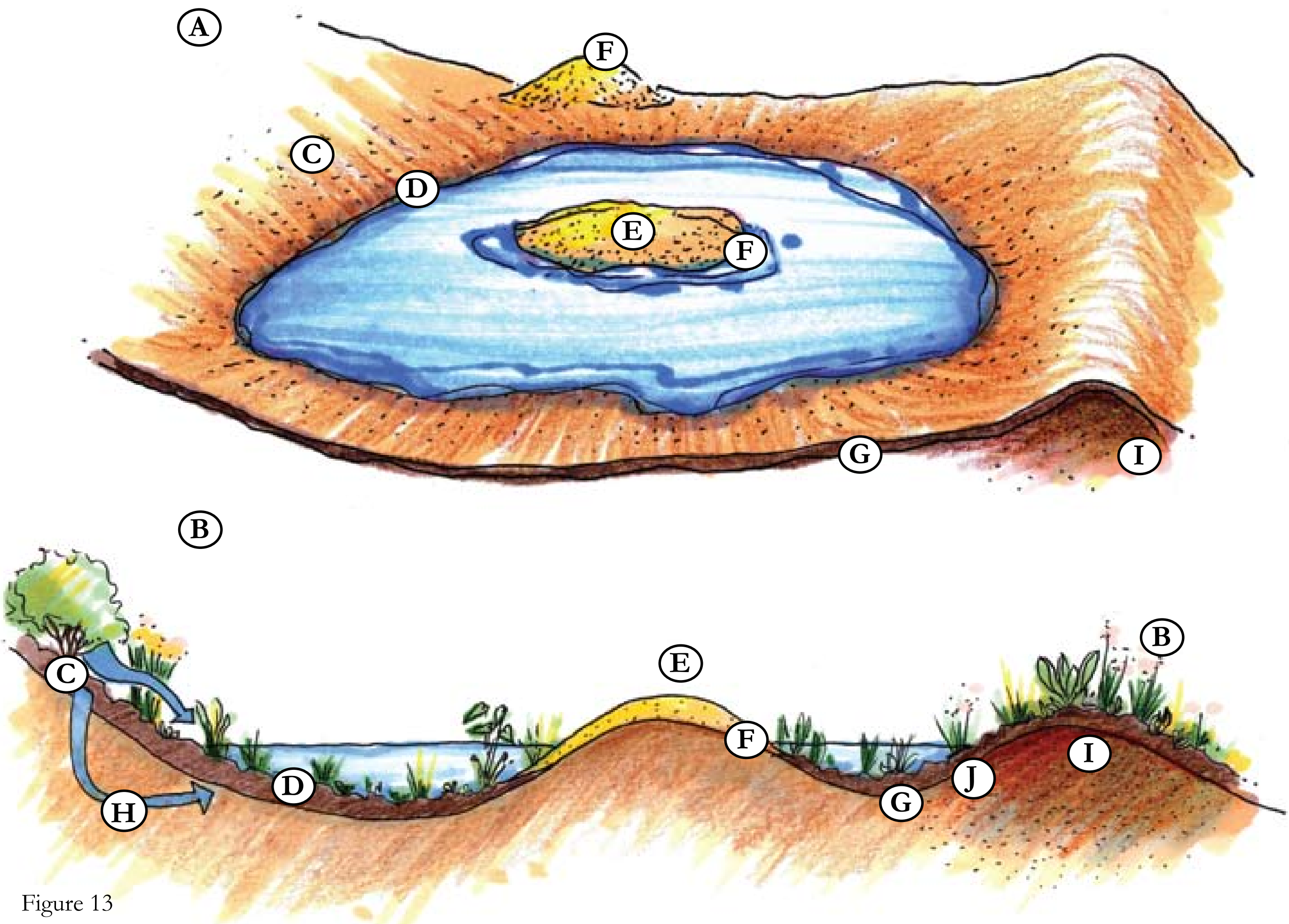


Figure 13

Figures 13. A conceptual drawing of final grading to create a wetland (A) and a section of the same wetland after vegetation has become established (B).

Create slopes that are <1:3-1:10 in upland areas (C) and slopes that are at least as shallow as 1:15-1:20 in portions of the wetland (D).

Create islands in wetlands to provide a protected area for turtle nesting and amphibian and reptile basking (E).

Sand can be used to create turtle nesting areas on islands and near the water (F). Soil high in organic matter can be distributed over a site to provide ideal growing conditions for a wide range of wetland and upland plants (G). Non-clay soils should be placed where infiltration is desired (H). Clay can be placed and compacted at the lower side of a wetland to create a berm which helps retain water (I).

Use fine grading to develop microtopographic features <6" deep (J).

Kathy Evans

Conservation Resource Alliance

1. Dredging in Muskegon Lake to remove toxins and pollution.

2. The above river is an example of a restored "natural channel".

Altered Hydrologic Processes and Aquatic Construction

Many amphibian and reptile communities rely on natural hydrologic processes to maintain seasonal water levels, water velocity, water chemistry, sediment movement, streambed structure, and lake bed composition that are suitable for their habitat requirements (Kupferberg 1996). Construction, dredging, impounding, and filling in aquatic systems as well as construction of impermeable surfaces and land draining in upland areas can alter the flow of water and sediment, stream stability, channel size, floodplain area, and fluctuations in water levels (Malmqvist and Rundle 2002; Graf 2006). These changes reduce the food, nesting, and cover opportunities that herpetofauna need, and thus alter the composition and reduce the diversity and breeding success of herpetofauna communities (Vandewalle and Christiansen 1996; Snodgrass 2000; Bodie 2001; Paton and Crouch III 2002; Lenhart, Nieber et al. 2011). Construction of dams or locks can also create barriers for and fragment populations of aquatic herpetofauna (e.g., Northern Map Turtles) (Bennett, Keevil et al. 2010), whereas seawalls can create barriers to more terrestrial herpetofauna that require access to land and water for nesting, basking, and cover (Engel and Pederson Jr 1998; Witherington, Hirama et al. 2011). The following information describes ways to avoid altering hydrologic processes.

Reduce disturbances to natural hydrologic processes – Altering the flow of water can create disturbances, which increase the likelihood of colonization by invasive plants and animals (Galatowitsch, Anderson et al. 1999; Zedler and Kercher 2004). When seasonally dry wetlands become inundated year-round fish may colonize the deeper water, and amphibians and reptiles without defenses against predaceous fish can suffer high predation (Bradford 1989; Figiel Jr and Semlitsch 1990; Hecnar 1997; Goodsell and Kats 1999). Increases in amphibian diversity and prolonged larval period can result from removal of predatory fish from these ponds (Walston and Mullin 2007). Many amphibians will also avoid breeding in these sites, thus reducing recruitment and population viability (Kats and Sih 1992).

Also, sites with a shortened hydroperiod have a decreased time frame for larval development, which can result in smaller adults at time of metamorphosis and lowered survival (Rowe and Dunson 1995). Managing water levels to mimic natural cycles and water depths will provide the necessary conditions (egg laying conditions, basking, food sources, cover areas, hibernacula) for herpetofauna and improve overall ecosystem function.

Maintain historical water connections – Historical connections and spatial flow regimes between water bodies should be examined and compared with current water levels and inputs to determine the location, size, and number of pipes and/or culverts. Often culverts are insufficiently sized to meet hydrologic and biological requirements – wildlife movements - at a site. Culvert sizing is typically assessed for the baseflow – water entering a stream via groundwater flow - and does not account for heavy precipitation or seasonal flooding. Undersized culverts can result in insufficient hydrologic equalization – impoundment of water upstream of a culvert and streambed scour and channel incision downstream of a culvert. Culverts should be sized appropriately to not disrupt the natural flow of water in all seasons. Placement of additional overflow culverts is beneficial to alleviate flooding in case of a severe storm (e.g., 500 year storm) and to enhance landscape connectivity for wildlife. An engineer or hydrologist with experience in culvert sizing and placement in natural systems should be consulted on high-risk or large projects.

1. For projects that involve direct habitat alteration such as dredging, or a draw down, animals should be collected from the area and relocated.

2. Dams alter the flow of water and sediment, water temperature, and habitat suitability for amphibians and reptiles.

Decrease impermeable surface area - Urbanization and increased impermeable surface within a watershed can alter hydrologic processes, degrade water bodies, and reduce wildlife diversity (Booth and C.R. 1997; Roy, Rosemond et al. 2003). Maintaining a high proportion of permeable surfaces and instituting water conservation construction techniques, such as rain gardens, bioswales, and non-combined sewer systems (e.g., in (United States Environmental Protection Agency 1999)), can help maintain more natural hydrologic processes.

Avoid impounding aquatic systems – Impeding the flow of water can change a wetland to a lake with reduced value for herpetofauna on the high side of the impediment, and virtually eliminate the wetland on the low side of the impediment, which also reduces herpetofauna habitat. If creation of impoundments is necessary, relocate animals prior to construction and associated drawdowns, and time construction and drawdowns for when herpetofauna is most mobile and able to respond to the change.

Conservation Resource Alliance

Design bridges to follow "natural channel" design principles - A useful alternative to road crossings are bridges that allow herpetofauna to cross streams safely. Temporary bridges can provide the benefits of a permanent crossing without the immediate and long-term effects that can result from building structures such as culverts. Bridges should be installed to span as much of the floodplain as possible to allow for the channel and floodplain to remain intact and reduce impacts to stream stability and habitat.

1. Impoundments, particularly those that have been around for 50+ years or more, develop a suite of wildlife associated with that community.

2. Restoration should consider natural water hydrodynamics and presence of oxbows and meander scars as important backwater habitats and when possible incorporate natural channel design principles

Do not fill or drain wetlands – Wetlands of all sizes (regulated and unregulated) are biologically important as they have a rich assemblage of amphibian species and provide valuable breeding and recruitment areas for several amphibians and reptiles (Semlitsch and Bodie 1998). Filling or draining even a small, seasonal wetland will displace or impact the population of amphibians and reptiles that rely on it to support their life cycle.

Avoid dredging in the littoral zone – The littoral zone is critical habitat for several species of herpetofauna that rely on this shallow, vegetated zone to carry out their life functions. Dredging in this area may displace herpetofauna to search for another suitable location. Often drawdowns are conducted prior to dredging operations, which will displace resident animals and could result in mortality if the drawdown is not conducted over a period of time that allows for movement out of the area or if conducted outside of the appropriate window.

Improve low-quality wetlands through dredging and restoration practices – Wetlands dominated by invasive vegetation (e.g., non-native cattails - *Typha angustifolia* and *T. x glauca* - or *Phragmites*) can provide little habitat for amphibians, reptiles, or other wildlife, and leaf litter from invasive vegetation may fill in areas of open water in the littoral zone. Although dredging is typically discouraged in littoral zones, in low-quality wetlands dredging (only in circumstances where this method is shown to be warranted and necessary) can provide a variety of water depths to support a rich diversity of amphibian and reptile species. If paired with responsible restoration practices, such as revegetation with native plants, well designed and carefully implemented dredging can improve wildlife habitat quality and meet other project objectives.

Repurpose materials slated for demolition to become habitat structures on site – The less material needed to be removed from a construction site, the less cost is incurred. Concrete, rocks, trees, logs, and other structures slated for demolition can be repurposed and installed on site as basking structures, hibernacula, egg laying areas, and cover for amphibians and reptiles. See Section 5 for details.

Install or maintain vegetated buffers and natural rock as an alternative to seawalls and hardened channels - Structures intended to reduce shoreline erosion are often subject to undercutting and washouts and prevent amphibians and reptiles from accessing upland habitat for basking, nesting, and foraging (Engel and Pederson Jr 1998; Mosier and Witherington 2002; Witherington, Hirama et al. 2011). This habitat fragmentation leads to reduced breeding success and greater competition for available resources. Planting or maintaining native vegetation in the 100-1,000 foot buffer along lake and river edges can stabilize the banks and shoreline while providing structure for amphibians and reptiles (Semlitsch 1998; Bodie 2001; Semlitsch and Bodie 2003; Calhoun, Miller et al. 2005). Natural rock provides crevices and irregular surfaces which diffuse water velocity and give herpetofauna a place to hide.

Create Oxbows during Dam Removal

Although not a true oxbow, a backwater portion of the Manistee River was preserved during a restoration of the fast-moving natural channel that had been impounded. This ponded area provides protection and food for sensitive hatchling turtles and other amphibians and reptiles that benefit from calm waters.

Michigan has over 2,500 dams (Michigan Department of Natural Resources and Michigan Department of Environmental Quality 2004). As these structures age, they need to be repaired or removed to ensure public safety. Repair is costly, making removal of dams which are no longer used or pose an environmental threat an economical option. Dams create barriers for amphibians and reptiles and can also greatly alter hydrologic processes and thermal conditions which effect breeding, nesting, basking, and hibernation (Lind, Welsh Jr et al. 1996; Bettaso 2013). The removal of these structures that impede the natural flow of water along watercourses can help restore the diversity of wildlife and may greatly increase population connectivity and enhance population viability in river systems. However, impoundments provide ponded areas which may support species not associated with the restored watercourse. Wetlands and exposed slopes within an impoundment often serve as important nesting areas for turtles. Dam removal and dewatering of riparian wetlands displaces animals, alters chemical, physical, and biological processes which affect herpetofauna habitat (Hart 2002). It is important to prepare for, and address, these potential problems to minimize impacts to the larger ecosystem. Wherever practical, consider creating an oxbow (a U-shaped lake formed when a meander is cut off from a river bend) areas or preserving some ponded portions along the watercourse to allow for species which have colonized wetlands and backwaters associated with the impoundment. The water current is much slower and water temperatures are warmer in these shallow wetlands than the main connecting watercourse and can be an ideal place for turtle mating, and basking, amphibian breeding and larvae development, and snake foraging grounds. Oxbows also provide excellent opportunities for placement of turtle nesting areas or other herpetofauna habitat structures. Review of historic aerial photography and soils maps will help guide locations of areas where wetlands were historically dominant prior to impounding. Consider the placement of turtle nesting structures along south slopes to provide secure replacement turtle nesting opportunities. When dewatering be prepared for migrating animals leaving the site and provide barriers to prevent reptiles and amphibians from entering adjacent roads. If possible, these animals can be relocated to nearby appropriate habitat or held and introduced to newly established backwater habitats onsite. When planning dam removal, it is extremely important to address short-term downstream sedimentation and possible contaminated soils. Increased sediment loads can very quickly impact macroinvertebrate communities thus causing serious disruptions to both aquatic and terrestrial food webs.

Dam removals are typically complicated, multifaceted projects that require coordination among many interested parties. Aquatic and upland areas are involved, and flowing water, removal of contaminated sediments, reconstruction of channel structure, restoration of aquatic and upland vegetation, protection of fish and wildlife communities, as well as typical construction concerns such as soil erosion control must be coordinated. Since these projects are complicated and each has a unique set of site conditions, a professional restoration biologist or other qualified professional should be contacted to proceed with any dam removal project. After a dam is removed, the exposed substrate in the previously impounded area is left bare and susceptible to colonization by invasive plants (Orr and Koenig 2006; Collins, Lucey et al. 2007). Invasive plants can be especially problematic if the substrate is high in micronutrients or is contaminated with toxic chemicals to which many native plants are not tolerant. Guidelines presented in this manual dealing with soil erosion control, wetland mitigation and restoration, stream and river restoration are applicable to dam removal.

Louis M. Landry

1. Aquatic plants like *Elodea canadensis* are an important food source and serve a role in nutrient absorption, oxygen production and critical cover for many amphibians and reptiles.

When seawalls, break waters, or jetties are necessary, include modifications to provide structure for herpetofauna - With a few minor modifications, break water, jetty, and seawall construction can provide herpetofauna cover, hibernacula, and basking structures. For example, using repurposed concrete and variable-sized stones to create crevices and tunnels into the structure provide places for snakes to take shelter and hibernate. A rough surface with several horizontal surfaces can provide places where a turtle or snake can climb out of the water to bask.

Aquatic Weed Control

Aquatic weeds can be native plants which are an important part of aquatic ecosystems and which provide habitat for amphibians and reptiles, or aquatic weeds can be non-native, invasive plants, such as Eurasian watermilfoil (*Myriophyllum spicatum)*, which alter ecosystem function. Herpetofauna-friendly strategies for weed control are detailed below.

Control nutrient inputs - The most effective and sustainable aquatic weed control is through management of nutrient inputs, usually nitrogen (N) and phosphorous (P) (Smith and Schindler 2009). These nutrient inputs often come from residential or agricultural land uses near a water body where aquatic weed control is a priority. Simple, yet wide-reaching changes, such as reductions in lawn fertilization and the creation of unmowed buffers near water bodies, can help to minimize fertilizer inputs and reduce growth of aquatic weeds.

Jim Harding

2. Red-eared Sliders can consume large amounts of both native and non-native vegetation, helping to provide health to aquatic ecosystems.

Intercept nutrients in the water – Filtration and abatement techniques for nutrient and pollution in water bodies are being developed and becoming more available on the market. One example is floating treatment wetlands, which use plants growing on floating mats to convert excess nutrients into plant matter, sequester phosphorous, and absorb pollutants through phytoremediation (Zhao, Xi et al. 2012). These mats also serve a similar function as floating bog mat structures by increasing the diversity of habitat structures within wetlands and providing protected basking sites for amphibians and reptiles.

Avoid mechanical weed harvesting - Removal of aquatic vegetation removes critical habitat for larval amphibians and hatchling turtles, and reduces available prey items for multiple species. Mechanical weed harvesting and cutting also displace, and often kill, turtles and amphibians (Booms 1999). Turtle fragments have been observed in the chopped plant material (Mifsud, personal observation). Weed harvesting can be largely ineffective as plants quickly regrow (Fox and Murphy 1990). Additionally, there is currently no machinery that excludes herpetofauna. Some machinery operators may try to avoid processing amphibians and reptiles with vegetation; however, this strategy is unlikely effective at avoiding small individuals which are difficult to see and individuals under the surface of the water.

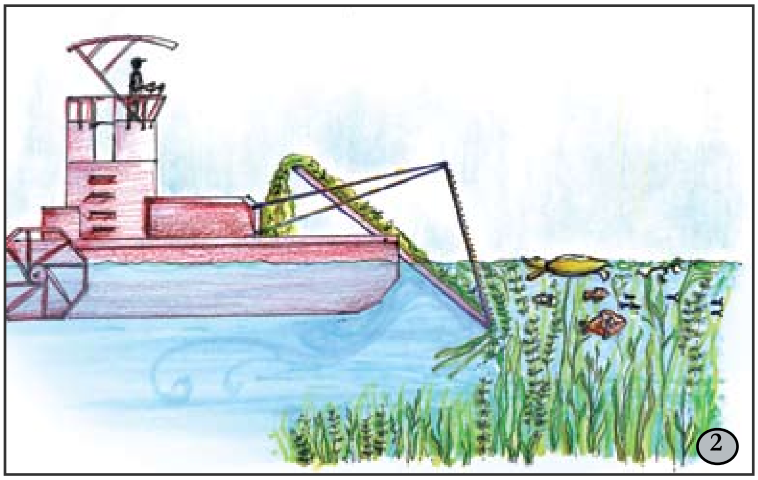
Avoid chemical control – Herbicides can harm amphibians and reptiles as well as other non-target plant and animal species (Getsinger, Netherland et al. 2008). Herpetofauna is especially sensitive to herbicides during egg and larval stages and chemicals should not be introduced into aquatic systems during these times. Low-concentration application of some herbicides used for aquatic weed control, such as Fluridone (brand name SONAR), while useful in controlling Eurasian watermilfoil, is required to be present in the water for over two months to effectively reduce Eurasian watermilfoil (Madsen, Getsinger et al. 2002). Although immediate amphibian and reptile die-offs have not been noted for this chemical, other herbicides have been linked to lowered reproduction rates and deformities from long-term exposure and/or bioaccumulation of herbicides (Johnson, Franke et al. 1999; Hayes, Collins et al. 2002; Hayes, Haston et al. 2003; Coady, Murphy et al. 2004; Howe, Berrill et al. 2009; Relyea and Jones 2009). Sadly, many herbicides and other chemicals used in the environment are not tested for their effects on amphibians and reptiles, and the negative impacts on amphibians and reptiles are unknown for these chemicals.

1. Eastern Spiny Softshell Turtles are masters of camouflage as they float among vegetation and can be difficult to spot from a boat.

2. Aquatic weed harvesters remove turtles and frogs basking at the surface of the water amongst submerged vegetation.

If avoidance is not possible, carefully time weed control - If suitable management of nutrient inputs is not possible, carefully timed herbicide application or mechanical weed harvesting may be considered based on the amphibian and reptile species present. If this option is selected for vegetation control, pre- and post-treatment monitoring of herpetofauna should be conducted. Monitoring can help assess the negative effects on herpetofauna and guide methods to reduce or avoid future losses.

Encourage native biological controls – Turtles, like Midland Painted Turtles and Red-eared Sliders (*Trachemys scripta elegans*), consume large amounts of aquatic plants. Creating suitable habitat conditions for these species may help to control weed growth. Encouraging native wildlife and maintaining healthy, diverse ecosystems is an effective strategy for reducing and preventing nuisance aquatic weeds.



Prevent introduction – The easiest way to control exotic vegetation is by preventing its introduction. One of the primary ways exotic vegetation is introduced to water bodies is by people transporting pieces of plants on equipment and boats. Following recommendations by Michigan Sea Grant (Gunderson, Kinnunen et al. 2004) to 1) assume every water body is contaminated 2) clean and dry boats and equipment between trips, and 3) decontaminate equipment following each use can reduce the likelihood of introduction of invasive vegetation to other water bodies.

1. Water control structures can help manage water levels to assist in habitat restoration, and to more naturally mimic hydrologic regimes. However, if timed poorly these activities can have significant effect on native wildlife.

Lake and River Level Alteration

To manage aquatic vegetation, reduce structural damage to marinas, boat docks, and launches, and increase habitat for waterfowl and other wildlife, wetland and lake levels are altered via drawdowns and inundations (Ducks Unlimited 2005). However, depending on the timing of these management techniques, herpetofauna numbers can be significantly reduced (See Section 3). Also, drawdowns can simulate drought conditions and force herpetofauna to travel in search of another water source. Many herpetofauna can only migrate short distances from wetlands and other bodies of water (approximately 200-300 meters) as they are sensitive to dry conditions and can easily desiccate (Schmid 1965; Grover and Ross 2000; Semlitsch 2000). The following management recommendations can provide information about when and how to alter water levels with minimal impacts to amphibians and reptiles.

Avoid artificially elevating water levels or conducting drawdowns when egg and larval stages will be affected - When altering water level, the life stages of herpetofauna present should be considered. Water levels artificially elevated in late summer may drown riverine turtle eggs laid in the riparian zone (Tucker, Janzen et al. 1997; Standing, Herman et al. 1999). When conducting early spring and summer drawdowns, be aware of amphibian eggs, larvae, and adults present and their level of mobility and ability to adjust to new conditions. Survival of juvenile amphibians is dependent on precipitation and inundated conditions (Berven 1990). Avoid draining areas with large numbers of amphibian eggs to prevent mortality (Kaltenecker, Beck et al. 1999). Without water these eggs will desiccate and the adult population the following year will likely be greatly reduced.

If necessary, conduct drawdowns during early fall – Drawdowns at any time of year can present risks to wetland herpetofauna; however, cooler temperatures and moist conditions in early fall can reduce stress on amphibians and reptiles. Most animals have metamorphosed by early fall, aside from a few species of frogs with tadpoles which can overwinter, and will have an opportunity to relocate to a suitable area for hibernation before a fall drawdown (Hoffman-Sailor West 2003). If drawdowns cannot be timed for early fall and suitable cover habitat and other wetland areas are available nearby, a late-summer drawdown may be considered, however drawdowns between March and July should be avoided (Paton and Crouch III 2002). In this instance, it is especially important to evaluate the ability of herpetofauna to relocate to nearby wetlands without a high mortality rate.

2. Rivers and streams provide habitat for species like Wood Turtle and Northern Water Snake as well as numerous fish and aquatic macroinvertebrate species.

Figure 14

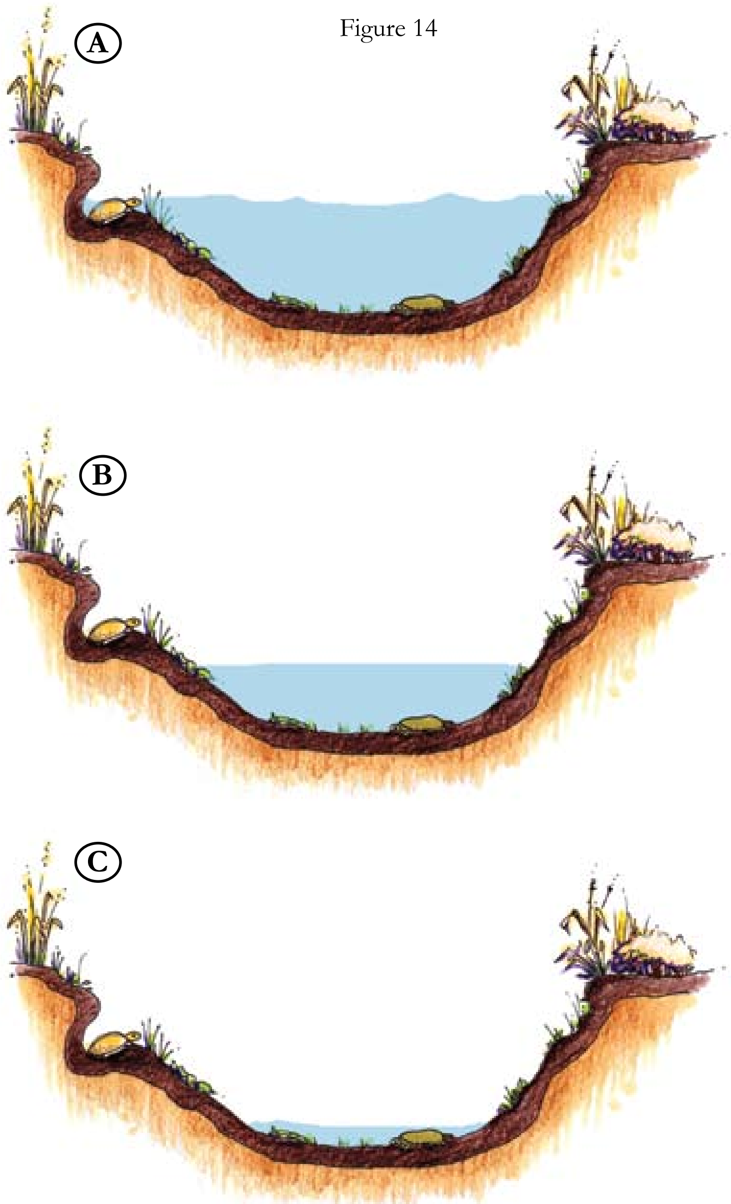


Figure 14. Late fall and winter draw downs can expose amphibians and reptiles that hibernate in the underwater banks of the wetland (A). Severe drawdowns can cause the remaining water to become anoxic as overwintering fish and turtles burrowed into sediments at the bottom continue to consume oxygen (B). An almost complete lack of water will cause what little water is left to freeze solid (C).

Do not conduct winter drawdowns – Winter drawdowns expose hibernating amphibians and reptiles to conditions and temperatures that cause them to freeze or desiccate and die (Bodie and Semlitsch 2000; Bodie and Semlitsch 2000). These drawdowns also kill littoral zone vegetation, which is inhabited by several species of herpetofauna, by exposure of the roots to freezing. Elect instead to conduct drawdowns in early fall.

Drain water towards small pools which will remain - When planning for a drawdown, locate 'low' areas within the area to be drained which will maintain water after the drawdown. Drain all water towards these areas. As water is slowly drained, any larvae will be able to move to these low areas and avoid being trapped in areas that will become dry. Additionally, by maintaining some inundated areas Green Frog and Bullfrog tadpoles will be able to overwinter.

Ensure suitable habitat nearby – Conducting a drawdown will reduce the habitat suitability for some amphibian and reptile species within the drawdown area. It is important to ensure that there is suitable habitat adjacent to the drawdown area and to evaluate the ability of herpetofauna to safely relocate.

Conduct trapping and relocation prior to late season drawdowns - Drawdowns that begin in late fall and early winter should be avoided since amphibians and reptiles hibernating at a specific water depth in a wetland will be exposed to fatal temperatures and conditions at a time when these animals are inactive. If a late season drawdown is necessary, trapping and relocation of herpetofauna to nearby wetlands should be evaluated and conducted by a certified wildlife biologist or professional herpetologist before the drawdown when herpetofauna is still active. State and/or Federal permits may be necessary to conduct amphibian and reptile recovery and translocation (See Appendix B).

Maintain water in newly inundated areas - Herpetofauna that may colonize this new wetland require water for the duration of egg and larval stages. Due to the variety of pond-breeding amphibians that can occur in the same wetland and their varied habitat requirements, water should be maintained for four to nine continuous months to provide for the life cycle of these amphibians (Paton and Crouch III 2002).

1. Watercraft of all sizes can impact amphibians and reptiles. Care should be taken to reduce risk to aquatic wildlife and their habitat.

Motorized Vessels

On water bodies with large populations of aquatic turtles, such as Northern Map Turtles and Eastern Spiny Softshell Turtles, use of high-powered motorized boats is discouraged because of possible injury to turtles. However, lower-powered motorized boats with electric or trolling motors do not typically harm turtles. Propellers can also cause turbulence, erosion, and destroy plants which results in loss of habitat for herpetofauna and other aquatic organisms. Improperly maintained and older engines can also introduce Polycyclic-Aromatic Hydrocarbon (PAH) contamination, and their use should be limited in sensitive wetlands or where sensitive or threatened species are known or likely present. Noise pollution produced by motors and motorized vessels can increase stress levels in fish and other wildlife (Morton and Symonds 2002; Wysocki, Dittami et al. 2006; Slabbekoorn, Bouton et al. 2010) and may also disrupt herpetofauna. Although these impacts are likely comparatively small to other threats to Michigan herpetofauna, little is known about how noise pollution impacts amphibians and reptiles, and this stressor may contribute to already declining herpetofauna populations. Use of non-motorized watercraft (e.g., row-boat, canoe, kayak) or electric watercraft can also avoid chemical and noise contamination.

2-3. Eastern Spiny Softshell and Northern Map Turtle are injured by high powered motorized boats. Incorporating no-wake zones and non-motorized zones can help maintain healthy turtle populations.

10. Conclusions and Next Steps

Cooperative Conservation

The protection and conservation of herpetofauna communities can be implemented into any maintenance, management, development, or ecological restoration work. Despite the many threats to the continued survival of herpetofauna species and communities in Michigan, people working in land management or development as well as concerned citizens can significantly improve habitat conditions and protect amphibians and reptiles. While all of the recommendations in this manual may not be feasible or practical at all sites, the potential to incorporate these BMPs can be considered whenever planning a project. The likelihood of sustained amphibian and reptile populations in Michigan can be greatly improved through planning, education, and thoughtfully planned and implemented restoration and habitat enhancement techniques focused on the natural history and conservation of herpetofauna communities. A lack of information about herpetofauna communities and threats to their viability is one obstacle to better conservation. Collecting information on species' status and distribution and threats to herpetofauna can help to clarify baseline conditions and present the 'big picture' of the condition of our herpetofauna communities. This information is vital in measuring success of conservation efforts, in

1-3. Implementing the practices introduced in this manual can contribute to improving the ecological integrity of a site. Utilizing herp-friendly activities will promote species richness and ensure long-term viability of Michigan herpetofaunal populations.

1-3. Long-term monitoring efforts like those conducted by Jim Harding on Wood Turtles in Michigan for over 45 years are critical to glean the extent of impacts and trends in threats. Few have been as dedicated as Mr. Harding to his work in amphibian and reptile conservation. Jim serves as a model for others in understanding the commitment necessary to conserve long-lived species. Our work today is built on the foundation of people like Jim and those that came before him. His work is also a reminder that the decisions we make today for amphibian and reptile conservation are not measured by the response next season but by the next generation.

prioritizing areas and species for conservation, and in helping to increase the efficiency and usefulness of species regulations. Only through a cooperative effort involving people in all fields with an impact on our natural resources can we protect not only herpetofauna, but all of Michigan's natural resources.

Measuring Success

The creation of this BMP Manual is a necessary step towards the protection and conservation of amphibians and reptiles in Michigan, but alone does not ensure success. A monitoring program to determine the success of recommendations described within the manual needs to be implemented. An adaptive approach could work to improve the efficacy of use of the BMP by setting realistic goals with measureable targets and realistic timeframes, monitoring those targets, and using collected data to reassess and revise the BMP. As the strategies and methods recommended in this manual are vetted in a wide variety of situations and conditions, in the short and long-term and at small and landscape scales, the solutions will be refined to be more economically and ecologically sound. We intend for this to be a living document and continued revisions will produce updated versions which are available in an on-line format through the HRM and project partners.

Appendices

Appendix A: Management and Development Action Timeline

Management or Development Action	January	February	March	April	May	June	July	August	September	October	November	December
Road maintenance	■	■	■				■	■			■	■
Herbicide, insecticide, and pesticide application	■	■	■				■			■	■	■
Dredging contaminents						■	■	■				
Aquatic weed harvest	■	■				■	■				■	■
Drawdowns						■	■	■	■			
Inundations					■	■	■	■				
Electrofishing					■	■	■	■	■			
Lampricide application	■	■	■								■	■
Mowing							■			■	■	■
Off-road vehicle and heavy machinery use							■	■				
Clearcutting and vegetation harvest						■	■	■	■			
Fire	■	■	■									
Construction						■	■	■				
Site grading						■	■	■				
Stream mitigation and dam removal						■	■	■	■			
Create habitat structures		■	■	■								
Relocation and translocation				■	■	■	■	■	■			

This timeline represents generalized recommendations, exact dates for activites are not provided due to variability in weather and site conditions. Decisions should be guided by species present and management objectives. It is recommended that a professional herpetologist or wildlife biologist with demonstrated experience with reptiles and amphibians be contacted before beginning any of the listed activities.

Appendix B: Community Matrix

		Michigan's Habitat Communities																									
	Species	Status	Lakes and Ponds	Streams, Rivers, and Floodplain	Emergent Marsh	Emergent Marsh Reed Canary Grass	Emergent Marsh Phragmites	Emergent Marsh Cattail	Great Lakes Coastal Marsh	Submergent Marsh	Bog/Muskeg	Fen	Wet Meadow	Wet Prairie	Floodplain Forest	Shrub Swamp	Deciduous Swamp	Coniferous Swamp	Vernal Pools	Deciduous/Mixed Coniferous Forest	Prairie /Grassland	Shrub/Scrub	Sandy Uplands /Dunes	Old Field	Agriculture Areas	Urban/Suburban
Snakes	Kirtland's Snake *(Clonophis kirtlandii)*	E											X	X	X	X	X			X	X					
	Blue Racer *(Coluber constrictor foxii)*	SN									X	X	X	X						X	X		X	X	X	X
	Northern Ring-necked Snake *(Diadophis punctatus edwardsii)*	SN													X				X	X	X					X
	Eastern Hog-nosed Snake *(Heterodon platirhinos)*	SN										X	X	X						X	X	X	X	X	X	X
	Eastern Milk Snake *(Lampropeltis triangulum triangulum)*											X	X	X						X	X	X	X	X	X	X
	Copper-bellied Water Snake *(Nerodia erythrogaster neglecta)*	E	X		X	X						X	X	X	X	X	X		X	X	X	X		X	X	X
	Northern Water Snake *(Nerodia sipedon sipedon)*		X	X	X	X		X	X	X		X	X		X				X							
	Eastern Smooth Green Snake *(Opheodrys vernalis vernalis)*	SN										X	X	X							X	X	X	X		
	Eastern Fox Snake *(Pantherophis gloydi)*	T	X		X	X	X	X	X				X	X						X	X	X		X	X	X
	Black Rat Snake *(Pantherophis spiloides)*	SC													X	X	X			X	X	X		X	X	X
	Western Fox Snake *(Pantherophis vulpinus)*	SN		X																X			X	X	X	X
	Queen Snake *(Regina septemvittata)*	SC	X	X	X																					
	Eastern Massasauga Rattlesnake *(Sistrurus catenatus)*	SC		X	X	X		X	X		X	X	X	X	X	X					X			X		X
	Northern Brown Snake *(Storeria dekayi dekayi)*				X	X			X			X	X	X		X				X	X			X	X	X
	Northern Red-bellied Snake *(Storeria occipitomaculata occipitomaculata)*				X	X			X			X	X	X		X				X	X			X	X	X

SN, species of greatest conservation need; SC, special concern; T, threatened; E, endangered; ND, population status not determined

		Michigan's Habitat Communities																								
	Species	Status	Lakes and Ponds	Streams, Rivers, and Floodplain	Emergent Marsh	Emergent Marsh Reed Canary Grass	Emergent Marsh Phragmites	Emergent Marsh Cattail	Great Lakes Coastal Marsh	Submergent Marsh	Bog/Muskeg	Fen	Wet Meadow	Wet Prairie	Floodplain Forest	Shrub Swamp	Deciduous Swamp	Coniferous Swamp	Vernal Pools	Deciduous/Mixed Coniferous Forest	Prairie /Grassland	Shrub/Scrub	Sandy Uplands /Dunes	Old Field	Agriculture Areas	Urban/Suburban
Snakes (Cont.)	Butler's Garter Snake *(Thamnophis butleri)*			X	X	X			X						X	X			X	X	X			X		X
Snakes (Cont.)	Northern Ribbon Snake *(Thamnophis sauritus septentrionalis)*		X	X	X	X		X	X			X	X	X		X			X		X					
Snakes (Cont.)	Eastern Garter Snake *(Thamnophis sirtalis sirtalis)*		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Turtles	Eastern Spiny Softshell *(Apalone spinifera spinifera)*		X	X					X	X																
Turtles	Eastern Snapping Turtle *(Chelydra serpentina serpentina)*		X	X	X	X		X	X	X	X	X							X							X
Turtles	Western Painted Turtle *(Chrysemys picta bellii)*		X	X	X	X		X	X	X	X	X							X							X
Turtles	Midland Painted Turtle *(Chrysemys picta marginata)*		X	X	X	X		X	X	X	X	X							X							X
Turtles	Spotted Turtle *(Clemmys guttata)*	T	X		X						X	X	X	X			X		X							
Turtles	Blanding's Turtle *(Emydoidea blandingii)*	SC	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X		X	X		X
Turtles	Wood Turtle *(Glyptemys insculpta)*	SC		X																X	X		X	X		
Turtles	Northern Map Turtle *(Graptemys geographica)*		X	X					X	X																
Turtles	Eastern Musk Turtle *(Sternotherus odoratus)*		X	X	X				X	X																X
Turtles	Eastern Box Turtle *(Terrapene carolina carolina)*	SC			X							X	X	X	X	X				X	X		X	X	X	X
Turtles	Red-eared Slider *(Trachemys scripta elegans)*		X	X	X	X				X																X

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		Michigan's Habitat Communities																								
	Species	Status	Lakes and Ponds	Streams, Rivers, and Floodplain	Emergent Marsh	Emergent Marsh Reed Canary Grass	Emergent Marsh Phragmites	Emergent Marsh Cattail	Great Lakes Coastal Marsh	Submergent Marsh	Bog/Muskeg	Fen	Wet Meadow	Wet Prairie	Floodplain Forest	Shrub Swamp	Deciduous Swamp	Coniferous Swamp	Vernal Pools	Deciduous/Mixed Coniferous Forest	Prairie /Grassland	Shrub/Scrub	Sandy Uplands /Dunes	Old Field	Agriculture Areas	Urban/Suburban
Salamanders, Newts and Mudpuppies	Blue-spotted Salamander *(Ambystoma laterale)*	SN			X											X	X	X	X	X						X
	Spotted Salamander *(Ambystoma maculatum)*	SN			X											X	X		X	X						X
	Marbled Salamander *(Ambystoma opacum)*	E														X	X		X	X						
	Unisexual Salamander *(Ambystoma sp.)*														X	X	X	X	X	X					X	X
	Small-mouthed Salamander *(Ambystoma texanum)*	E														X	X		X	X						
	Eastern Tiger Salamander *(Ambystoma tigrinum)*	SN	X		X								X	X		X	X		X	X	X			X	X	X
	Southern Two-lined Salamander *(Eurycea cirrigera)*	ND		X																X						
	Northern Dusky Salamander *(Desmognathus fuscus)*	ND		X																X						
	Four-toed Salamander *(Hemidactylium scutatum)*	SN									X					X	X	X	X	X						
	Mudpuppy *(Necturus maculosus)*	SN	X	X																						
	Central Newt *(Notophthalmus viridescens louisianensis)*		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X						X
	Red-spotted Newt *(Notophthalmus viridescens viridescens)*		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X						X
	Eastern Red-backed Salamander *(Plethodon cinereus)*														X					X						X
	Western Lesser Siren *(Siren intermedia nettingi)*	SC	X	X	X																					

SN, species of greatest conservation need; SC, special concern; T, threatened; E, endangered; ND, population status not determined

		Michigan's Habitat Communities																								
	Species	Status	Lakes and Ponds	Streams, Rivers, and Floodplain	Emergent Marsh	Emergent Marsh Reed Canary Grass	Emergent Marsh Phragmites	Emergent Marsh Cattail	Great Lakes Coastal Marsh	Submergent Marsh	Bog/Muskeg	Fen	Wet Meadow	Wet Prairie	Floodplain Forest	Shrub Swamp	Deciduous Swamp	Coniferous Swamp	Vernal Pools	Deciduous/Mixed Coniferous Forest	Prairie /Grassland	Shrub/Scrub	Sandy Uplands /Dunes	Old Field	Agriculture Areas	Urban/Suburban
Frogs and Toads	Blanchard's Cricket Frog *(Acris crepitans blanchardi)*	T	X	X	X				X			X	X	X							X					
	American Toad *(Bufo americanus)*		X		X	X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Fowler's Toad *(Bufo fowleri)*	SN	X		X			X	X			X	X	X						X	X		X	X		X
	Cope's Gray Treefrog *(Hyla chrysoscelis)*		X	X	X	X		X	X			X			X	X	X		X	X	X	X		X		X
	Eastern Gray Treefrog *(Hyla versicolor)*		X	X	X	X		X	X			X			X	X	X		X	X	X	X		X		X
	Northern Spring Peeper *(Pseudacris crucifer crucifer)*		X	X	X			X	X			X	X	X	X	X	X	X	X	X	X	X		X	X	X
	Boreal Chorus Frog *(Pseudacris maculata)*	SC	X		X				X		X								X							
	Western Chorus Frog *(Pseudacris triseriata)*	SN	X	X	X	X		X	X			X	X	X	X	X	X	X	X	X	X	X		X	X	X
	Bullfrog *(Rana catesbeiana)*		X	X	X	X		X																	X	X
	Green Frog *(Rana clamitans melanota)*		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X						X	X
	Pickerel Frog *(Rana palustris)*	SN	X	X	X						X	X	X	X							X			X		
	Northern Leopard Frog *(Rana pipiens)*	SN	X	X	X	X		X	X		X	X	X	X		X					X			X	X	X
	Mink Frog *(Rana septentrionalis)*	SN	X		X	X		X			X	X														
	Wood Frog *(Rana sylvatica)*		X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X						X

SN, species of greatest conservation need; SC, special concern; T, threatened; E, endangered; ND, population status not determined

Rana (=Lithobates); Bufo (=Anaxyrus)

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