



Michigan Amphibian & Reptile Best Management Practices



Third Edition



Michigan Amphibian and Reptile Best Management Practices Third Edition



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Table of Contents

Acknowledgements	i
1. Introduction	1
Purpose and Intended Use of This Manual.....	1
2. Amphibians and Reptiles of Michigan	5
The Ice Age and Herpetofauna in Michigan	7
Paleoecological Context: The Hypsithermal and the Prairie Peninsula	10
Relict Populations and Post-Glacial Dispersal Patterns	11
Glacial Geology and Modern Habitat Distribution	12
The Unprecedented Nature of Contemporary Change	13
Natural History of Herpetofauna in Michigan.....	13
Michigan Herpetofauna: Ecological and Habitat Requirements	15
Amphibians	16
Reptiles	17
Michigan Herpetofauna Community Associations and Habitats	18
Rare Species Showcase	19
Eastern Massasauga Rattlesnake	19
Blanding’s Turtle.....	22
<i>Northern Mudpuppy</i>	25
Blanchard’s Cricket Frog	27
3. Threats to Amphibians and Reptiles.....	29
Habitat Loss, Degradation, Fragmentation, and Urbanization.....	29
Wetland Mitigation	31
Construction Impacts.....	32
Shoreline Hardening	32

Landscape Succession 34

Functional Value vs. Botanical Composition 35

Watercourses in Successional Landscapes..... 37

Roads and Other Transportation 37

Urbanization 39

Prescribed Fire.....39

Herps and Agriculture 40

Agricultural Landscapes as Habitat 41

Machine-Related Mortality in Agricultural Landscapes 41

Pesticide Toxicity in Agricultural Settings.....41

Chemical Use 42

 Salts and Heavy Metals 43

 Polycyclic aromatic hydrocarbons (PAHs) and other Hydrocarbons 43

 Pharmaceuticals and hormones 44

 Excess Nutrients..... 44

 Pesticides 45

 Piscicides 48

Alterations to Hydrologic Processes 51

 Dams and Impoundments 53

 Habitat Fragmentation and Population Isolation 54

 System-Wide Ecological Transformation 54

 Dams and Riverine Alterations..... 55

 Dam Maintenance, Drawdowns, and Refill Operations..... 55

 Drawdowns.....56

 Lake Refill..... 57

 Dam Removal, Restoration, and Repair 58

Pre-Construction Planning and Baseline Data..... 59

Design for Functional Habitat 59

Emergency and Non-Standard Timing Work.....61

Infrastructure Impacts 61

Construction Impacts of Alternative Energy Infrastructure to Herpetofauna
62

Wind Energy: Direct Habitat and Ecological Impacts 63

Habitat Loss, Degradation, and Fragmentation 63

Anthropogenic Noise and Vibration Pollution..... 64

Species-Specific Behavioral and Ecological Responses 65

Mitigation Strategies for Renewable Energy Development..... 66

Strategic Siting and Pre-Construction Assessment 66

Impact-Minimizing Design..... 67

Maintaining Connectivity 67

Habitat Creation and Operational Co-Benefits..... 67

Decommissioning and Site Restoration..... 67

Illegal Collection and Overharvesting..... 67

Persecution 69

Invasive Species/Nuisance 70

Non-native Herpetofauna in Michigan 74

Disease 75

 Emerging Infectious Diseases (EIDs) 76

Climate Modification 78

 Projected Climate Trends and General Impacts 80

 Hydrological Extremes: Drought and Flooding.....80

 Phenological Shifts and Life History Responses.....82



The Great Lakes as a Potential Climate Refuge 83

Insufficient Assessment 83

4. Conservation Efforts 85

Existing Conservation Guidelines 86

State, Federal, and International Regulations 89

Herp HAT: the Herpetofauna Habitat Assessment Tool for Michigan..... 93

The Michigan Herpetological Atlas 97

5. Project Planning..... 101

Obtain the Appropriate Permits.....101

Evaluating the Site..... 102

Plan to Maintain Ecologically Functional Landscapes 105

Herps and Riverine Impacts: Dams 108

Implement Herp-friendly Work..... 115

6. Ecological Restoration and Mitigation and Habitat Design..... 119

Planning Restoration and Mitigation 119

Wetland Mitigation and Restoration 123

Stream and River Restoration and Mitigation.....129

Shoreline Hardening and Habitat Loss..... 129

Riprap Management and Habitat Enhancement..... 131

Ecological Value for Snakes.....131

Streambank Stabilization and Erosion Control 132

Stream Restoration Design Elements 135

Wildlife Passages and Culvert Design 137

Wildlife Passages 139

Dam Bypasses and Fish Ladders 140

Turtle-Specific Passages 140

Shoreline Access Ramps 141

Wetland Mitigation and Banks.....141

Habitat Design 144

Agricultural Habitat Mitigation..... 146

Mitigation Strategies for Chemical Use in Agricultural Landscapes..... 146

Operational Modifications to Reduce Impacts 147

Backyard Habitat 149

The Role of Private Landowners in Herpetofauna Conservation..... 149

Core Habitat Features for Backyard Implementation 150

Aquatic Habitat: Backyard Ponds 150

Supplemental Artificial Habitat Features 151

Turtle Nesting 152

Turtle Hibernacula 156

Turtle Basking.....157

Snake Hibernacula 157

Snake Nesting Structures 158

Snake and Lizard Basking and Cover 158

Snake and Lizard Nesting Sites 159

Amphibian Egg Laying Sites.....159

Frog and Toad Cover and Basking Sites..... 160

Salamander Cover and Foraging Sites 161

Upland Conditions for Reptiles 162

Upland Conditions for Amphibians 162

Relocation, Translocation, and Rescue 162

Captive Breeding and Rare Species Headstarting 165



Headstarting as a Population Augmentation Tool for Turtles 165

Definition and Rationale 165

Documented Efficacy and Post-Release Ecology 166

Strategic Applications for Population Recovery 167

Integration with Complementary Conservation Measures 168

Critical Considerations and Limitations 169

7. Management Techniques.....173

Chemical Applications and Management 173

 Pesticides, Nutrients, and Fertilizers 174

 Chemical Reduction and Natural Landscaping 175

Oil and Chemical Spill Response..... 180

Metal and Toxic Contamination.....181

Stormwater Management and Soil Erosion Control 182

 Wildlife Barrier Fencing (WBF) 183

 Effectiveness for Turtles and Snakes..... 184

 Commercial Exclusion Fencing Products 186

 Wildlife-Friendly Soil Erosion Control 187

 Forest Health and Herps 191

 Succession..... 193

 Forest Management and Silviculture 194

 Historical Context and Modern Practices 195

 Best Management Practices for Silviculture 196

 Harvest Techniques 198

 Vehicle Use.....200

 Vernal Pool Protection and Conservation 202

 Streamside/Riparian Zone Harvest 209

Prescribed Burns 210

Planning Considerations 213

Mowing 219

Managing with Animals.....220

Rewilding 220

Managed Grazing..... 221

Lakes, Ponds, and Rivers..... 223

 Aquatic Weed Control..... 223

 Lake and River Level Alteration 225

 Lake Refill 229

Fisheries Sampling and Management 229

 Hook and line fishing.....230

 Electroshocking/electrofishing 231

 Chemical Fish Control and Sampling..... 231

 Lamprey Control.....232

 Fish Hatchery Rearing Ponds.....234

 Net Sampling 234

Decontamination of Clothing and Equipment..... 236

 Decontamination of Aquatic Vessels and Gear 238

 Decontamination of Terrestrial Vehicles and 239

 Heavy Equipment 239

Invasive Species Management 240

Importance of Herps for Invasive Species Management..... 242

 Plant Invaders.....243

 Animal Invaders.....246

Subsidized Predator Management 249



8. Development Techniques 252

Horizontal Directional Drilling and Boring 252

Site Grading and Topography 253

Transportation 256

 Road Placement 256

 Road Crossing Structures 257

 Curbs, Gutters, and Drains 264

 Maintain Amphibian and Reptile Friendly Roadways 265

 Railroad Mitigation Measures 267

 Boating Mitigation Measures 269

Maintained Landscapes and Park Open Space 270

 Mowing 270

 Light Pollution 271

 Controlling Access 272

Altered Hydrologic Processes and Aquatic Construction 273

 Dam Bypasses and Fish Ladders 281

 Turtle-Specific Passages 282

 Shoreline Access Ramps 283

 Dam Removal and Restoration 283

 Pre-Construction Planning and Baseline Data 284

 Dewatering and Wildlife Considerations 284

 Creating Oxbows and Habitat Features 284

 BMPs for Removal Projects 285

 Streambank Stabilization and Erosion Control 286

Alternative Energy 289

 Wind Energy 289

Other Alternative Energy Sources (Biomass, Hydropower, Solar) 291

9. Conclusions and Next Steps..... 294

 Cooperative Conservation 294

 Measuring Success 295

Appendix A: Community Matrix..... 298

Appendix B: Management Timelines..... 302

References 304



Acronym List

ACO- Artificial Cover Object	NPE – Nonylphenol Ethoxylates
ATV – All-terrain Vehicle	NRCS – Natural Resources Conservation Science
ARTAC- Amphibian and Reptile Technical Advisory Committee	NREPA – Natural Resources and Environmental Protection Act
BMP – Best Management Practices	NPS- National Park Service
CARL – Conservation and Recreation Lands	PAH – Polycyclic Aromatic Hydrocarbons
CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora	PARC- Partners in Amphibian and Reptile Conservation
CRP – Conservation Resource Program	PCB- Polychlorinated Biphenyl
C-Scores – Coefficient of Conservatism Scores	POEA – Polyethoxylated Tallowamine
DDT – Dichloro-Diphenyl-Trichloroethane	RD- Rural Development
DDE- Dichlorodiphenyldichloroethylene	SBS- Shifting Baseline Syndrome
EGLE – Michigan Department of Environment, Great Lakes, and Energy	SCA- Service Center Agencies
EID – Emerging Infectious Disease	SFD - Snake Fungal Disease
EMR – Eastern Massasauga Rattlesnake	SGCN - Species of Greatest Conservation Need
EPA – Environmental Protection Agency	SMZ- Streamside Management Zone
ESA – Endangered Species Act	TFM - 3-Trifluoromethyl-4-Nitrophenol
FDA – Food and Drug Administration	USDA - United States Department of Agriculture
FSA – Farm Service Agency	USFWS - United States Fish and Wildlife Service
GIS – Geographic Information Systems	USGS - United States Geological Survey
HAB- Harmful Algal Bloom	UV - Ultraviolet
HDD – Horizontal Directional Drilling	WBF - Wildlife Barrier Fencing
HCO- Holocene Climatic Optimum	WBHG - Woody Biomass Harvesting Guidelines
Herp HAT – Herpetology Habitat Assessment Tool	WDD - Wildlife Detector Dogs
HRM – Herpetological Resource and Management	
IBI- Index of Biotic Integrity	
IMR – Inadvertent Mud Release	
IPaC – Information for Planning and Conservation	
IPA- Isopropyl Alcohol	
IPM- Integrated Pest Management	
IVM- Integrated Vegetation Management	
LEED – Leadership in Energy and Environmental Design	
LWD- Large Woody Debris	
LC50- Lethal Concentration for 50% of a Test Population	
MARC- Michigan Amphibian and Reptile Conservancy	
MCL – Maximum Containment Level	
MDNR – Michigan Department of Natural Resources	
MDOT – Michigan Department of Transportation	
MIPN – Midwest Invasive Plant Network	
MiRAM – Michigan Rapid Assessment Method for Wetlands	
MNFI – Michigan Natural Features Inventory	
NAP – Natural Area Preservation	
NMFS- National Marine Fisheries Service	
NOAA – National Oceanic and Atmospheric Administration	



Species List Amphibians (Class Amphibia)

Salamanders (Order Caudata)
Mudpuppies (Family Proteidae) •Northern Mudpuppy (<i>Necturus maculosus</i>)
Sirens (Family Sirenidae) •Western Lesser Siren (<i>Siren intermedia nettingi</i>)
Newts (Family Salamandridae) •Eastern Newt (<i>Notophthalmus viridescens</i>) •Red-spotted Newt (<i>Notophthalmus viridescens viridescens</i>) •Central Newt (<i>Notophthalmus viridescensouisianensis</i>)
Mole Salamanders (Family Ambystomatidae) •Spotted Salamander (<i>Ambystoma maculatum</i>) •Blue-spotted Salamander (<i>Ambystoma laterale</i>) •Unisexual Salamander (<i>Ambystoma laterale complex</i>) •Small-mouthed Salamander (<i>Ambystoma texanum</i>) •Marbled Salamander (<i>Ambystoma opacum</i>) •Eastern Tiger Salamander (<i>Ambystoma tigrinum</i>)
Lungless Salamanders (Family Plethodontidae) •Eastern Red-backed Salamander (<i>Plethodon cinereus</i>) •Four-toed Salamander (<i>Hemidactylium scutatum</i>) •Northern Dusky Salamander (<i>Desmognathus fuscus</i>) •Southern Two-lined Salamander (<i>Eurycea cirrigera</i>)

Frogs and Toads (Order Anura)
True Toads (Family Bufonidae) •Eastern American Toad (<i>Bufo [Anaxyrus] americanus americanus</i>) •Fowler’s Toad (<i>Bufo [Anaxyrus] fowleri</i>)
Treefrogs and Relatives (Family Hylidae) •Blanchard’s Cricket Frog (<i>Acris blanchardi</i>) •Midland Chorus Frog (<i>Pseudacris triseriata</i>) •Boreal Chorus Frog (<i>Pseudacris maculata</i>) •Northern Spring Peeper (<i>Pseudacris crucifer crucifer</i>) •Eastern Gray Treefrog (<i>Hyla versicolor</i>) •Cope’s Gray Treefrog (<i>Hyla chrysoscelis</i>)

Typical Frogs (Family Ranidae)
•Bullfrog (<i>Rana [Lithobates] catesbeiana</i>) •Green Frog (<i>Rana [Lithobates] clamitans</i>) •Mink Frog (<i>Rana [Lithobates] septentrionalis</i>) •Wood Frog (<i>Rana [Lithobates] sylvaticus</i>) •Northern Leopard Frog (<i>Rana [Lithobates] pipiens</i>) •Pickerel Frog (<i>Rana [Lithobates] palustris</i>)

Species List Reptiles (Class Reptilia)

Turtles (Order Testudines)
Snapping Turtles (Family Chelydridae) •Eastern Snapping Turtle (<i>Chelydra serpentina</i>)
Musk and Mud Turtles (Family Kinosternidae) •Eastern Musk Turtle (<i>Sternotherus odoratus</i>)
Pond and Box Turtles (Family Emydidae) •Spotted Turtle (<i>Clemmys guttata</i>) •Wood Turtle (<i>Glyptemys insculpta</i>) •Eastern Box Turtle (<i>Terrapene carolina carolina</i>) •Blanding’s Turtle (<i>Emydoidea blandingii</i>) •Northern Map Turtle (<i>Graptemys geographica</i>) •Painted Turtle (<i>Chrysemys picta</i>) - oMidland Painted Turtle (<i>Chrysemys picta marginata</i>) - oWestern Painted Turtle (<i>Chrysemys picta bellii</i>) •Red-eared Slider (<i>Trachemys scripta elegans</i>)
Softshell Turtles (Family Trionychidae) •Eastern Spiny Softshell (<i>Apalone spinifera spinifera</i>)
Lizards (Order Squamata, Suborder Lacertilia)
Skinks (Family Scincidae) •Common Five-lined Skink (<i>Plestiodon fasciatus</i>)
Racerunners and Whiptails (Family Teiidae) •Six-lined Racerunner (<i>Aspidoscelis sexlineatus</i>)

Snakes (Order Squamata, Suborder Serpentes)
Typical Snakes (Family Colubridae) •Northern Water Snake (<i>Nerodia sipedon sipedon</i>) •Copper-bellied Water Snake (<i>Nerodia erythrogaster neglecta</i>) •Queen Snake (<i>Regina septemvittata</i>) •Kirtland’s Snake (<i>Clonophis kirtlandii</i>) •Eastern Garter Snake (<i>Thamnophis sirtalis sirtalis</i>) •Butler’s Garter Snake (<i>Thamnophis butleri</i>) •Northern Ribbon Snake (<i>Thamnophis sauritus septentrionalis</i>) •Northern Brown Snake (<i>Storeria dekayi dekayi</i>) •Northern Red-bellied Snake (<i>Storeria occipitomaculata occipitomaculata</i>) •Smooth Green Snake (<i>Opheodrys vernalis</i>) •Blue Racer (<i>Coluber constrictor foxii</i>) •Gray (Black) Ratsnake (<i>Pantherophis spiloides</i>) •Western Fox Snake (<i>Pantherophis vulpina</i>) •Eastern Fox Snake (<i>Pantherophis gloydi</i>) •Eastern Milksnake (<i>Lampropeltis triangulum triangulum</i>) •Northern Ring-necked Snake (<i>Diadophis punctatus edwardsii</i>) •Eastern Hog-nosed Snake (<i>Heterodon platirhinos</i>)
Pit Vipers (Family Viperidae) •Eastern Massasauga (<i>Sistrurus catenatus</i>)



“In the end, we will conserve only what we love; we will love only what we understand; and we will understand only what we are taught.” — Baba Dioum, 1968



1. Introduction

Purpose and Intended Use of This Manual

Herpetological Resource and Management, LLC (HRM) created the Michigan Amphibian and Reptile Best Management Practices (BMPs) Third Edition manual in collaboration with the Michigan Department of Environment, Great Lakes, and Energy (EGLE), to provide an updated comprehensive guide to improve the conservation and management of Michigan’s amphibian and reptile populations, securing their viability for generations to come. Building off the information of the original two manuals, the Third Edition expands upon the success of its predecessors by incorporating expanded content sections and updated scientific research. Similar to the previous versions, this manual addresses existing and emerging threats to Michigan’s amphibian and reptile (i.e., herpetofauna) communities posed by development and associated conservation management practices. The manual contains alternatives that are based on the best available science and professional peer reviewed resources to facilitate conservation actions to protect specific species and the communities that support them. These BMPs are designed to guide land management, development, and conservation activities, including restoration and mitigation. This BMP manual is a Michigan-focused guide that provides specific recommendations to regulators, agencies, land managers, consultants, commercial and residential developers, and private citizens to protect, preserve, and restore the herpetofauna of Michigan. That said, this resource can and has been applied to other states in the region as well as more broadly, as the concepts are often applicable with some modification and adaptation to local habitats and species needs.

1. The Blanchard’s Cricket Frog is a rare species and an indicator of environmental health. This relatively short-lived species is a sentinel for our need for proactive conservation.



The Michigan Amphibian and Reptile BMP Third Edition features new informative sections including a greater focus on riverine herpetofauna and their needs; dams (including other alternative energy sources) and their threats and measures to mitigate; shoreline management and best practices; ecosystem succession and management strategies; forest and silviculture management; wildlife passages and exclusion systems; expansion of backyard habitats for herpetofauna and measures to minimize threats from agricultural activities; headstarting and its importance as a conservation tool; and expansion on Michigan’s climatic history on herpetofauna and the role it played in species

1. Introduction



1. Protecting and restoring high quality, functional landscapes is essential for supporting amphibian and reptile abundance and diversity across Michigan.

2. Wood Turtles, generally uncommon to very rare across the Great Lakes range, benefit from environments with low disturbance and management that addresses their natural history needs.

colonization. Other additions to the Third Edition include an expanded section on decontamination and cleaning protocols to reduce the spread of diseases and invasives, updated and extended case studies, and an overhaul and expansion on photographs and illustrations. In addition to new content, the Michigan Amphibian and Reptile BMP Third Edition incorporates the most recent scientific literature and updated State and Federal regulations to provide the most effective and valuable information. Michigan amphibian and reptile nomenclature has been moved into a central location for ease of access and review, and in most cases, is not used in the body of the BMP manual.

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. Since the publication of the original manual, over a decade’s-worth of data regarding the testing, implementation, and resulting efficacy of various BMPs has been gathered and incorporated into this Edition. As the recommended BMPs within this manual continue to be implemented and evaluated, new information will continue to be used to refine protective 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) Michigan’s Wildlife Action Plan (Clark-Eagle et al. 2005; Derosier et al. 2015) and includes current climate change adaptation recommendations (Angel et al. 2018). The restoration, management, and development practices recommended in this manual not only benefit amphibian and reptile populations, but all of Michigan’s fauna and flora.

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 EGLE. This document was a catalyst for developing a more comprehensive and detailed document focused on all of Michigan’s amphibians and reptiles. In 2014, the original BMP manual was published to meet the demand for an all-encompassing guide for amphibian and reptile conservation in Michigan and has successfully served as an invaluable resource for project managers and concerned citizens alike. The BMP was later updated and revised in 2023 and expanded to address continued threats and management needs. The continued need for an updated manual is driven by the continued significant decline in amphibian and reptile populations in Michigan and the need for increased conservation actions. At the time of publishing, approximately 60% of



1. Although, historically abundant across their range, the Eastern American Toad has quietly experienced declines throughout Michigan over the last 100 years. Efforts must be made to not only protect our most rare species but also our most vulnerable and declining species before their recovery becomes to difficult to achieve.



Michigan herpetofauna are considered rare or Species of Greatest Conservation Need (SGCN), as identified by the State of Michigan Amphibian and Reptile Technical Advisory Committee (Herpetological Resource and Management 2019; Herpetological Resource and Management 2014), as well as the MDNR Michigan's Wildlife Action Plan (Clark-Eagle et al. 2005; Derosier et al. 2015). 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

2. Maintaining and preserving landscapes is more critical than ever in Michigan. Habitat loss and fragmentation are the leading cause of declines in herpetofauna and other wildlife.

species in Michigan, the Great Lakes, and globally (Dodd et al. 2003; Marchand and Litvaitis 2004; Weyrauch and Grubb 2004; Cushman 2006; Gardner et al. 2007; Tan et al. 2023; Fahrig 2017). 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 (Roe et al. 2003; Bell 2005; Moore and Gillingham 2006; Ryan et al. 2008; Michigan Natural Features Inventory 2012a; Harding and Mifsud 2017). The unique natural histories and biological characteristics of amphibians and reptiles make these animals vulnerable to both aquatic and terrestrial disturbances. Collectively, we are in a state of crisis conservation for herpetofauna. We are experiencing declines of even the most abundant species and overall degradation of the landscape at an unsustainable rate. We are in a pivotal time of action to help reduce these threats and shift the pendulum to favor herpetofauna. 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 for landscape stewardship,

1. Effective management must include considerations for generalist species and those regarded as more abundant for effective and long-term viable conservation. The idea of keeping common species common is a key theme in this manual.



management techniques arise, revisions will be made to help best manage and protect Michigan's herpetofauna.

The manual is broken down into key sections based on use, interest, and needs. In many cases, a subject that overlaps with another focus will be discussed, though greater detail may be provided elsewhere in the manual. Sections are designed to function semi-independently and where needed, cross-referencing is provided. While the BMP has an incredible wealth of resources, it is not all inclusive and a work in progress. We welcome opportunities to include and incorporate additional subject matters and challenges herpetofauna face and provide tangible and achievable conservation and management recommendations.

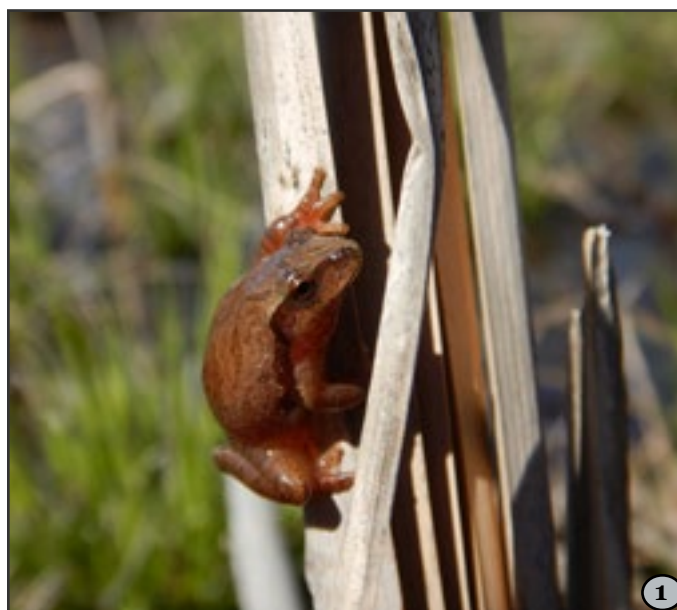


2. Engaging the public can help foster a positive stewardship attitude and support long-term conservation.



2. Amphibians and Reptiles of Michigan

1. Amphibians and reptiles, such as this Northern Spring Peeper, serve as an essential mid-level position in the food web, functioning as both prey and predator depending upon the species and life stage.



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 due to their similar ecological limitations and ectothermic life-histories. These two taxa are incredibly diverse as over 7,200 amphibian species and over 9,800 non-avian reptiles occur globally. In stark contrast, only approximately 5,500 mammal species exist worldwide, yet this comparatively small group receives a disproportionately large share of public attention and conservation funding. Despite the lack of public awareness and conservation efforts, herpetofauna are incredibly ecologically important as they mobilize energy through multiple trophic pathways due to their amphibious life cycles. Amphibians exhibit a biphasic lifestyle which is particularly important for the transfer of energy through the food web. As tadpoles in aquatic habitats, they are herbivorous before transferring these resources to land in their adult phase where they are both a

carnivorous predator and prey for other wildlife. Michigan's herpetofauna are 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; Walls and Williams 2001; Congdon and Keinath 2006; Harding and Mifsud 2017). Amphibians and reptiles are also important as they are key bioindicators of environmental health and habitat quality (Cooperrider et al. 1986; Adamus and Brandt 1990; Welsh and Ollivier 1998; Shear et al. 2003; Guilfoyle 2010).

Despite the ecological importance of the state's herpetofauna, these groups have not been as comprehensively surveyed or studied compared to other vertebrate groups such as birds, mammals,

2. Amphibians and Reptiles of Michigan

1. The Eastern Milk Snake is a cryptic snake species that performs critical ecosystem services by consuming small rodents and having a mid-level position in food webs.

2. The Eastern Red-backed Salamander is considered relatively abundant, especially where forested ecosystem health is high. While an indicator species and somewhat easy to encounter under logs, their true abundance or lack of is generally unknown without comprehensive study and inventory.

or game fish. This may be partly due to a historical neglect 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. Other species are deceptively seasonally perceived as abundant (i.e., loud frog calls and turtles crossing roads), which may present the appearance of thriving populations that are of no conservation concern when these populations are actually declining. 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 approximately 60% of species (Clark-Eagle et al. 2005; Derosier et al. 2015), and there is plentiful anecdotal evidence that the abundance and distribution of many (even formerly common) amphibian and reptile species have declined significantly. We are also experiencing shifting baseline syndrome (SBS). This is a psychological and sociological phenomenon where each generation accepts the degraded state of the environment they are born into as the "normal" baseline, ignoring historical, healthier conditions. SBS is a type of change to how a system is measured, usually against previous reference points (baselines), which themselves may represent significant changes from an even earlier state of the system that fails to be considered or remembered (Pauly 1995).



This is true for herpetofauna as well, and an overly simplistic approach and attitude is often affixed to these species, their role and their presence. Historic data is often dismissed or disregarded rather than integrated as part of an assessment. A perception of convenient resilience is assigned to justify practices and management approaches that do not favor herpetofauna or their natural history requirements. 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 et al. 1999;



1. Presence does not equal abundance or species health. Too often the observation of a species like a Blanding's Turtle suggests that the species is doing fine. Long-lived species require consideration for presence of multiple age class detection to reasonably demonstrate population health.

2. Seasonal abundance can sometimes skew the perception of a species' health. Eastern American Toads can produce numerous metamorphs, with only a few surviving to adulthood.

McKinney 2002; Dodd et al. 2003; Marchand and Litvaitis 2004; Weyrauch and Grubb 2004; Saumure et al. 2007; Skidds et al. 2007; Humbert et al. 2009; Böhm et al. 2012). 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. To shift the baseline in a positive direction and dispel the misconceptions about these species, this BMP resource was developed to facilitate a holistic approach to the understanding of herpetofauna natural history as well as their conservation and management needs.

The Ice Age and Herpetofauna in Michigan

Michigan's chaotic climatic and geologic history, attributed to the succession and recession of glacial ice sheets within the region, has dramatically influenced the herpetofauna present and their abundance across the state today.

Before the most recent Ice Age, the Pleistocene Epoch, which lasted from 1.8 million years ago to 10,000 years ago, Michigan was a warm, dry, upland area, and was likely home to many amphibian and reptile species (Palmer and Geissman 1999; Holman



1. The extent of North American ice sheets at the last glacial Maximum approximately 18,000 years ago.

2. Mink Frogs are extremely cold-adapted and likely were more abundant during cooler glacial and postglacial periods.

period (Clausen et al. 1979; Holman 1991).

The herpetological re-colonization of Michigan following the recession of the most recent glacial period of North America, the Wisconsin Glacial Stage (14,800 years ago to present day), occurred in three waves of primary, secondary, and tertiary invaders. Determination of what and when species made their way into Michigan is based on the paleobotanical records, geological record, herpetofauna fossil records, archeological finds, and ecological tolerances (cold-hardiness) of present day herpetofauna (Holman 2004; Holman 2012). Primary invaders dispersed into mostly coniferous forest and swamp habitats and could tolerate the cold tundra landscape that followed the recession of ice sheets (Holman 2004). Primary invaders included salamanders, Mudpuppies and newts, such as the Blue-spotted Salamander, Spotted Salamander, and Eastern Tiger Salamander; frog and toad species such as the Eastern American Toad, Eastern Gray Treefrog, and Green Frog; turtle species such as the Eastern Snapping Turtle, Midland Painted Turtle, and Blanding's Turtle; and snake and lizard species including the Five-lined Skink, Northern Watersnake, Northern Ribbon Snake, and Eastern Garter Snake (Holman 2012).



Scott Gillingwater

1. The Eastern Garter Snake is a cold adapted primary invader of Michigan that ranges across the state.

Secondary invaders dispersed into mixed conifer-broadleaf areas in the Lower Peninsula of Michigan. Secondary invader amphibian species included the Fowler's Toad, and Blanchard's Cricket Frog (Holman 2012). Secondary invader turtle species included the Spotted Turtle, Eastern Box Turtle, and Red-eared Slider. Snake species considered to be secondary invaders included the Blue Racer, Eastern Hog-nosed Snake, and Eastern Massasauga Rattlesnake, commonly abbreviated as EMR (Holman 2012).



Lastly, tertiary invaders dispersed into broadleaf (deciduous) areas in the state. Tertiary invaders included three amphibian species, the Marbled Salamander, Small-mouthed Salamander, and Western Lesser Siren. Reptile tertiary invaders included the Six-lined Racerunner, Kirtland's Snake, and Copper-bellied Water Snake (Holman 2012).

Climatic events of the Holocene Epoch (10,000 years ago to present day) were also quite influential in the distribution of modern herpetofauna across the state of Michigan. From 9,000 to 5,000 years ago, a global climatic temperature increase, known as the Hypsithermal Interval or Holocene Climatic Optimum (HCO), allowed many herpetofauna species to make their way further north into Michigan than what was previously possible (Holman 2012). This period was marked by significant global warming, with summer temperatures in the Northern Hemisphere estimated to be 1.8 to 5.4°F higher than preindustrial levels, accompanied by increased aridity in mid-latitude regions (Shakun and Carlson 2010; Holman 1995). These herpetofauna invaders came from Indiana and Ohio migrating up the Lower Peninsula in a random fashion and dispersing into coniferous forest and swamp habitats. The Upper Peninsula of Michigan was colonized by herpetofauna coming through the state of

2. The Blue Racer is considered a secondary invader of Michigan exhibiting a greater tolerance for colder conditions and continuing to expand its range in the northern lower peninsula of the state.



1. Grassland habitat once was widespread across Michigan, allowing for the expansion of prairie associated species migrating from Indiana.



Wisconsin (Holman 2012). Additionally, a few species may have been able to disperse across the Straits of Mackinac. Following the Hypsithermal Interval, a cooling period that began around 1,200 years ago known as the "Little Ice Age" caused the withdrawal of some herpetofauna species across the state (Kapp 1999). From the year 1750 to present day, Michigan has once again warmed. The warming and cooling of Michigan structured the dispersal of herpetofauna species before European settlement in the Americas during the Holocene Epoch.

Paleoecological Context: The Hypsithermal and the Prairie Peninsula

In Michigan, the Hypsithermal Interval initially brought a warm and dry climate that facilitated the eastward expansion of prairie and savanna habitats, Transeau's renowned "Prairie Peninsula", into the lower Great Lakes region, before conditions became more cool and wet as the Holocene progressed (Brugam et al. 1997; Brugam and McCance Johnson 1997; O'Connor 2006 Transeau 1935). This warm, dry period acted as both a climatic filter and a landscape corridor. It allowed grassland-associated reptiles, such as the Ornate Box Turtle (*Terrapene ornata*), Six-lined Racerunner, Western Slender Glass Lizard (*Ophisaurus attenuatus*), and Plains Garter Snake (*Thamnophis radix*), to extend their ranges into the Midwest, while potentially displacing some forest-associated species (Schmidt 1938; Smith 1957). Species such as the Kirtland's Snake and Eastern Massasauga Rattlesnake remain closely associated with the historical extent of these grassland, wet prairie, and savanna habitats. Conversely, the spread of drier habitats may have contributed to the absence of the Wood Turtle from southern Michigan and Ohio, the scarcity of the Eastern Box Turtle in northeastern Ohio, and the absence of the Northern Ring-necked Snake from the prairie peninsula. These patterns potentially reflect the Holocene forest decline or the failure of some species to recolonize these areas post glacially.



Dick Bartlett

1. Our known knowledge of the extent of the Western Lesser Siren is limited to Southwest Michigan where this species likely colonized via Indiana. Recently rediscovered, this species and other potential species warrant greater conservation attention and caution with assumptions that these populations are introduced. Most of Michigan has not been surveyed and requires more comprehensive assessments.



Dick Bartlett

Relict Populations and Post-Glacial Dispersal Patterns

Relict populations may still remain from the Hypsithermal Interval (warming period) of the Holocene (Bernabo 1981; Kapp 1999; Holman et al. 2003). These species may survive in populations isolated from the rest of their range due to the lake-influenced climate in the state, that is, the warming effect of the Great Lakes. For example, the Western Lesser Siren is found in only two counties in Michigan, Van Buren County and Allegan County. Here they are separated from the rest of their range which occurs mainly in the southeastern United States, extending from Indiana down through Kentucky and Tennessee to the eastern coasts of Virginia, North and South Carolina, Georgia, and Florida, and the southern coasts of Alabama, Mississippi, Louisiana, and Texas, and into Mexico (Minton 2001). Other “southern” species in the Great Lakes region, including the Marbled Salamander and Copper-bellied Water Snake, represent similar relict populations persisting as remnants of this northward dispersal during the Hypsithermal Interval, isolated from the core of their ranges due to the moderating influence of the Great Lakes on local climate.

Additionally, some “slower colonizers” may still be making their way northward into new habitats (Holman 1992). The southern half of Michigan’s Lower Peninsula has nearly twice as many reptile species as all other areas above the mid-point of the state. This bottom half also has tertiary invader species that do not occur anywhere else in the state. The Upper Peninsula of Michigan also contains mostly primary invaders. The islands that speckle the Great Lakes surrounding Michigan are also home to predominantly primary invading species who likely made their way onto these islands 8,000 to 4,000 years ago when lake levels were lower and these islands were connected to the mainland (Hatt et al. 1948; Holman 1992). Following the retreat of the Laurentide Ice Sheet, fluctuating lake levels during glacial isostatic adjustment created temporary land bridges, enabling amphibian and reptile dispersal to what are now offshore islands and explains the surprisingly diverse herpetofauna assemblage found on many Great Lakes islands today.

Evolutionary Legacies of Climatic Fluctuation

Past climatic fluctuations have also driven evolutionary processes in the region’s herpetofauna. Isolation during glacial periods is implicated in the speciation of the Eastern Gray Treefrog from Cope’s Gray Treefrog, with populations diverging genetically during separation before recontacting after ice retreat (Hendry 2000). Similarly, glacial vicariance likely contributed to the subspecific variation seen in the wide-ranging Painted Turtle, with two integrating subspecies in the Great Lakes region resulting from population fragmentation during glacial advances followed by secondary contact and interbreeding as glaciers receded (Starkey et al. 2003).

The complex biogeographic history of Fox Snakes (*Pantherophis* spp.) in the Great Lakes further illustrates the role of climate-driven habitat change in shaping genetic structure and species boundaries. Two disjunct forms occur in the region: the Western Fox Snake (*P. vulpinus*) largely west and north of Lake Michigan, and the Eastern Fox Snake (*P. gloydi*) along Lake Huron and the shorelines of Lake Erie. While once thought to represent separate postglacial recolonizations from different refugia, recent genetic evidence suggests their divergence may be more recent, potentially driven by habitat fragmentation during the xerothermic period (Row et al. 2012). Taxonomic consensus remains unsettled, with some studies highlighting a genetic split between the populations at the Mississippi River rather than between the Great Lakes (Burbrink et al. 2000); however, Michigan recognizes both species and affords protection to *P. gloydi*.

1. The Gray Tree Frog including both the Eastern and Cope’s, occur across Michigan with significant overlap in range, though calls are somewhat separated seasonally.

2. The Fox Snakes of Michigan do not overlap in ranges and typically utilize very different habitat.

Glacial Geology and Modern Habitat Distribution

Distinct glacially derived landforms now form the mosaic of habitats across the landscape in which herpetofauna in Michigan are dispersed. Many other states located within the southern and eastern United States have flat, flaky bedrock shales, offering the perfect shelter and hibernacula for many species of salamanders and snakes. Due to the grinding, tilling, and erosion of Michigan’s geologic layers during glacial periods, the state possesses more rounded boulders, cobbles, pebbles, and sand, limiting the availability of habitat (Holman 2012). However, some Michigan herpetofauna have adapted to this geologic disposition and seek out alternative microhabitats (Holman 2012; Harding and Mifsud 2017). Deposits of sand and silt concentrated within historic glacial out wash locations within the southwestern region of the state provide sandy soils ideal for turtle nesting and habitat for ‘sand-loving’ species such as the Fowler’s Toad and Eastern Hog-nosed Snake (Holman 2012; Harding and Mifsud 2017).



The Unprecedented Nature of Contemporary Change

The emergence of past warm periods, such as the Hypsithermal Interval, is linked to long-term cosmic climate forcing mechanisms known as Milankovitch cycles—cyclical changes in Earth’s orbit (eccentricity over approximately 100,000 years), axial tilt (obliquity over approximately 41,000 years), and rotational direction (precession over approximately 26,000 years). These gradual orbital shifts align with major historical climate transitions and undoubtedly influenced the postglacial recolonization of Michigan by herpetofauna (NASA 2020).

However, the rapid warming observed over the past 200 years cannot be explained by these slow celestial cycles. Instead, contemporary climate change may be linked to anthropogenic activities as well as natural greenhouse gas releases from ocean-atmosphere exchanges, thawing permafrost, an increase in temperature, variations in the intensity of the sun, and volcanic eruptions emitting carbon dioxide. These factors primarily influenced long-term, pre-industrial climate shifts. Regardless of source, this rapid climatic shift may exceed the adaptive and dispersal capacity of many amphibian and reptile species, challenging their ability to locate suitable climate conditions through natural means alone. Many herpetofauna species lack the capacity to disperse or evolve quickly enough to survive depending on the rate of temperature increase and landscape condition. Conservation strategies should extend beyond protecting existing habitats to include proactive measures such as the identification and preservation of dispersal corridors, adaptive habitat management, and carefully considered interventions to facilitate species persistence under rapidly shifting climatic conditions.

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; Semlitsch 2008; Harding and Mifsud 2017; Hocking and Babbitt 2014). 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) (Holman 2012; Harding and Mifsud 2017). Amphibians have moist, highly-permeable

1. The Eastern Hog-nosed snake is often found within xeric, dry upland habitats within Michigan, such as dune ecosystems. This species has experienced population declines in conjunction with the loss of their primary prey, toads.



1. All frog species require water to complete development from tadpole to frog. If conditions dry too early, annual recruitment can be lost.

2. The Wood Turtle is a critical landscape species, utilizing both large, sandy bottom rivers riparian habitat of northern Michigan and the Upper Peninsula as well as uplands seasonally.

amphibians and reptiles have extensive contact with water, high water quality is imperative for the viability of diverse amphibian and reptile communities.

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 et al. 2004; Attum et al. 2008; Attum et al. 2009; Ream et al. 2025). Many species, such as Copper-bellied Water Snakes, Wood Frogs, and Eastern Tiger Salamanders, 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.

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, Michigan comprises at least 59 species of native herpetofauna. Additional research must be conducted to properly evaluate potential species in southern Michigan and western Upper Peninsula as species likely naturally migrated in and are undetected. Michigan species include:

- 18 species of snakes
- 11 species of turtles
- 2 species of lizards
- 14 species of frogs and toads
- 14 species of salamanders



Jim Harding & Hailey Brown





1. Microhabitat like logs and leaf litter are essential for supporting some species of herpetofauna.

2. Rock piles such as this limestone outcrop can serve as critical hibernacula for several snake species in Michigan as well as provide conditions for supporting egg development.



Michigan Herpetofauna: Ecological and Habitat Requirements

Amphibians and reptiles in Michigan live in diverse ecological community types which support distinct habitat features necessary for their presence (Appendix A). These animals are constrained by their physiology to occupy specific areas that provide these key features, including:

Basking structures – Areas where amphibians and reptiles can warm themselves to regulate their body temperature. Amphibians and reptiles can warm themselves (thermoregulate) on or under sun-exposed rocks and logs or in gaps in the vegetation canopy where the sun shines through.

It is equally important that structurally diverse areas of vegetation and substrate 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 interspecifically 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 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 salamanders typically require submerged vegetation, rocks, branches, or other underwater structures for egg attachment.

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 Herpetological Resource and Management Species overview section on the website (www.HerpRMan.com/species), and The University of Michigan Animal Diversity



1. The Blue-spotted Salamander is part of a unique genetic complex of unisexual salamanders that date back millions of years. Their presence and genetic composition often are linked to local environmental conditions. They undergo cleptogenesis where genetic material is ejected or accepted based on local landscape conditions that are most advantageous.

2. Unlike other anurans, Michigan Toad species lay strings of eggs compared to clusters like frogs.

Some of the characteristics that typically define the amphibian 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 United States. 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* spp.), which incorporate 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 and Mifsud 2017). 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, and small vertebrates, as well as serving as a food source 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 food source for another animal before they can complete metamorphosis.

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 and 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 structures that contain 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. Shed skin will remain in the environment for a week or two and occasionally up to a month (Gray 2012). Species can sometimes be identified by sheds, indicating the presence of a snake even if the snake is not observed.

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 withdraw and cover their limbs, head, and tail completely (e.g., Eastern Box Turtle 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 offset the naturally high mortality of turtle eggs and hatchlings, as well as the long time periods needed for young turtles to reach sexual maturity. For example, the minimum age of sexual maturity for female Blanding's Turtles is 14 years, though 20 years is more typical (Congdon et al. 1993).

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



Jim Harding & Hailey Brown

1. The Five-lined Skink is a cold tolerant lizard species though even within Michigan, they tend to be associated with specific habitat conditions and soil types. Females guard their nests providing some parental care for their young.

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 is known to guard its eggs until hatching. Lizards are generally short-lived compared and typically live less than 10 years.



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 amphibian and reptile species.

2. The Six-lined Racerunner is listed as Threatened in Michigan and are currently only known from Tuscola County. Anecdotal reports from Southwest Michigan suggest this species may have colonized the state during the hypsithermal when prairie habitat was more expansive. This species is still known to occur in Indiana near the state boarder and likely occurs or may recolonize the state with suggested increased temperatures.

On larger sites that cannot easily be as effectively surveyed on foot, general categories of natural communities often can be identified on aerial photographs. These photographs are available for view at no cost online (e.g., using Google Earth, Bing, state, county, or local GIS portals, 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 accurate 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.**





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

Rare Species Showcase

Many amphibian and reptile species within Michigan are considered to be rare and all species are in decline to some degree. These species need expeditious conservation efforts to ensure their continued presence across their Michigan ranges. The Eastern Massasauga Rattlesnake and Blanding’s Turtle are both representative species that illustrate the complexity of herpetofauna life history and the importance of formulating viable conservation strategies. Michigan is often considered to be a stronghold for both species, and the widespread understanding of their biology, ecology, and conservation is crucial for their continued existence. They are both also landscape level species (umbrella species), and protection and management favoring these species will directly benefit every trophic level of a landscape. Other species Like the Northern Mudpuppy and Blanchard’s Cricket are not necessarily a landscape level species, rather critical members and indicators within the landscape.

2. An adult Eastern Massasauga Rattlesnake emerging from an overwintering refuge during early spring. Residual clay and soil adhered to the body indicate recent emergence from a subterranean hibernaculum within saturated wetland soils. Individuals often utilize crayfish burrows, small mammal burrows, or natural soil cavities below the frost line to survive winter conditions in northern portions of the species’ range.

Eastern Massasauga Rattlesnake

The Eastern Massasauga Rattlesnake is listed as Threatened in Michigan and is federally listed as Threatened under the Endangered Species Act (ESA) (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1973; U.S. Fish and Wildlife Service 2016). Their range extends from western New York and southern Ontario to western Iowa, and southern Missouri. Within Michigan, the species is found only in the Lower Peninsula, where it is widely distributed yet uncommon (Harding and Mifsud 2017). Wetland communities including, fens, bogs, sedge meadows, and wet prairies are utilized from early fall until late spring where snakes hibernate underground in crayfish chimneys or small mammal burrows (Harding and Mifsud 2017). Studies have shown high fidelity toward overwintering sites, and they will often return to the same location each year (Johnson et al. 2000; Smith 2009). Eastern Massasauga Rattlesnakes move to adjacent upland habitats, that include shrubby fields and grasslands, during the summer where they utilize the warm weather for foraging and development of young (Harding and Mifsud 2017). Eastern Massasaugas and



1. Eastern Massasauga Rattlesnakes are ovoviviparous, meaning that eggs hatch within the mother and offspring are born alive.

similar rattlesnakes are known to exhibit postpartum mother-offspring associations that may promote neonate survival (Reinert and Kodrich 1982; Butler et al. 1995; Greene et al. 2002; Hileman et al. 2015). Within upland habitats, this species typically avoids closed canopy forests and those that do enter these habitats favor areas where sunlight penetrates the canopy (Center for Reptile and Amphibian Conservation and Management). Home range and movement patterns are often site dependent, making it important for project managers to understand what populations they are working with. Typically, Eastern Massasauga Rattlesnakes have larger home ranges in populations located further north in their range (Harvey and Weatherhead 2006; Smith 2009; DeGregorio et al. 2011). Small mammals make up a majority of this snake’s diet, but they will also feed on amphibians, other snakes, birds, and insects (Keenlyne and Beer 1973; Seigel 1986; Hallock 1991; Shepard et al. 2004; Harding and Mifsud 2017). Rattlesnake consumption of small mammals also helps to control tick populations, potentially benefitting humans by decreasing the risk of Lyme disease transmission (Kabay et al. 2013). Although the Eastern Massasauga Rattlesnake is a venomous snake, the first line of defense is their cryptic coloration and behavior (Harvey and Weatherhead 2006). When encountered, they typically stop moving and remain undetected, however if a potential predator approaches and the snake does not flee, it will stand its ground and vibrate its rattle as a warning before striking. This species is generally shy and unaggressive, yet they are heavily persecuted by humans and often killed unnecessarily (Harding and Mifsud 2017). Visual encounter surveys for this species should be conducted between the first week of April through the second week of September (Ontario Ministry of Natural Resources and Forestry 2016b; Casper et al. 2001). Additionally, land management practices, including timber harvesting, mowing, disking, and prescribed burning, should be conducted during the Eastern Massasauga Rattlesnake’s inactive season of November through early March (Lee and Legge 2000; Cross et al. 2015).



2. A coiled Eastern Massasauga Rattlesnake utilizing coarse woody debris and a tree root structure for thermoregulation and concealment. Downed logs and root masses provide important microhabitats that offer shade, ambush cover, and moderated thermal conditions within forest–wetland ecotones frequently occupied by this species.



Populations of this species have declined rapidly in recent decades mainly as a result of habitat loss and persecution. The wetlands inhabited by the Eastern Massasauga Rattlesnakes have largely been degraded or lost due to draining for agriculture, residential



development, roads, and pollution (Lee and Legge 2000). Additionally, much of their upland habitat has also been destroyed or fragmented. This species requires open upland habitat adjacent to wetlands, conservation and restoration efforts that focus solely on wetlands typically fail to preserve this species (Harding and Mifsud 2017). Vehicle-caused mortalities are also a significant threat to this species as well as human persecution, particularly during their active and mating seasons (Lee and Legge 2000; Shepard et al. 2008a). Venomous species like the Eastern Massasauga Rattlesnake may be particularly vulnerable to vehicles as they often move across roads more slowly than nonvenomous species (Andrews and Gibbons 2005b). Habitat fragmentation often forces these snakes to cross roads in search of suitable habitat, mates, etc. (Baker et al. 2016). Eastern Massasauga Rattlesnakes avoid road crossings, but road mortalities may introduce a selective pressure that favors individuals that avoid roads, thus reducing road mortalities but inhibiting gene flow (Shepard et al. 2008b). The most important management step for the conservation of Eastern Massasauga Rattlesnakes is the protection of existing populations and suitable wetland habitats that are adjacent to upland habitat (Lee and Legge 2000). In addition, burrowing crayfish species (*Lacunicambarus* spp and *Creaseriunus* spp) which the Eastern Massasauga Rattlesnake relies on for access to overwintering habitat in parts of their range **MUST** be studied and protected. Habitat loss, degradation, and fragmentation have a very high probability of causing localized extinction of Eastern Massasauga Rattlesnake populations within 25 year horizons (Faust et al. 2011). Without the implementation of significant conservation action to address these risk factors, the Eastern Massasauga Rattlesnake will remain at risk of imminent extirpation throughout portions of its range (Szymanski et al. 2016).

1. A tightly coiled Eastern Massasauga Rattlesnake exhibiting a defensive posture within herbaceous wetland vegetation. When threatened, individuals typically remain motionless or form a compact coil with the head elevated, relying on crypsis and warning rattles rather than active flight. Most negative encounters with this species are avoidable.



1. An adult Blanding's Turtle basking along the edge of a vernal pool. Individuals of this semi-aquatic species frequently emerge from aquatic habitats in early spring to thermoregulate in sunlit areas adjacent to wetlands, marshes, and shallow ponds. They will opportunistically consume breeding amphibians, eggs, and larvae.

Blanding's Turtle

The Blanding's Turtle is listed as a species of Special Concern in Michigan and is either threatened or endangered throughout most of its remaining range (Harding and Mifsud 2017). The Blanding's Turtle currently does not receive federal protections at the time of publishing, though the species' status is currently listed as Under Review to assess whether it warrants listing under the ESA (U.S. Fish & Wildlife Service 2022a). The range of the Blanding's Turtle extends from southwestern Quebec and southern Ontario west to Minnesota and Nebraska and to southern Illinois (Harding and Mifsud 2017). In Michigan, they can be found throughout the Lower Peninsula and are rarer and more localized in the Upper Peninsula. This turtle species requires a mosaic of habitat types for their survival. For much of the year, Blanding's Turtles prefer wetland community types such as marshes, ponds, swamps, lake shallows, slow moving rivers, oxbows, and pools adjacent to rivers. This species will utilize shallow water areas for basking and foraging while overwintering occurs in deep wetlands where the turtles burrow into the mud below the frost line (Van Dam 1993). Upland habitats are critical for activities such as nesting, and dispersal. Females require well drained soils, usually with southern exposure for nesting during summer months. Blanding's Turtles exhibit high fidelity toward nesting sites, generally returning to the same nesting location each year (Congdon et al. 1983). Blanding's Turtles are known to move large distances to reach each of these habitats at different times of the year, and total seasonal distance traveled can reach 4.2 miles (Joyal et al. 2001). Both male and female turtles will maintain a long-term (>40 years) site fidelity to a single resident wetland but frequently utilize other habitats outside of this wetland, including travel to and from neighboring wetlands (McGuire 2013). Additionally, females will sometimes make long migrations to nesting



1. Blanding's Turtles utilize a variety of habitats seasonally, including wetlands, swamps, backwater sloughs, marshes, and upland habitat, demonstrating the need for contiguous ecosystems. This critical landscape species should be a conservation priority of regulators, managers, and stewards.

sites as they do not necessarily nest in proximity to their resident wetland. Females often use multiple nesting sites over their lifespan, which, in combination with repeat paternity, can facilitate gene flow across the landscape further than the movement of individual turtles (McGuire 2013; McGuire et al. 2015). For instance, a male Blanding's Turtle may move over 1.24 miles, but his genes may move over 3.73 miles as a result of his female mate traveling with his stored sperm. The mating of individuals from separate resident wetlands, as well as the dispersal of hatchlings away from their mother's resident wetland, contributes to the demographic and genetic connectivity between resident wetlands (McGuire 2013). The diet of this species consists mainly of crayfish, snails, insects, small fish, tadpoles, frogs, and some vegetation. Blanding's Turtles have a life span of at least 95 years and do not reach sexual maturity until around 20 years of age in some areas of Michigan (Congdon 2001; Harding and Mifsud 2017). Adult turtles have few natural predators, but hatchling and juvenile turtles suffer very high mortality rates from mammals such as raccoons, skunks, and foxes in addition to fish, frogs, snakes, and birds (Harding and Mifsud 2017). The ideal survey period for the Blanding's Turtle ranges from mid-April through mid-September and is typically conducted through utilizing the visual observation of basking sites as well as hoop and net traps (Armstrong 2016; Harding and Mifsud 2017; Millar et. al 2012).

2. Hatchling Blanding's Turtles will often select to overwinter within upland habitat during their first hibernation as opposed to aquatic environments. In much of Michigan, successful recruitment of this species is limited and effort to help protect nests is essential for recovery.

Destruction and degradation of wetlands is the leading cause of population declines throughout the species' range (Harding and Mifsud 2017). The primary drivers of this habitat loss stem from urbanization as well as various agricultural activities, including the drainage of wetlands, channelization of rivers, development of upland nesting areas, introduction of herbicides and pesticides, water impoundments (Harding and Mifsud 2017; Kofron and Schreiber 1985). These sources of habitat loss also limit movement



between Blanding's Turtle habitats, fragmenting populations, and disrupting the mechanisms that maintain genetic diversity (Rubin et al. 2001). Habitat fragmentation also increases the mortality rates of individuals moving between habitats (Grgurovic and Sievert 2005). Road mortality can intensely decrease Blanding's Turtle populations as this turtle often migrates long distances, making it particularly vulnerable to this threat (Harding and Mifsud 2017). Lastly, increased populations of mesopredators that predate Blanding's Turtle nests, such as raccoons, pose a significant threat (Harding and Mifsud 2017). The most important conservation need for Blanding's Turtles is the preservation of suitable habitat, including the mosaic of habitats it requires rather than individual wetlands alone (Harding and Mifsud 2017; Ontario Ministry of the Environment, Conservation, and Parks 2019). As Blanding's Turtles, particularly gravid females, exhibit large core habitats, maintaining corridors between permanent bodies of water is necessary to support genetic connectivity (Howes et al. 2009; Millar and Blouin-Demers 2011). Reducing or restricting certain activities near wetlands, including herbicide and pesticide use, timber harvesting, road construction, and agricultural operations, would benefit this turtle species (Ontario Ministry of the Environment, Conservation, and Parks 2019; Missouri Department of Conservation 2022; Illinois Department of Natural Resources 2016). Additionally, the use of predator exclusion devices and active predator control around key Blanding's Turtle nesting areas may increase successful population recruitment (Harding and Mifsud 2017). **For detailed discussion of predator control, see Section 6: Ecological Restoration, Mitigation, and Habitat Design under Turtle Nesting: Mitigate Predator Damage**

1. The presence of juvenile and young adult Blanding's Turtles suggests that a viable population is present, which is often associated with large, contiguous blocks of habitat and minimal subsidized predators.





1. An adult Northern Mudpuppy resting among submerged rocks and filamentous algae in a freshwater river system. This fully aquatic salamander shelters within rocky crevices and benthic substrates, where it forages for aquatic invertebrates and small fish while remaining concealed from predators.

Northern Mudpuppy

The Northern Mudpuppy is Michigan’s largest fully aquatic salamander and a species of once abundant throughout the Great Lakes region; however, Northern Mudpuppy populations have declined significantly in recent decades. It is listed as special concern in Michigan and rare or declining across much of their range, which extends from New England, New York, and southern Quebec west through the Ohio Valley to southeastern Manitoba and south along the Mississippi Valley to Missouri, Tennessee, and northern Alabama. They are found throughout most of the Great Lakes region, though may be absent along much of the western shore of Lake Superior (Faisal 2006; Francis 2006; Millsap 2006; Holman 2012; Harding and Mifsud 2017; Stapleton et al. 2018). Major contributing factors to their decline include habitat loss and degradation, changes to aquatic communities due to invasive species, and ongoing mortality from anglers (Harding and Mifsud 2017; Stapleton et al. 2018).

Due to their amphibious nature, permeable skin, longevity, and sensitivity to pollutants, Northern Mudpuppies serve as valuable bioindicators that reflect the overall health of aquatic environments. Their response to habitat disruptions and susceptibility to environmental contaminants provide early insights into stressors that may impact other aquatic life. As cold-water dependent creatures thriving in temperatures



2. Northern Mudpuppies conceal themselves beneath rocks in a freshwater habitat. Their external gill are used for respiration and their coloration (red blood cells) help visually indicate water quality and ecosystem conditions.

between 32°F and 50°F, Northern Mudpuppies are also important for studying the effects of climate change and rising water temperatures on Great Lakes ecosystems (Environment Canada 2005; Barrett and Guyer 2008; Beattie et al. 2017; Chellman et al. 2017; Stapleton et al. 2018).

The Northern Mudpuppy serves as the exclusive obligate host organism for the Salamander Mussel (*Simpsonaias ambigua*), a state Endangered and federal Candidate species. The Salamander Mussel relies entirely on the Northern Mudpuppy to complete its life cycle, making Mudpuppy populations critical for mussel recovery and population viability. Arguably, the Northern Mudpuppy can be considered critical habitat for a life stage of the Salamander Mussel and essential for their survival. Salamander Mussels are estimated to have been lost from 35 – 45% of their entire range and have declined from at least 60% of their historical sites in Michigan alone (Carman 2002; Bogan et al. 2017; U.S. Fish & Wildlife Service 2023). Preservation of Northern Mudpuppies and their habitat is therefore essential to sustain and recover this imperiled mussel species.

Northern Mudpuppies play a pivotal role in maintaining resilient, functioning aquatic ecosystems by foraging on several invasive species, including Round Goby (*Neogobius melanostomus*), Rusty Crayfish (*Orconectes rusticus*), and Zebra Mussels (*Dreissena polymorpha*) (Beattie et al. 2017; Stapleton et al. 2018). They also feed on carrion, helping to maintain and improve water quality within their ecosystems (Harding and Mifsud 2017). The continued presence of Mudpuppies in Michigan’s aquatic habitats significantly contributes to the overall health and function of these landscapes.

1. Northern Mudpuppies are a critical landscape species within their respective aquatic habitats. Unlike many species of herpetofauna, this species remains active year round and can be observed under the ice during winter months. They are important consumers of several invasive species including Round Gobies, Zebra Mussels, and Rusty Crayfish.





Blanchard's Cricket Frog

1. A Blanchard's Cricket Frog perched along the edge of a shallow freshwater shoreline. This small hylid frog commonly inhabits ponds, lakes, and slow-moving streams where sparse vegetation and exposed substrate provide basking sites and quick access to the water for escape from predators.

The Blanchard's Cricket Frog, named in honor of one of Michigan's first herpetologists Frank Blanchard, is a tiny (0.6 to 1.5 inches in length), warty-skinned member of the treefrog family and is considered the most aquatic treefrog in North America (Harding and Mifsud 2017). The range of the Blanchard's Cricket Frog extends across the central United States, from Ohio, Michigan, and southern Ontario west through Indiana, Illinois, and Wisconsin to southeastern South Dakota, and south through Texas and northern Mexico (Harding and Mifsud 2017; Powel et al. 2016). They are a short-lived species seldom living greater than 3 years at most (Harding and Mifsud 2017).

Since the early 1970s, this formerly abundant frog has experienced dramatic population declines throughout the northern portions of its range, including the upper Midwest and the Great Lakes basin (Harding and Mifsud 2017). This species is listed as Threatened in Michigan with varying degrees of rarity and abundance across its range. In Michigan, it is now largely restricted to small, localized colonies. Historically documented from 19 counties in southern Michigan, and a disjunct population in Leelanau County, the species has drastically declined since the mid-1980s. Currently, extant populations are primarily concentrated in the southwest corner of the state, with a few isolated populations in the southeast (Harding and Mifsud 2017; Herp Atlas 2026).

2. Blanchard's Cricket Frog positioned at the water's edge, where individuals are known for their rapid, erratic jumping behavior when disturbed. This distinctive escape response, resembling the movement of a cricket, is the origin of the species' common name.

Blanchard's Cricket Frogs typically inhabit the open edges of permanent bodies of water such as ponds, lakes, bogs, and slow-moving streams and rivers (Harding and Mifsud 2017). They show a strong preference for open or partially vegetated mud flats, muddy or sandy shorelines, and mats of emergent aquatic vegetation in shallow water (Holman 2012; Harding



1. Individuals frequently utilize floating or emergent plants as basking and calling sites during the breeding season, allowing them to remain close to the water while maintaining vantage points for detecting predators and attracting mates.



and Mifsud 2017). While they require permanent water, they can also utilize temporary water bodies if they are located near a permanent water source (Minton 2001). This frog is rarely found far from the water's edge after the breeding season, except during rainy weather (Oldham and Campbell 1986). In more recent years, this species has been positively associated with the presence of gravel pit ponds and lakes and old quarries, particularly in southwest Michigan.

Due to their highly permeable skin and aquatic nature, they are exceptionally susceptible to aquatic pollutants, including pesticides, herbicides, and agricultural runoff (Oldham and Campbell 1986; Minton 1972). High levels of DDE and PCB have been reported in Blanchard's Cricket Frogs from Pelee Island, Ontario, a predominantly agricultural area (Campbell 1978). The introduction of fish into ponds and lakes also poses a significant threat, as fish prey on both tadpoles and adult frogs (Harding and Holman 1992). Fish introductions into extant cricket frog sites should be avoided or discontinued where possible (Bronmark and Edenhamn 1994). Even native predators like Bullfrogs can negatively impact cricket frog populations by consuming them and their eggs (Oldham and Campbell 1986).

The primary threats to Blanchard's Cricket Frogs in Michigan are habitat loss and degradation. Their short life expectancy and necessity for a metapopulation structure necessitate large, contiguous blocks of habitats to help facilitate recolonization. The loss of wetlands and the development of lake front property have eliminated the open, sparsely vegetated mud flats and shorelines this species requires (Harding and Mifsud 2017). Shoreline "improvements" such as the removal of vegetation and debris and placement of seawalls eliminate critical habitat.



3. Threats to Amphibians and Reptiles



1. Habitat loss is the leading cause of decline in herpetofauna in Michigan.

2. Road related mortality of an Eastern Massasauga Rattlesnake resulting from habitat fragmentation and lack of connecting corridors.

Habitat Loss, Degradation, Fragmentation, and Urbanization

Habitat loss, degradation, and fragmentation (secondary effect of habitat destruction and degradation) are among the most serious causes of reptile and amphibian population declines and species extinctions (Knutson et al. 1999; Dodd et al. 2003; Marchand and Litvaitis 2004; Weyrauch and Grubb 2004; Böhm 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 collective species extinction rates of 4% per decade, which is significantly higher than current rates [PM3.1]of extinction (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. Some amphibian species are known to experience high breeding site fidelity, traveling upwards of 6.2 miles (Smith and Green 2005). 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, and reduced critical zones - areas that are critical for life function, and invasive species colonization (Fahrig and Merriam 1985; Petranka et al. 2007; Bennett et al. 2010; Bennett and Litzgus 2012; Row et al. 2012). The effects of fragmentation on herpetofauna populations may not present themselves for decades after the fragmentation event is a phenomenon known as a time lag (Löfvenhaft et al. 2004).

3. Threats to Amphibians and Reptiles



1. Wetlands are significantly negatively impacted by habitat loss, urbanization, and pollution.

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

Genetic variation has been suggested to experience detrimental impacts following this time lag (Richmond et al. 2009; Maigret et al. 2020).

Habitat fragmentation can also negatively impact herpetofauna metapopulations (Hels and Nachman 2002). A metapopulation is a collection of partially isolated subpopulations in breeding habitat patches among which dispersal occasionally happens, and the persistence of each patch is dependent upon the existence of the metapopulation. Metapopulations can have a source-sink structure in which source subpopulations provide all external recruits into sink subpopulations, which contribute a negligible amount of recruitment to the source subpopulation. Fragmentation can exacerbate the isolation between subpopulations within a source-sink metapopulation, potentially extirpating the sink subpopulations by reducing dispersal from source subpopulations. Dispersal can be significantly reduced by high dispersal mortality or low dispersal rate. The persistence of corridors connecting wetland habitats has been shown to maintain necessary metapopulation processes in turtle species (Howeth et al. 2008).



Historically, Michigan had abundant wetlands, streams, lakes, and terrestrial areas that provided suitable communities for amphibians and reptiles (Holman 2012). However, Michigan has lost approximately 50% of these important habitats between the 1780s and mid-1980s (Dahl 1990; Fizzell 2014). Several wetland protection, loss mitigation, and restoration programs have been established through EGLE, United States Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS), the USFWS, the MDNR, and several nonprofit conservation organizations at the local, regional, and global level.



Wetland Mitigation

Mitigation is required as a condition of many permits issued under state law (Part 303, Wetlands Protection, and Part 301, Inland Lakes and Streams, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended) and federal law (Part 404 of the Clean Water Act). This replacement addresses the “no net loss” of aquatic resources at State and Federal jurisdictional levels. While mitigation wetlands provide some ecological services (e.g., flood control and waterfowl habitat), these wetlands take several years to fully develop, and sometimes support predatory fish populations that threaten the survival of amphibian larvae (Ficetola and De Bernardi 2004; Porej et al. 2004; Cunningham et al. 2007). The science of wetland mitigation design and management has significantly improved in recent years, but in the 1990’s and

1. Mitigation of wetland impacts can result in higher quality wetlands than those lost when proper design, landscape connectivity, and species natural history needs are considered.

2. Both illegal and permitted impacts along coastal wetlands can degrade overall habitat condition and quality. Coastal wetlands include dune-swale complexes, which serve as critical habitat for several species in Michigan.

early 2000’s, many wetland mitigation projects resulted in significant areas of open water which did not replace the ecological function and value 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 (Shulze et al. 2010). Mitigation wetlands may take many years to develop fully enough to provide the appropriate food resources, cover, hydroperiods (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 2003a; Vasconcelos and Calhoun 2004; Petranks et al. 2007; Shulze et al. 2010). In addition, complete amphibian communities are generally absent from most created wetlands (Lehtinen and Galatowitsch 2001; Porej 2003a; 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). These are some of the reasons that present day wetland mitigation is typically required to be restoration of lost wetlands, and not creation of new wetlands where there were not wetlands historically.

Mitigation “credits” can also be purchased to offset damage, shifting responsibility to a wetland mitigation bank. Wetland mitigation banks are large-scale (10-300 acres, though some are much larger) restored wetland areas. Historically, systems were



1. Shoreline hardening and degradation limit available habitat for most amphibians and reptiles. It also can fragment connectivity and pose direct harm for species trying to access upland habitats.

2. Seawalls provide no ecological value for herpetofauna. The vertical walls make access to upland habitat impossible, even for most snake species. Incorporating rock ramps into these structures provides some value to wildlife while meeting the intended need.

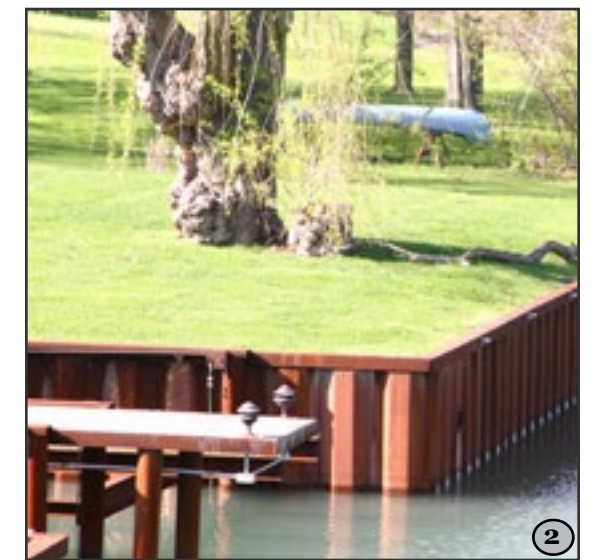
Construction and development can also remove amphibian and reptile habitat features from the landscape. This impacts specific amphibian and reptile species in the destroyed community as well as those that relied on that area as a connection between other habitat features (Knutson et al. 1999; McKinney 2002; Skidds et al. 2007). Changing the natural contours and composition of a landscape can alter drainage patterns, thereby altering the hydroperiods, water depth, and overall community structure in wetlands and entirely altering 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 et al. 2012). **For a detailed discussion of construction-related impacts and mitigation techniques, including erosion control, soil compaction prevention, and habitat protection measures, see Section 8: Development Techniques.**

Shoreline Hardening

Shoreline hardening removes natural shorelines and replaces them with constructed features to minimize wave action and prevent erosion. Engineered structures include seawalls, bulkheads, riprap, and revetments.

designed for more deep-water habitat. In the early years of wetland mitigation band development, this has shifted to targeting a more singular hydrological regime that dries annually. This can negatively impact the overall value of a site and is ecologically limiting, especially for herpetofauna, reducing species richness and overall functionality (Porej 2003a; Porej 2003b). As these wetland mitigation bank wetlands progress over the long term, microtopography and interspersions of habitat areas tend to develop in more complexity. The habitat value wetland mitigation banks provide for herpetofauna may increase over the longer term, rather than the short term.

Construction Impacts





1. Northern Water Snakes emerging from an overwintering site comprised of limestone along Charity Island in the Saginaw Bay.

2. Natural shorelines with smaller stones provide the greatest wave action abatement, while providing critical habitat for herps in high wave action areas.



Map Turtles, and Eastern Spiny Softshell Turtles require open, well-drained soils with specific thermal properties for successful egg incubation (Kolbe and Janzen 2002; Paterson et al. 2012).

2. Movement Barrier and Access Impediment: Vertical or overhanging structures like seawalls create absolute barriers that prevent aquatic turtles and amphibians from accessing essential terrestrial habitats for nesting, basking, and upland dispersal. This disrupts life-cycle completion and fragments populations.

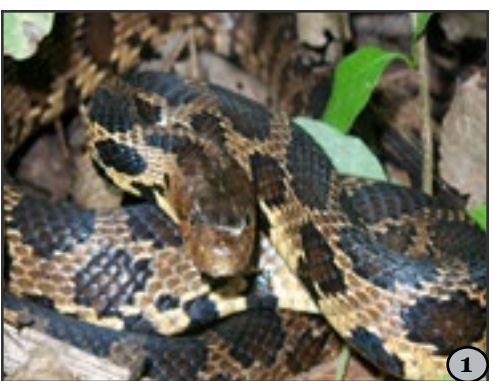
3. Entrapment Hazard: Loose riprap creates a labyrinth of unstable gaps where small turtles, particularly hatchlings, can become trapped, leading to exhaustion, predation, or desiccation. **For a detailed discussion of mitigation measures, design modifications, and habitat restoration techniques related to shoreline hardening, including void-filled riprap and egress ramps, see Section 6: Ecological Restoration, Mitigation, and Habitat Design.**

Riprap as Reptilian Refugia: A critical nuance in herpetofauna management is that certain hardened structures, particularly riprap, provide surrogate habitat for some snake species that historically utilized rocky outcrops and talus slopes. Riprap functions as a surrogate for the natural historic shoreline, which would have included limestone shelves with fractures providing natural gaps as refugia and locations for egg deposition. These habitats are now largely lost across its historic extent, making existing riprap a critical habitat alternative. Species like the Eastern Fox Snake, Butler's Garter Snake, and Northern Water Snake show high affinity for riprap, which offers thermoregulatory basking sites, refuge from predators, and egg-laying and birthing opportunities (Harding and Mifsud 2017). Telemetry studies on Eastern Fox Snakes have documented individuals selecting riprap habitat over 80% of the time when available, underscoring its value where natural rock features have been lost (Kucher and Seldon 2009). Therefore, wholesale removal of existing riprap

This transformation fundamentally modifies habitat structure and ecological function, replacing gentle, undulating slopes and organic-rich soils with steeper, drier, biologically impoverished shorelines that have reduced capacity to support native riparian food webs (Wensink and Tiegs 2016).

For riverine herpetofauna, shoreline hardening presents three primary threats:

1. Loss of Critical Nesting Habitat: The elimination of natural, loose substrates (e.g., sandy or loamy soils) along the shore directly reduces or eliminates suitable nesting sites for all riverine turtle species. Turtles such as Wood Turtles, Northern



1. The Eastern Fox Snake has largely adapted to coexist with more urban landscapes when compared to other species. They can be observed using more degraded landscapes and natural area when compared to other species which require more specific habitat conditions. As a result degraded or lower quality sites are often disregarded as not supporting this State Threatened Species. Projects occurring along the Detroit River and Lake Erie coastline should strongly consider this species as potentially occurring.

can be detrimental to these species. Careful consideration should be given to any landscape modification project that results in the elimination of such a critical feature where this and other species may be present.

The management goal should be a balanced approach: maintaining or enhancing the value of riprap for snakes while eliminating its entrapment hazard for turtles. A constructive compromise would be void-filling, a technique that addresses turtle safety while preserving the complex interstitial spaces snakes rely on, thereby allowing for connectivity between aquatic and terrestrial habitat. This strategy aims to support reptile diversity by mitigating risk for turtles without eliminating critical refugia for snakes.

Landscape Succession

Succession, whether occurring naturally or accelerated by human activities, can pose significant threats to herpetofauna when it results in degraded habitat conditions. While successional processes are a natural part of ecosystem dynamics, anthropogenic influences, particularly the introduction and spread of invasive species, have dramatically accelerated these changes, leading to widespread habitat degradation and loss of functional value for amphibians and reptiles.

Invasive plants present a major threat by rapidly altering the structure and composition of riparian zones and adjacent uplands. Species such as Buckthorn (*Rhamnus cathartica*), Autumn Olive (*Elaeagnus umbellata*), and Japanese Barberry (*Berberis thunbergii*) aggressively overtake understories, forming dense monocultures that fundamentally alter habitat conditions. These invasions limit light penetration, reduce soil temperature variability, and simplify the leaf litter layer, all of which are essential microhabitat characteristics for numerous amphibians and reptiles (Delaney et al. 2021; Maerz et al. 2009). The loss of structural complexity reduces available cover, foraging opportunities, and thermoregulatory sites.

Beyond physical habitat alteration, certain invasive plants directly impact herpetofauna survival and development. Buckthorn, for example, alters soil hydrology and chemistry, and its leaf litter leaches phytochemicals that negatively affect embryonic development and larval survival in amphibians (Havel and Shurin 2004). Buckthorn also negatively impacts hydrology by wicking water from soils, accelerating wetland drying, and has been linked to developmental issues and reduced larval survival (Sacerdote and King 2014).

Aquatic invasive species pose equally severe threats. Plants such as Common Reed (*Phragmites australis*) (hereafter referred to as *Phragmites*), non-native Cattail (*Typha angustifolia* and *T. x glauca*), and Eurasian Milfoil (*Myriophyllum spicatum*)



can homogenize aquatic habitats, lowering oxygen levels and compromising breeding sites (Bourgeau-Chavez et al. 2013). These invasions reduce habitat heterogeneity, eliminate open water areas needed for amphibian reproduction, and can alter predator-prey dynamics within aquatic communities. The cumulative effect of these successional changes is a decline in habitat suitability that can lead to reduced species richness, localized extirpation, and diminished population viability across the landscape. **For a detailed discussion of management strategies to address threats, including invasive species control and habitat restoration techniques, see Section 7: Management Techniques under Succession and Habitat Management.**

Functional Value vs. Botanical Composition

While some systems can have significant impacts from invasives, some areas that may support a lower botanical richness may still provide necessary ecological utilities. This often occurs in urban, suburban, rural, and agricultural landscapes. When assessing landscapes for herpetofauna, it is critical to consider the functional value more so than merely the botanical composition of the landscape. Herpetofauna often will thrive in less pristine habitats that meet their biological and natural history requirements, regardless of botanical “pristineness.” These species were some of the earliest colonizers, often establishing in spartan, oligotrophic landscapes. Numerous species demonstrate considerable ecological adaptability, flourishing in habitats that are structurally appropriate yet floristically simplistic, such as urban floodplains, coastal riprap, abandoned fields, and suburban woodlots with vernal pools (Ghoddousi et al. 2021; Halliday et al. 2020; Riley et al. 2005; Sutor et al. 2023). These environments can fulfill critical needs: sites for thermoregulation, substrates for foraging, and shelter from predators. Their adaptive nature and plasticity must be considered and accounted for when considering measures to modify or even destroy habitats that seem undesirable. As a result, habitat evaluations should emphasize functional value rather than subjective aesthetic considerations. Resources like the Herpetofauna Habitat Assessment Tool (Herp HAT) have been developed to perform

1.The Wood Turtle in Michigan is a riverine specialist occupying sandy clear water rivers and associated tributaries. They will also use riparian habitats and have been found as far as a mile from the rivers edge using upland habitat.



such thorough assessments, which may accurately determine that the best management strategy is to take no action to maintain the current functional value. **For a comprehensive overview of the Herp HAT, including its development, methodology, and application, see Section 4: Conservation Efforts under Herp HAT: The Herpetofauna Habitat Assessment Tool for Michigan.**

Figure 1

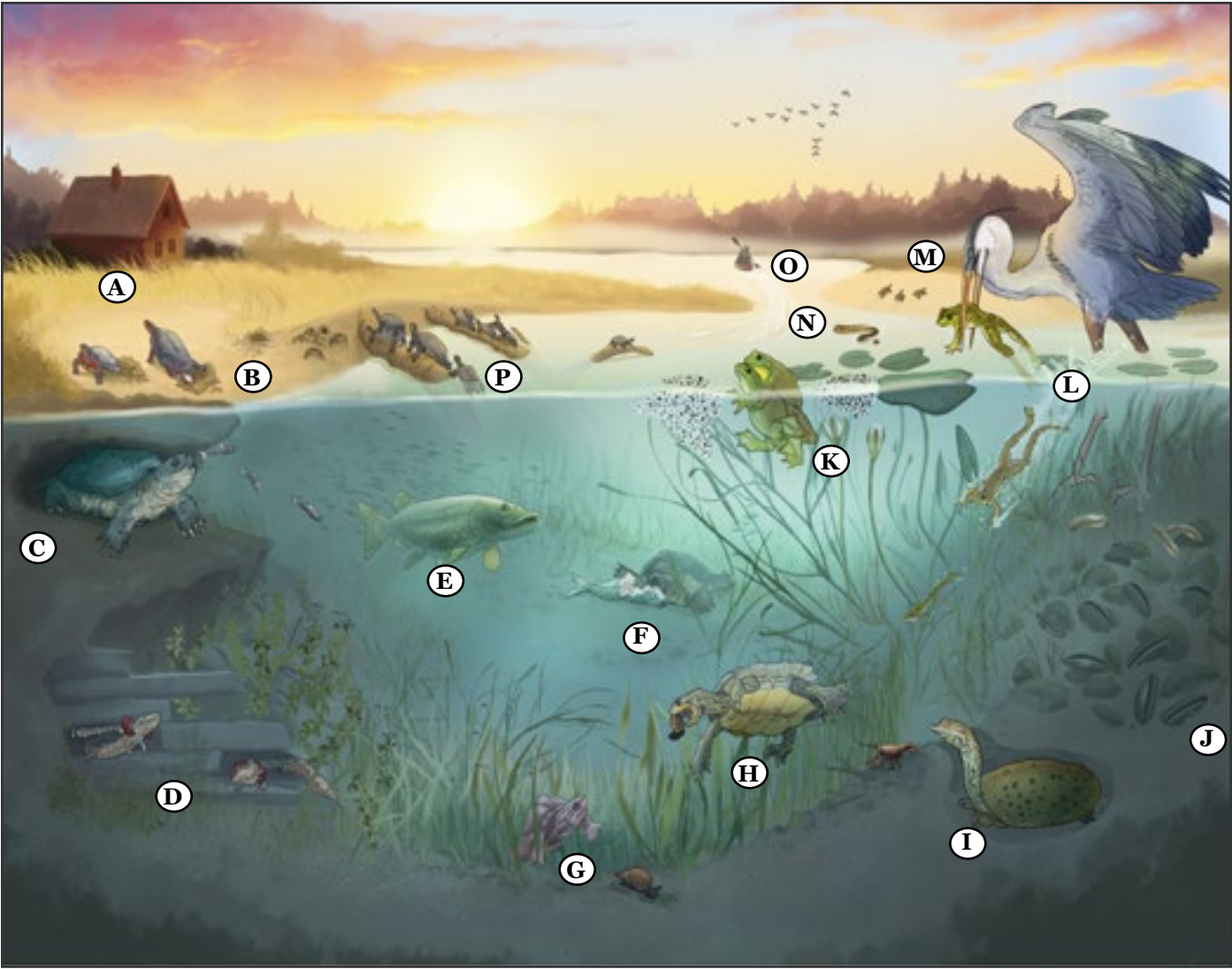


Figure 1.
A. Michigan’s supports numerous seasonal “up north” cottages and cabins. These sites can co-exist with habitat for herpetofauna.
B. Riverine banks provide critical Wood Turtle nesting sites.
C. Eastern Snapping Turtles will use banks of rivers as shelter and locations to stalk prey.
D. Northern Mudpuppies use limestone shelves and other structure as refugia and nurseries for their young.
E. Large predatory fish can be significant predators on many species of herpetofauna especially young turtles.
F. Eastern Snapping Turtles are critical landscape species feeding on dead and dying animals serving as the “kidneys” of aquatic habitats.
G. Eastern Musk Turtles can stay submerged under water for several hours due to specialized skins cells allowing them to forage and feed on prey including non-native snails and other invertebrates.
H. Northern Map Turtles are important riverine species feeding on Zebra Mussels and non-native snails helping to improve habitat quality.
I. Eastern Spiny Softshell Turtles will bury themselves under sand to stalk prey including invasive Rusty Crayfish.
J. Salamander Mussels are in decline and are only present or abundant where Mudpuppy populations are stable and healthy.
K. Bull Frogs are one of the few species of frog who will actively breed in submergent and floating leaf wetlands associated with riverine habitat.
L. Blue Herons are a native and natural predator of herpetofauna.
M. Blanding’s Turtles will utilize riverine habitats though they prefer oxbows and sloughs associated with rivers.
N. Northern Water Snakes actively hunt for small fish and amphibians in or near riverine habitats.
O. Recreation opportunities and stewardship of our rivers is a critical component to effective management and preservation. Maintaining the balance of use by people as well as the needs of the wildlife is critical to keep these sites available for generations to come.
P. Riparian logs and those found within the river are critical habitat for herpetofauna. They serve as basking sites as well as refugia from predators.





1. Roads present a barrier to amphibian and reptile species that seek new ranges due to climate change. Slow moving species like Eastern Box Turtles are frequently injured or killed on roads traveling between habitats.



2. An Eastern American Toad killed on the road due to a curb restricting movement. Creating and restoring habitat connectivity will be a key factor in the recovery and continued presence of Michigan's herpetofauna communities.

Watercourses in Successional Landscapes

Rivers and streams (also referred to as watercourses), as well as other associated aquatic habitats like floodplains, support a diverse range of herpetofauna. Many species rely on these habitats for at least part of their life cycle, with some largely selecting for these flowing aquatic landscapes. In Michigan, at least twelve (12) amphibians and thirteen (13) reptiles use at least some components of a river and surrounding riparian habitat seasonally (Harding and Mifsud 2017). Not only do watercourses serve as critical refugia for herpetofauna, they also provide important breeding habitat, immigration and migration corridors, and a means for genetic dispersal. The ecological functions provided by watercourses are multifaceted: they serve as primary refugia, essential breeding and nesting sites, key corridors for dispersal and migration, and vital pathways for genetic exchanges across the landscape (Fagan 2002). The integrity of these functions is directly linked to natural hydrological processes, including seasonal flooding, sediment transport, and temperature regimes.

Threats, including damming, shoreline development/hardening (seawalls, bulkheads, riprap), urbanization, and contamination, negatively impact riverine ecosystems and degrade the functional value to herpetofauna and other organisms. These threats have a range of negative impacts on herpetofauna and their viability and presence on a landscape. These alterations have demonstrable, negative consequences for herpetofauna viability, leading to population fragmentation, reduced reproductive success, and local extirpation. The use of management techniques to help mitigate these negative impacts can help to conserve herpetofauna and continue their persistence and occupancy across these landscapes. Consequently, the implementation of science-based best management practices (BMPs) is imperative to mitigate these impacts, conserve herpetofauna biodiversity, and maintain ecological resilience within Michigan's riverine networks. Specific threats and their associated BMPs are discussed in greater detail throughout this document, including in the preceding sections on shoreline hardening mitigation and within this section on succession management.

Roads and Other Transportation

Roads and other forms of transportation can have significant negative long-term effects

on biodiversity and population sustainability (Findlay and Bourdages 1999; Bartoszek and Greenwald 2009; Bulté et al. 2010; Hartzell 2015; Bilkovic et al. 2019; Dornas et al. 2019). Roads are a significant barrier for amphibian and reptile movement across the landscape, with tens of thousands of turtles, snakes, and frogs being killed along roadways every year (Steen and Gibbs 2004; Steen et al. 2006; Row et al. 2007; Patrick et al. 2011; Cosentino et al. 2014). In some places, roads are a significant source of mortality for herpetofauna and can threaten the existence of local populations (Beaudry et al. 2010; Gunson 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 ecological communities or near reptile habitat features (e.g., snake hibernacula) have higher rate of reptile mortality (Fortney et al. 2012). 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 and Smith 2006; Szerlag and McRobert 2006; Row et al. 2007; Shepard et al. 2008b; Patrick et al. 2011; Fortney et al. 2012). Behaviors associated with road interactions, such as avoidance and crossing speed, can vary from species to species (Andrews and Gibbons 2005a). 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 2005a; Aresco 2005a; Barrientos and Bolonio 2009; Clark et al. 2010; Hawlena 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 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 2005b; Jaeger et al. 2005; Andrews 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). Railroads share many of the aforementioned negative impacts with roads, including their contribution to the decline of herpetofauna populations through fragmentation and direct mortality (Bartoszek and



1. The degradation of wetlands can significantly reduce suitable habitat for amphibians and reptiles. With restoration, these areas can serve as habitat again.



1-2. A prescribed fire in amphibian and reptile habitat used to maintain open ecosystem structure. While fire is an important management tool, it can pose risks to herpetofauna if adequate refugia are not available. Subterranean features such as crayfish chimneys, mammal burrows, and root cavities provide important shelter and overwintering habitat that can allow amphibians and reptiles to survive fire events.

3. Slow moving species, like the Eastern Box Turtle, often succumb to fatal injuries during fires associated with using prescribed burn as a restoration technique.

Greenwald 2009; Iosif 2012; Clauzel et al. 2013; Hartzell 2015; Dornas et al. 2019). Similarly, boat traffic is often responsible for the direct mortality of herpetofauna, primarily turtles (Bulté et al. 2010; Lester et al. 2013; Hollender et al. 2018), as well as the habitat degradation and erosion of shoreline habitat caused by boat wakes (Fonseca and Malhotra 2012; Bilkovic et al. 2019; Schafft et al. 2021).

Urbanization

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 (Saumure et al. 2007; Humbert et al. 2009; Mifsud personal observation, 2026). 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 the 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 also harms amphibians and reptiles. Machines indiscriminately remove non-target flora and fauna, including amphibians and reptiles from the surface of the water and processes them with the targeted vegetation, sometimes crushing the animals (Wile 1978; Haller 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 can also 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 et al. 2008). Many amphibians and reptiles respond to visual cues, and life processes such as migrations, mating, nesting, and hibernation may be unintentionally influenced by light pollution.

Prescribed Fire

Although often used as a wildlife conservation and plant community restoration measure, controlled (prescribed) burns can cause serious injury and direct mortality to herpetofauna as well as alter habitat



1. Isolated wetlands often have more reduced herpetofauna species richness due to a lack in connectivity and adjacent landuse impacts. This can be particularly true on agricultural landscapes.

2. Haying can directly harm herpetofauna though the cutting process. Although drying hay provides a warm habitat for snake species, it is not uncommon for snakes and even salamanders to be found in hay bales compressed, desiccated, and dead.

potential impacts to herpetofauna, specifically appear not to be evaluated. As a result, fire management (e.g., change in leaf litter, vegetation structure, response of various life stages, effect on food source, etc.) can alter the site in a manner that may negatively affect some species. Turtle and snake mortality have been documented at burn sites in Michigan (Cross 2009; Gibson 2009; Woodley and Kingsbury 2011; Mifsud personal observation 2026; Buchanan et al. 2020; Edmonds et al. 2023; Melvin and Roloff 2018; Laarman 2018). 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 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 et al. 2010). The temporary decrease in the abundance of post-burn insect communities that live closest to the ground (in the “fuel” layer (Siemann et al. 1997; Tooker and Hanks 2004) may decrease the availability of prey items to amphibians and reptiles directly after a burn.

Herps and Agriculture

Agricultural landscapes represent a significant land use type across Michigan, and their interaction with herpetofauna is complex. While agriculture can be a source of habitat loss and chemical contamination, agricultural lands themselves, particularly when managed with wildlife in mind, it can also provide valuable habitat for amphibians and reptiles.





1. Cutting practices on agricultural landscapes vary in terms of impact based on timing. Mowing, tilling and harvesting are the most impactful physical activities with the exception of pesticides application.

2. The eggs and larvae of amphibians, like Eastern American Toads, are particularly sensitive to pesticides and herbicides. Not only to pesticides directly affect herpetofauna, they also impact their prey.



Agricultural Landscapes as Habitat

Agricultural areas, including pastures, field margins, hedgerows, drainage ditches, and fallow fields, can serve as important habitat components for herpetofauna, particularly in regions where natural habitat has been diminished. These areas may provide foraging grounds, migration corridors, and even breeding habitat for some adaptable species. For example, drainage ditches and irrigation ponds, if properly managed, can support breeding populations of frogs and salamanders. Field margins and hedgerows offer critical cover and movement corridors for snakes and turtles moving between remaining natural areas (Denton et al. 1997; Porej and Hetherington 2005;

Lourdais et al. 2025; Montgomery and Reid 2024; Youngquist and Boone 2014). The conservation value of agricultural landscapes for herpetofauna is highly dependent on management practices. Extensive management practices, such as rotational grazing, maintenance of vegetative buffer strips along waterways, and retention of non-crop habitat features, can greatly enhance habitat suitability (Knutson et al. 2004). However, intensive practices, including those involving heavy chemical use and frequent mechanical disturbance, can diminish or eliminate the value of agricultural habitat to herpetofauna.

Machine-Related Mortality in Agricultural Landscapes

Agricultural operations can pose direct physical threats to herpetofauna through the use of machinery. Mowing, tilling, harvesting, and other mechanical operations can cause direct mortality to amphibians and reptiles (Saumure et al. 2007; Humbert et al. 2009; Mifsud personal observation 2026). Snakes, frogs, toads, and turtles are particularly vulnerable to mowing and tillage because of their low profile, cryptic coloring, and tendency to use agricultural fields for foraging, basking, or nesting. Mortality can occur through direct contact with blades, tires, or tillage equipment. Additionally, the compacting of soil by heavy machinery can cause direct mortality to individuals burrowing or hibernating below the surface (Bol 2007). The timing of mechanical operations is a critical factor; operations conducted during peak activity periods or during sensitive life stages (e.g., nesting, hibernation) can have disproportionate impacts on local populations.

Pesticide Toxicity in Agricultural Settings

These mechanical threats are compounded by the widespread application of pesticides in agricultural settings, including insecticides, herbicides, fungicides,



1. Spotted Salamander egg masses in a vernal pool. Salamanders are predatory from larvae through adult and can be incredible predators to pest species. Use of pesticides can not only directly impact salamanders, but also can impact their prey reducing fitness and available resources.

and rodenticides, which pose a significant, multi-faceted threat to herpetofauna. Amphibians, with their permeable skin and aquatic life stages, are especially vulnerable. **For a comprehensive discussion of pesticide toxicity, including detailed information on specific compounds, direct and synergistic effects, sublethal impacts, and the latest research findings, see Chemical Use – Pesticides below.**

Chemical Use

Amphibians and some reptiles have highly permeable skin and typically have extensive contact with water or soil. These characteristics make them particularly sensitive to chemical use and 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 et al. 1999; Unrine et al. 2007). Their sensitivity to chemicals 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 and Eastern Musk Turtles, which can respire through specialized tissue in the cloaca and tongue (Heiss et al. 2010). Reptile and amphibian population declines have been linked to increased chemical use and pollution (Fontenot et al. 2000; Johansson et al. 2001; Weir et al. 2010), but relatively little work has been done to document the response of amphibian and reptile communities to various types of chemical contaminants (Egea-Serrano et al. 2012; Slaby et al. 2019). 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 levels of nutrients, pesticides, and herbicides which can result in the 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; Hall and Henry 1992). Runoff from roads, parking lots, sidewalks, rooftops, lawns, and other surfaces can introduce 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 et al. 2002; Schueler 2003; Collins and Russell 2009; Denoel et al. 2010; Sanzo and Hecnar 2006). Chemical contaminants may weaken the immune system of amphibians and reptiles and increase their susceptibility to parasites, disease and ultraviolet (UV) radiation (Blaustein et al. 2003; Daszak et al. 2003; Gendron et al. 2003). However, these negative impacts to herpetofauna associated with chemical use can occur solely as a result of permissible, on-label, ubiquitous use by all, without ill intent.



1. An Eastern Snapping Turtle nest along a road behind a guard rail. When resources are limited, turtles will utilize what ever nesting sites they can, often resulting in increased risk of harm or death and exposure of eggs to predation.

2. Eastern American Toads and other amphibian larvae are highly susceptible to chemical contaminants in their environment.

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 released from motor vehicle use. This suite of pollutants can affect water quality, which in turn can harm herpetofauna populations (Karraker 2006; Andrews et al. 2008; Bennett et al. 2011). These pollutants reduce water quality and degrade terrestrial resources on which amphibians and reptiles rely (Findlay and Kelly 2011; Thompson et al. 2017). 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 Environmental 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 et al. 2008). Environmental salinity from the 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 *Phragmites*, (Karraker 2006). Lower-impact alternatives to conventional road salts are used and recommended by the Michigan Department of Transportation (MDOT) (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). As a state, Michigan uses approximately two million tons of road salt annually. This salt in the environment discharges 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 et al. 1999; Paul and Meyer 2001; Jackson and Jobbágy 2005; Kaushal et al. 2005).

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 (Agency For Toxic Substances and Disease Registry 1995) that can cause lethal and sublethal effects and deformations in wildlife (Albers 2002; Douben and Wiley 2003).



1. Developing larval metamorph amphibians like this Wood Frog have many challenges and stressors limiting their chances of reaching adulthood.

2. Where *Phragmites* grows in dense stands, turtles, must travel farther distances to find nesting areas. This extra traveling can be exhausting to any animal, let alone a gravid turtle. These individuals increased overland exertion causes them to become more vulnerable to predation and persecution.

These compounds have also been linked to immune suppression (Dickerson 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 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 et al. 2006), reduced fertility and hatchling mortality in Eastern Snapping Turtles and Midland Painted Turtles, and toxicity and cancer in amphibians (Balls 1964; Fernandez and L’Haridon 1992; Djomo et al. 1995; Bell 2005).

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;

Säfholm et al. 2014). 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 et al. 2009). The environmental contamination associated with pharmaceuticals are in part regulated by the Food and Drug Administration (FDA), which evaluates environmental impacts of drug use (U.S. Food and Drug Administration 2011) and the EPA, which 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 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).

Excess Nutrients

Nutrients (e.g., nitrogen 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 et al. 1999; Ortiz-Santaliestra et al. 2012) and the expansion of *Phragmites* (King et al. 2007). The runoff of organic fertilizer, like





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

poultry litter, can be particularly damaging to amphibian larvae and is lethal to eggs and damaging but sublethal to tadpoles (Curi et al. 2017). 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 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). Additionally, nitrates may increase predation risk in tadpoles by decreasing their overall activity level and predator detection ability (Ortiz-Santaliestra et al. 2010). Algal blooms also have been linked to compromised immune function and mortality of herpetofauna (Tornabene et al. 2024 ; Garcia 2019; Refsnider et al. 2021).

Pesticides

Pesticides represent one of the most significant chemical threats to herpetofauna, encompassing a wide array of compounds including insecticides, herbicides, fungicides, and rodenticides. Amphibians, with their permeable skin and aquatic life stages, are especially vulnerable. Pesticide applications can have ranging effects on herpetofauna species, including both direct and synergistic effects.

In one study, amphibians were exposed to a combination of organophosphorus insecticides and herbicides at two representative application concentrations. At 1 mg/L concentrations demonstrated 5% declines in survival and 35% declines in growth. At 2 mg/L, survival was reduced by 35% and growth by 70% when compared to a control (Relyea 2004). Sublethal effects are equally damaging and include immunosuppression, which can increase susceptibility to diseases like chytridiomycosis, and endocrine disruption, affecting reproduction and development (Hayes et al. 2006; Brühl et al. 2013). Broad-spectrum insecticides can decimate arthropod prey bases, while herbicides eliminate plant cover, indirectly impacting herpetofauna by reducing food availability and increasing exposure to predation and desiccation (Boone and James 2003). Toxicity varies greatly by chemical compound, formulation, and the life stage of the organism. Larval amphibians are often the most sensitive. The lethal concentration for 50% of a test population (LC50) is a standard metric, but field-relevant, chronic exposures to pesticide mixtures often present a greater risk than indicated by laboratory tests of single compounds indicate (Fryday and Thompson 2012; Karlsson et al. 2021).

Pesticides, including herbicides and insecticides commonly applied to agricultural fields and manicured landscapes, can cause developmental abnormalities, deformities, and altered behavior and have been documented as the impetus for declines in

1. Species like the Northern Leopard Frog are highly sensitive to chemicals in their environment and are negatively impacted from pesticides.

multiple 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; Pompermaier 2024). Amphibians are particularly at risk from pesticide exposure due to the nature of their life histories: most species have an aquatic larval stage as well as some form of a terrestrial stage, exposing them to toxins in multiple environments at different life stages (Brühl et al. 2013).



2. Species like the Small-mouthed Salamander can be impacted from the use of chemicals to control insects by reducing prey as well as direct impact to these species during development.

Recent studies suggest that pesticides and fungicides may have extremely harmful effects on amphibians in terrestrial environments (Brühl et al. 2013; Belden et al. 2010; Barbi et al. 2023; Rowley et al. 2024). Reduced abundance of Mink Frogs has been linked to large scale insecticide use (McAlpine et al. 1998). Acute and chronic mortality and deformations in salamander and frog communities have been observed after insecticide applications (Ingermann et al. 2002; Boone and James 2003). The historical use of Dichloro-Diphenyl-Trichloroethane (DDT) 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 et al. 2004). Although not as widespread as in the past, chemical control of mosquitoes 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”). Chemicals used in fogging to kill adult mosquitoes (e.g., malathion) and, organophosphates targeting mosquito larvae are both toxic to tadpoles (Berrill et al. 1994; Sparling et al. 1997; Relyea 2004) and may result in amphibian declines. Removal of larval and adult mosquitoes from an ecosystem can also remove a significant food source for larval amphibians, fish, birds, and other wildlife (Blaustein and Kotler 1993; Blaustein 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





1. Mole salamanders like the Spotted Salamander are affected from compounds like glyphosate resulting in development issues.

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 the human consumption of turtles and for the 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 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, resulting in reproductively viable hermaphroditic transformations that skews sex ratios, disrupts population structure, and may reduce genetic diversity (Allran and Karasov 2000; Sower et al. 2000; Hayes et al. 2002a; Hayes et al. 2002b; Hayes et al. 2003; Coady et al. 2004; Hayes et al. 2010;

Herpetological Resource and Management 2011a). Additionally, atrazine exposure can increase the 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; increase the risk of renal, spleen, and liver damage; and promote 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 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 the Northern Leopard Frog, Green Frog, and Bullfrog (Cheek et al. 1999; Mann et al. 2009).

Glyphosate based herbicides (e.g., Roundup®, Rodeo®, Accord®) and surfactants (e.g., POEA, polyethoxylated tallowamine; NPE, nonylphenol ethoxylates) are commonly used in land management (Dill 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 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). Since surfactants are proprietary mixtures protected under trade-secret laws, manufacturers are not required to list



Jim Harding

1. Short lived species like the Blanchard's Cricket Frog can be particularly impacted from use of chemicals due to the limiting ability for populations to recover.

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 and 1 mg acid equivalent/L) (Govindarajulu 2008) have been detected in nearby waterways one week after application (Battaglin et al. 2009). Additionally, some herbicides, such as triclopyr, can be detected in nearby aquatic systems for up to 13 months after treatment (Battaglin 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 et al. 2009). The deleterious impacts of multiple types of pesticides can combine to be even more damaging to amphibians, with a singular frog potentially containing a mixture of up to eight different herbicides in their tissue (Smalling et al. 2015).

It is important to note that even “organic” pesticides are still harmful to herpetofauna. Natural pesticides and insecticides, often perceived as safer, can significantly impact amphibians by causing developmental deformities, immune system suppression, and increased mortality. Some compounds function as a neurotoxin, and direct exposure to individuals or habitats can have negative effects (Gutierrez-Villagomez et al. 2021; Berrill et al. 1993).

Piscicides

Lampricide is used as a piscicide to kill invasive Sea Lamprey (*Petromyzon marinus*) in Michigan waters. The control of the invasive Sea Lamprey is a cornerstone of fisheries management in the Great Lakes, vital to the restoration of native fish populations. However, the primary tool for control, the application of chemical lampricides, poses a significant and well-documented threat to non-target aquatic organisms, particularly amphibians (Christie et al. 2003; Birceanu et al. 2014; Wilkie et al. 2021; Neuderfer et al. 2024).

The two primary lampricides used are 3-trifluoromethyl-4-nitrophenol (TFM) and





1. Application of lampricides often results in the mortality of Northern Mudpuppies in areas where these fully aquatic salamanders live. Mortality is often undetected unless animals wash onto shore and observed.

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 Northern Mudpuppies, and sometimes results in large-scale mortalities (Gilderhus and Johnson 1980; Kane et al. 1993; Boogaard et al. 2003; Dawson 2003; Hubert 2003; Billman et al. 2011; Neuderfer et al. 2024; State of Vermont 2011). The Northern Mudpuppy, a fully aquatic salamander, is exceptionally vulnerable. Lampricide treatments routinely cause large-scale, acute mortality events in Northern Mudpuppy populations, with mortality rates often exceeding 90% in treated stream reaches. Due to their longevity and low reproductive rate, the recovery of affected populations can take decades (Matson 1998; Boogaard et al. 2003; Neuderfer et al. 2024; Matson 2022; Hinkle et al. 2016; Gilderhus and Johnson 1980). Several turtle species may be impacted by lampricide as well, particularly Eastern Spiny Soft-shells and Eastern Musk Turtles, as these species respire through specialized tissue in the cloaca and tongue, which likely increases sensitivity to toxins (Heiss et al. 2010). Long-term accumulation of lamprey-killing chemicals in Northern Mudpuppies may shorten the life span of these long-lived (~25 years) amphibians and decrease their ability to reproduce (Parren and Hart 2012). Direct mortality, sometimes in the hundreds of Northern 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). Impacts extend beyond direct kill; sublethal exposure can impair growth, development, and immune function in surviving individuals and other amphibian species. The removal of a top benthic predator like the Northern Mudpuppy can also trigger trophic cascades, altering invertebrate community structure and overall stream ecosystem function (Browne et al. 2009; Brönmark and Weisner 1996; Ellis et al. 2011; Robinson et al. 2021). Researchers have identified a need for further investigation into how non-target, non-fish vertebrate and invertebrate species (specifically larval amphibians, mollusks, and endangered species) are impacted (McDonald and Kolar 2007).

Lampricide application presents a profound conservation conflict between restoring native fish communities and protecting native amphibians. The recovery of ecologically

Bayluscide (niclosamide). These compounds are applied to tributary streams to target larval lampreys buried in sediment. While selectively toxic to lampreys, these chemicals are also highly toxic to amphibians, which share physiological similarities in respiratory surfaces and skin permeability. Lampricide has deleterious effects on several non-target species (Boogaard et al. 2003; Dawson 2003; Hubert 2003). This chemical is toxic to many insects,



1. Northern Mudpuppies are an important indicator of aquatic systems and a critical host species for the Salamander Mussel. They are both a critical landscape species and arguably themselves critical habitat for the larval life stage of the Salamander Mussel.

2020). Complicating this trade-off is the Northern Mudpuppies likely role as a native predator. Research indicates Northern Mudpuppies may also consume larval lampreys. Their potential as a biocontrol agent for lampreys remains unclear and is likely minimal compared to the efficacy of chemical control (Becker 1983; Stasiak 2006; Derosier 2007).

Balancing these competing conservation goals requires refined application practices and investment in alternative control technologies. Managers continually refine treatment protocols to minimize non-target impacts. This includes: using the minimum effective dose based on precise water chemistry calculations; avoiding treatment of stream reaches with known, significant Northern Mudpuppy populations when possible; and conducting thorough pre-treatment surveys to identify and document herpetofauna presence (Robinson et al. 2021). Reducing reliance on lampricides requires scaling up alternative control methods. These include physical barriers (permanent and seasonal low-head barriers to block lamprey spawning migrations), trapping (enhanced trapping of adult lampreys in streams and nearshore areas), and sterile-male release (a biologically-based technique that reduces reproductive success in the spawning population) (Hansen et al. 2016; Twohey et al. 2003). Robust, long-term monitoring of Northern Mudpuppies and other amphibian populations in treated watersheds is essential for understanding population recovery trajectories, assessing the cumulative impact of repeated treatments, and informing adaptive management strategies that strive to protect both fishery and herpetofauna resources (Browne et al. 2009; Brönmark and Weisner 1996; Ellis et al. 2011). Mitigation for mortality should also be reviewed and strongly considered.



2. Eastern Musk Turtles are particularly sensitive to chemicals in their environments and due to the amount of expose skin they are susceptible to compounds like rotenone resulting in die offs during applications.



Rotenone is a broad-spectrum pesticide used to treat a problematic fish community. The application of rotenone during the winter has not shown adverse effects on amphibian populations overwintering (Walston and Mullin 2007; Fried et al. 2018). Since cold weather also lengthens the half-life of rotenone (Dawson et al. 1991), the desired management effect is likely to be more successful. This product has also been shown to have high lethality on species like Eastern Musk Turtle and Spiny Softshell Turtles when applied in the active season.



Alterations to Hydrologic Processes

Massive efforts throughout 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 wetland (Dahl 1990). Watershed level alterations in hydrologic processes can reduce habitat availability, connectivity, suitability and recruitment success for various amphibians and reptiles (e.g., Eastern Massasauga Rattlesnake, Blanding’s Turtle, Red-spotted Newt, Wood Frog, Spotted Salamander) (Chin 1996; Willson and Dorcas 2003; Faulkner 2004; Riley et al. 2005; Skidds et al. 2007; Hamer and McDonnell 2008).

As Michigan became more developed, roads, sidewalks, and roofs replaced areas of vegetation. Vegetation typically reduces the impact of rain events by providing a physical barrier that breaks large raindrops 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 deeper into the soil to be 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, rainwater 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

- 1. Impervious surfaces results in increased flashiness causing degradation to wetlands.
- 2. Perched culverts form undersized pipes fragment aquatic landscapes and impacts stream morphology and habitat condition.

- 1. Combined sanitary and storm sewer overflows are becoming less common, though where present pose a threat and harm to water quality.
- 2. Flashiness from urban landscapes results in higher velocity and volume of water degrading habitat. Seasonal wetlands, like vernal pools, that typically do not have contact with floodplains are inundated resulting in high turbidity and potentially the colonization of fish.

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, while 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 causing contaminants to accumulate 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 degrade aquatic communities that support amphibian and reptile populations (Murray and Hoing 2004; Massal 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 et al. 2002). Sediment from upland and streambank erosion suspended in surface waters results in increased turbidity and reduced dissolved oxygen. Turbidity reduces





1. Dams pose direct and indirect threats to herpetofauna in Michigan. They result in a fragmented landscape and alter hydrologic regimes impacting travel corridors and habitat suitability.

water clarity and quality, decreasing amphibian and reptile aquatic habitat suitability (Roy 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).

Stream morphology is also altered due to 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 used by amphibians and reptiles for cover, hibernation, foraging, and nesting (Bodie 2001). Hardening and straightening waterways alter the flow of water, changing the character of sediment transport and deposition, and decreases infiltration.

Dams and Impoundments

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, and prevent flooding, they also dramatically impact native wildlife and fisheries resources. Dams represent one of the most severe and pervasive threats to riverine herpetofauna, inducing impacts through physical fragmentation, hydrological alteration, and geomorphic change. Dams often create barriers to amphibian and reptile movement and serve to fragment populations (Bennett 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 (Ligon et al. 1995; Lind et al. 1996; Ashton et al. 2011; Bettaso

1. Impoundments resulting from installation of dams alters hydrology, temperatures, nutrient cycles and results in a riverine landscape becomes a lotic impoundment. While several species of herpetofauna can thrive in this created habitat, it remains fragmented and species that can travel between these landscapes are often killed on roads that cross over dams.

2013). Dams reduce areas of suitable aquatic communities upstream and downstream (Eskew et al. 2012). For example, higher water levels upstream of a dam can inundate the sandy banks turtles use for nesting (Bateman et al. 2014; Hunt et al. 2013).

Habitat Fragmentation and Population Isolation

Dams act as physical barriers, fragmenting once contiguous aquatic landscapes and reducing flood-dependent wetland connectivity. This fragmentation bisects populations and can result in a cascade of ecological impacts on herpetofauna by restricting individual movement for foraging and breeding, and severely limiting gene flow, leading to increased genetic drift, inbreeding depression, and elevated extinction risk (Fagan 2002; Bárcenas-García et al. 2022). Furthermore, dams disrupt lateral connectivity between the channel and its floodplain. By altering the timing, duration, and intensity of natural flood pulses, dams degrade or eliminate seasonally inundated wetland habitats critical for amphibian breeding, turtle foraging, and nutrient cycling (Magilligan and Nislow 2005; Tockner and Stanford 2002). Species dependent on these flood pulses, such as the state-endangered Blanchard’s Cricket Frog, experience direct reproductive loss.

System-Wide Ecological Transformation

The creation of an upstream impoundment forces a radical shift from a flowing, lotic ecosystem to a stagnant or semi-lentic one. This transformation replaces diverse riverine habitats with variable depths, velocities, and substrates with a uniform, deep-water environment (Alho 2011). The resultant “reservoir effect” eliminates critical habitat features, such as well-oxygenated pool complexes used by Wood Turtles for hibernation. The loss of habitat heterogeneity disproportionately affects species with specialized requirements. For example, Northern Map Turtles, Eastern Softshell Turtles, and Blanding’s Turtles are often extirpated from dammed river segments due to the loss of sandy nesting beaches, shallow basking sites, and diverse benthic prey communities (VanDeWalle 1993; Howey and Dinkelacker 2013). Intolerant species including Northern Map Turtles, Blanding’s Turtles, and Smooth Softshell Turtles (*Apalone mutica*), were absent when river modification eliminated their habitat and created a more uniform and simplified environment (VanDeWalle and Christiansen 1996).

The process of impoundment creation induces a fundamental shift in the aquatic environment, converting a flowing river (lotic system) into a still or slow-moving water body (lentic or semi-lentic system). This radical conversion of the physical habitat disrupts the entire ecological community that evolved under riverine conditions. This sudden and forced shift of flora and fauna from one community type to another is often





1. Dam designs inherently limited connectivity for wildlife and require mitigation to connect the landscapes. Where roads are placed over dams additional threats result from road related interactions for herpetofauna.

accompanied by mass mortality (Alho 2011). The shorelines created by reservoirs do not replicate the riparian habitats that existed along rivers prior to damming. The creation of reservoirs also disrupts or destroys important habitat features for aquatic turtles that utilize adjacent upland edges and riverbanks. These reservoirs restrict animal movement, dispersion, and migration through the river system and surrounding upland habitat (Alho 2011).

Dams and Riverine Alterations

Dams and impoundments represent one of the most significant threats to riverine herpetofauna, fundamentally altering aquatic ecosystems through physical fragmentation, hydrological modification, and changes to sediment and

nutrient dynamics. These structures act as physical barriers that fragment once-contiguous aquatic landscapes, reducing flood-dependent wetland connectivity and bisecting populations (Magilligan and Nislow 2005). This fragmentation restricts individual movement for foraging and breeding, severely limits gene flow, and increases the risk of local extirpation (Fagan 2002; Bárcenas-García et al. 2022).

The creation of impoundments fundamentally shifts riverine environments from flowing lotic systems to stagnant or slow-moving lentic conditions. This transformation eliminates critical habitat features such as well-oxygenated pool complexes used by species like the Wood Turtle for hibernation, and reduces habitat diversity necessary for species requiring complex habitat mosaics, including the Blanding's Turtle (Alho 2011; VanDeWalle 1993).

Dams also disrupt natural sediment transport, starving downstream reaches of materials essential for maintaining channel morphology and turtle nesting beaches (Kondolf 1997). Simultaneously, impounded reservoirs become sinks for nutrients, leading to eutrophication, hypoxia, and harmful algal blooms that can cause direct mortality of overwintering turtles, Northern Mudpuppies, and amphibian larvae (Bárcenas-García et al. 2022; Refsnider et al. 2021). The altered conditions frequently favor invasive species over native biota, forcing dietary shifts in native predators such as Northern Map Turtles, with unknown long-term health consequences (Richards-Dimitrie et al. 2013; Gacheney et al. 2021). **For a comprehensive discussion of dam-related impacts, including detailed information on ecological transformations, sediment and nutrient dynamics, invasive species interactions, and cumulative population effects, see Section 5: Plan to Maintain Ecologically Functional Landscapes under Herps and Riverine Impacts: Dams.**

Dam Maintenance, Drawdowns, and Refill Operations

Manipulating water-levels for waterfowl management, recreational use, or restoration

1. Water level lowering associated with dams are a common practice. Depending on time of year this can result in significant harm and threat to herpetofauna populations.

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 young turtles if conducted at inappropriate times of the year (Kaltenecker et al. 1999).

Drawdowns

In water resource management, a drawdown is an operational procedure where land managers, regulators or dam operators reduce the water levels of an impoundment for reasons including maintenance, management of aquatic vegetation, and in emergency flooding situations (New Hampshire Department of Environmental Services 2019). These activities are conducted across Michigan annually. Often, drawdowns are conducted to avoid damage to docks and marinas on residential inland lakes and impoundments. The depth of the drawdown can vary, though it is often several feet, and is typically conducted later in the season when herpetofauna have already selected overwintering sites. 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 2000a; Bodie and Semlitsch 2000b). The lowered lake level exposes the shoreline and removes the insulating layer of ice, resulting in frozen ground. The reduction in water initially impacts herpetofauna by directly exposing them to often freezing or near freezing temperatures. This can result in direct mortality while also exposing animals to significantly increased predation pressure. Water level drawdowns conducted during late fall and winter can be detrimental to herpetofauna hibernating within the sediment of lake and riverbeds causing hypoxia. 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 2005b; Spencer and Thompson 2005). Reduced surface water levels can also subsequently lower nearby groundwater tables, putting some species at elevated risk of desiccation, freezing, and/or predation. Numerous herpetofauna and more specifically several snake species, including the state-threatened Eastern Massasauga Rattlesnake, rely on the stable microclimatic conditions within subsurface burrows as critical overwintering hibernacula created





1. Dam water level manipulation is particularly impactful for slow moving species including herpetofauna. Species like snakes, particularly Eastern Massasauga Rattle Snakes can be susceptible to water level alteration especially flooding when animals are inactive utilizing crayfish chimneys.

by burrowing crayfish including Paintedhand Mudbug (*Lacunicambarus polychromatus*), Great Plains Mudbug (*Lacunicambarus nebrascensis*) and Digger Crayfish (*Creaserinus fodiens*). A high-water table plays a key role in buffering subsurface temperatures against sudden surface temperature fluctuations while maintaining hydric conditions essential for preventing dehydration (Harvey and Weatherhead 2006; Markle et al. 2020). The Eastern Massasauga Rattlesnake and other snakes rely on crayfish burrows that maintain a stable, humid, above-freezing environment buffered by a high-water table; a lowered water table can lead to freezing or desiccation mortality (Harvey and Weatherhead 2006; Markle et al. 2020).

Drawdowns can also dry ephemeral pools and other shallow ponds utilized by amphibians as crucial breeding habitats that have a subsurface hydrologic connection. This elimination of standing water can result in mass larval mortality and disrupt important life cycle processes (Swan et al. 2015). Duration of the 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 and led to population declines for pond-breeding amphibians (Paton and Crouch III 2002). It has been calculated that most pond-breeding amphibians require ponds to be inundated for about 4-9 months, with water present from March to August (Paton and Crouch III 2002). Drawdowns can substantially alter the spatial and temporal availability of aquatic habitat, displacing turtles from established refugia, and either forcing them to estivate or migrate functioning similarly to drought conditions (Anthonysamy et al. 2013; Windle et al. 2020; Watzen et al. 2008). Blanding's Turtles have been documented to travel distances of over 2 miles in search of suitable habitat, with such overland travel significantly increasing their vulnerability to predation and road mortality events (Hall and Cuthbert 2000).

Lake Refill

The refilling of impoundments and managed water bodies can have significant negative impacts on herpetofauna, with outcomes largely tied to the timing, rate, and depth of water level increases. Adding water to an emergent marsh in early spring can drown herpetofauna such as Midland Painted Turtle hatchlings, which overwinter in terrestrial areas (Baker et al. 2007). When refill is conducted while herpetofauna are still hibernating along shorelines that were previously dewatered, the sudden influx of water can inundate and drown these animals before they have an opportunity to emerge and seek shelter. The rate of refill is also a critical factor. If water levels rise too quickly, even species that have begun to become active may not be able to move to terrestrial refugia fast enough to escape rising waters. Overwintering species that rely on crayfish burrows

and other subsurface refugia, including Eastern Massasauga Rattlesnakes, Garter snakes, salamanders, and frogs, are particularly vulnerable to deep flooding. When water bodies are refilled to levels that exceed typical spring recharge, these subsurface hibernacula can become inundated, resulting in the drowning of the animals within. The effects of such mortality events often go unnoticed, as the animals remain concealed within their aquatic tombs and are not visible during post-event surveys.

Refilling too late in the spring season presents additional threats. When water level increases occur in late May or June, they can inundate and destroy freshly laid turtle nests on exposed shorelines. Turtle species that nest close to the water's edge, such as the Eastern Spiny Softshell, are especially vulnerable to nest flooding during this period (Tucker et al. 1997; Galois et al. 2002).

When water is added to shallow areas that support amphibian development, fish may become established within these habitats. The introduction of fish into previously fishless wetlands has severe consequences for amphibian reproduction, as fish actively prey upon amphibian eggs and larvae (Snodgrass et al. 2000). Many amphibian species can chemically detect the presence of fish within a water body and will actively avoid these sites for breeding, even if they had successfully reproduced at those locations for decades (Hecnar and M'Closkey 1997). This avoidance behavior functionally reduces the availability of suitable breeding habitat across the landscape and can lead to local population declines. **For detailed mitigation measures, including recommended timing, refill rates, and best management practices to avoid these impacts, see Section 7: Management Techniques under Lake and River Level Alteration.**

Dam Removal, Restoration, and Repair

Efforts to mitigate the impact of dams has resulted in the removal of these structures across Michigan. Some are rather sizable structures while others are more moderate in scale. While dam removal is a critical restoration tool, the process itself presents significant short-term risks that must be managed to avoid undermining long-term conservation goals. The removal of such hydrologic impediments requires thoughtful and collaborative efforts between regulators, engineers, landscape architects, and

1. Incidents of dam failure can be catastrophic for herpetofauna. Even when orchestrated removal is conducted, BMP measure must be put in place to avoid and reduce mortality events.



1. Baseline herpetological surveys are an essential part of a holistic and comprehensive approach to any project. Understanding community composition helps facilitate best design and impact minimization strategies.

biologists with subject matter expertise. These projects often take several years from conception to completion. **For a comprehensive discussion of development techniques applicable to dam removal projects, including excavation practices, erosion control, and site stabilization methods, see Section 7: Development Techniques.**

Pre-Construction Planning and Baseline Data

When considering such significant landscape modification, several things should be considered from a herpetological standpoint. First, establishment of baseline data to understand the current community composition and spatial distribution. A comprehensive herpetological assessment is a non-negotiable prerequisite. This must establish baseline data on species presence, relative abundance, age structure, and spatial ecology, including nesting areas, hibernacula, and movement corridors, both upstream and downstream of the structure (Sousa et al. 2021; Graeter et al. 2013; Sousa et al. 2024; Gonçalves-Sousa et al. 2022). This includes understanding the age classes and breeding sites of species that have called this landscape home for potentially generations. Understanding the community composition across all major taxa will help provide a more holistic approach to restoration. As part of this analysis, a historic review of data prior to construction of the dam provides context regarding which species may be present. Review of adjacent nearby landscapes with conditions more typical of those at the dam will also help determine objectives of restoration objectives and steps.

Design for Functional Habitat

When evaluating the post-restoration site design, incorporation of landscape features that species have become accustomed to over the last potentially 100 years or more is an important consideration. As an open water habitat, species have become reliant on these for their survival. Incorporating open water landscape features, like oxbows and meander scars, provides a surrogate habitat to the impoundment and increases the overall functional value of the site. Post-removal restoration plans should not simply re-create a generic stream channel. They must incorporate retained or engineered habitat surrogates, such as backwaters, oxbows, and stable sand deposits, to replace lost impoundment features that resident species may have depended on for decades. **Additional guidance on habitat design and the incorporation of structural elements can be found in Section 7; under Habitat Creation and Restoration Techniques.**



1. Water level manipulation when poorly timed for herpetofauna natural history can result in significant harm and threat to local populations. Understanding species composition and their natural history requirements is a key component to effective management, regardless of species.

2. Turtles will leave impoundments when dewatering occurs and seek refugia elsewhere. Where roads are present this can result in significant mortality events. Care must be taken to consider what impacts any activity will have and what mitigation measures are needed.



Dewatering and Wildlife Exclusion

As part of dewatering operations, the implementation of wildlife barrier fencing is a necessity to reduce mortality of species as they instinctively migrate away from the site. These open water landscapes, whether a hydroelectric dam being decommissioned and restored to river again or a river impoundment managed for wildlife, the impacts are the same from dewatering. Several projects have resulted in high rates of mortality even habitat within the impounded wetland system is being restored or managed like game area floodings.



The dewatering phase during removal or repair can result in a significant mortality event if not properly managed. As water levels decrease, aquatic and semi-aquatic species are compelled to migrate, often converging on predictable terrestrial pathways. During a recent habitat enhancement project that involved the dewatering of an impoundment, the subsequent emigration of turtles coincided with a major roadway bisecting the site. This resulted in the catastrophic mortality of several dozen to potentially hundreds of turtles, including large Eastern Snapping Turtles, Blanding's Turtles, Midland Painted Turtles, Northern Map Turtles, and Eastern Musk Turtles. The segment that bisected the major road was littered with dead turtles because BMP measures that could have been integrated were not considered and the timing of the activities were at the peak of turtle activity including female turtle nesting. This perfect storm of conditions possibly led to a population level collapse. Recovery and

mitigation for this will take several steps including establishing a permanent barrier fence, improving nesting sites, and giving a greater consideration to the timing of construction and management activities here and across the state to avoid similar impacts. Given the quantity and size of turtles, this might have been a critical event, making recovery difficult even with recommended BMP measures included. Efforts to augment the population may be warranted and necessary to recover this site. Even with targeted headstarting it might take 15-20 years before results of recovery efforts are truly observed, underscoring the irreversible cost of inadequate planning. Without proper exclusion fencing and guided passage, dewatering directly leads

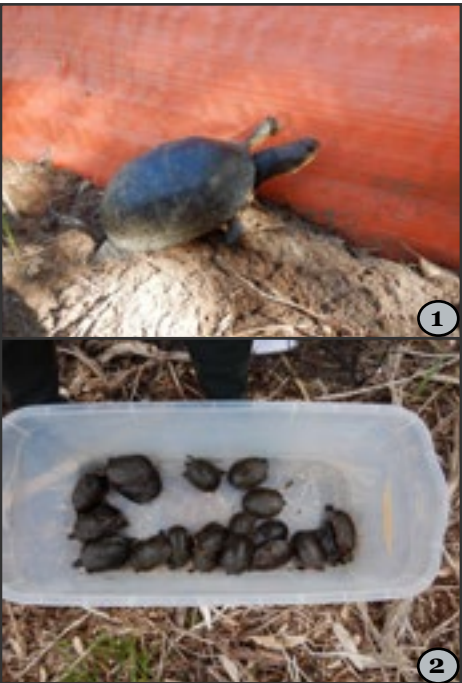


to mass stranding, overland movement across roads, and catastrophic road mortality (Gibbs and Shriver 2002). It is the hope that events like this can teach us what not to do and how to better approach these projects more holistically.

Similar mortality has been observed on dam removal projects or dam failure events, turtles fleeing the site only to be hit by vehicles. Implementing a barrier fence design and proactive planning can significantly reduce this unnecessary mortality. **For detailed specifications on wildlife barrier fencing, including installation depths, materials, and configuration for target species, see Section 7: Development Techniques under Wildlife Barrier Fencing and Exclusion.**

Emergency and Non-Standard Timing Work

Dam failure events typically occur with minimal advance notice. Similarly, emergency maintenance requests may necessitate action during seasonally inappropriate times. For emergency repairs or work conducted outside ideal seasonal windows due to regulatory or safety imperatives, the standard BMPs of fencing and relocation are even more critical. In such cases, compensatory damages for the loss of wildlife resources should be strongly considered. When considering a Blanding’s Turtle takes 15-20 years to reach sexual maturity and a female must live another 20-30 years to replace herself and her mate, the pressure of survival is great and the annual losses greater than 4% is catastrophic. Events such as those described, can eliminate species from a local landscape. The timing of maintenance should fall within designated windows, and when that is not possible, consideration for migration is required. Using the impact tree to guide seasonal drawdown operations can be helpful for determining the best approach to minimize harm to the landscape and its inhabitants. In these cases, agencies should formally consider compensatory mitigation for unavoidable wildlife losses, given that the loss of even a few adult female turtles from a declining population can have decades-long recovery implications.



- 1. Incorporation of wildlife barrier fence for excluding animals out of a construction area coupled with wildlife clearance of animals within these areas can result in potentially 1,000s of animals rescued.
- 2. Trapping and relocation efforts can be incredibly effective. Over 20 Midland Painted Turtles rescued from a single morning trapping prior to construction activities helps preserve population viability and rescue ecosystem harm.

Infrastructure Impacts

The development of alternative energy infrastructure is a rapidly growing sector that

- 1. While alternative energy is designed to reduce landscape impacts, these project have an unintended negative consequences on herpetofauna and other wildlife.

is centered around generating non-carbon sourced energy. Alternative energy can be created by utilizing renewable options such as wind, solar, hydroelectric, geothermal, and nuclear. While subjectively less destructive to the environment than traditional carbon-based energy derived from the extraction processes, they still present some impacts and considerations. Their siting, construction, and operation, can impose significant, localized impacts on herpetofauna. It is important to consider the adverse impacts of the construction of renewable energy infrastructure to herpetofauna and that an adequate management plan is determined prior to the start of a project. Proactive assessment, avoidance, and mitigation are required to ensure that the expansion of



alternative energy does not come at the cost of biodiversity loss, particularly for already vulnerable amphibian and reptile populations (Northrup and Wittemyer 2013; Jones et al. 2020; Irwanto and Nampira 2025;).

Construction Impacts of Alternative Energy Infrastructure to Herpetofauna

The construction phase of renewable energy facilities, regardless of the specific technology, involves significant ground disturbance, vegetation clearing, road building, and heavy equipment operation. These activities collectively pose several direct and indirect threats to herpetofauna:

Habitat Loss and Degradation: The physical footprint of infrastructure, including turbine pads, solar panel arrays, substations, and associated buildings, results in the permanent conversion of natural or semi-natural habitats. This directly eliminates breeding sites, foraging grounds, and overwintering refugia.

Habitat Fragmentation: Utility-scale sites and their associated service roads can significantly fragment habitats, which can prevent the intraspecific movement and exchange of genetic material (Lovich and Ennen 2011).

Direct Mortality: Use of heavy equipment

- 2. Habitats are sometimes bisected and fragmented as a result of alternative energy projects. WBF and other BMPs should be incorporated for construction activities and when permanent fragmentation occurs in areas supporting rare species measure to reconnect habitat should be explored.





during construction can compact soil, which can cause direct mortality to amphibians and reptiles in the project area (Bol 2007). Ground disturbance during construction and maintenance, including soil compaction from heavy equipment, can directly crush individuals and collapse subterranean burrows, rock crevices, and root channels used as refugia and hibernacula by salamanders, toads, and snakes (Lovich and Ennen 2011). Loose soils are at particular risk of compaction that occurs during the construction process and maintenance of wind farms and solar facilities (Lovich and Ennen 2011).

Wind Energy: Direct Habitat and Ecological Impacts

Wind energy is generally harnessed through wind turbines, which utilize the kinetic energy of wind to spin large turbine blades. The resulting mechanical rotation created by the spinning blades then spins a shaft connected to an internal generator that produces electricity. Wind turbines are typically built in a mosaic, which are referred to as wind farms. These wind farms require large tracts of cleared land for their construction as well as for the development of service road networks.

Land conversion for turbine pads, substations, and permanent service road networks can have negative direct and indirect effects on herpetofauna. While these are often sited in agricultural landscapes, it also reduces available tillable land, resulting in the potential conversion of land elsewhere to meet agricultural demand.



1. Traditional construction project can result in significant local mortality. Incorporating wildlife exclusion fencing and conducting clearance have save most if not all of these animals.

2. Construction even through wetlands can have reduced impacts when proactive measures are taken.

Habitat Loss, Degradation, and Fragmentation

The initial clearing for infrastructure results in immediate habitat loss. This can directly result in habitat loss, degradation, and fragmentation, which can be devastating to herpetofauna (Kuvlesky et al. 2007). More critically, the dense grid of gravel or paved service roads creates persistent linear barriers that fragment the landscape. For herpetofauna with limited dispersal capabilities, such as most terrestrial salamanders, turtles, and many snakes, these barriers can subdivide populations, restrict access to essential resources (e.g., breeding wetlands, nesting sites, hibernacula), and ultimately impede genetic exchange, increasing the risk of local extirpation (Kuvlesky et al., 2007; Lovich & Ennen, 2011). These disturbances can negatively impact habitat suitability as well as put herpetofauna with low mobility at risk of mortality (Lovich and Ennen 2013). Habitat edges created by clearing can also facilitate the invasion of non-native plants and alter microclimates,

1. Solar is becoming an increasingly incorporated alternative energy. Integration of landscape management techniques and creative habitat creation can result in a more viable and product landscape than traditional project conduct.



further degrading adjacent habitat quality.

Increased Anthropogenic Fire Risk: Wind farms can also present a heightened risk of fire. Sparks emitted by malfunctioning electrical components have been documented to ignite surface level vegetation (Lovich and Ennen 2013). Electrical malfunctions or maintenance activities can ignite wildfires within project areas. On fragmented wind farm landscapes, herpetofauna may have limited escape routes from fire fronts. Fires on fragmented landscapes, like wind farms, can be exceptionally damaging to herpetofauna, even to species recognized as being fire-adapted (Driscoll et al. 2021). Amphibians are particularly vulnerable to the effects of fires due to their physiological need for moisture as well as specialized aquatic habitat requirements. Amphibians are acutely vulnerable due to their permeable skin and reliance on moist microhabitats; even low-intensity fires can cause direct mortality and desiccate critical refuge sites. Frog populations inhabiting fire-affected, fragmented landscapes have shown declines in occupancy, species richness, body size and genetic diversity (Lovich and Ennen 2013; Driscoll et al. 2021; Potvin et al. 2016).

Anthropogenic Noise and Vibration Pollution

Wind turbines produce anthropogenic noise, generated by rotating turbine blades as well as from internal mechanized components. The operational noise emitted by wind



1. Frog calling during the breeding season can be negatively impacted as a result of wind farms. A holistic approach to placement and mitigation of impacts should be considered on any project.

turbines, a combination of low-frequency blade swish, mechanical hum, and sub-audible vibration, constitutes a form of sensory pollution. This noise has been observed to have a negative impact on frog communities, especially on species that communicate at low frequencies (Maloney 2024). For amphibians, this noise can mask mating calls, particularly for species that vocalize at low frequencies, disrupting breeding behavior and reducing reproductive success. Frogs occurring within wind farms have altered behavioral and physiological characteristics, and the diversity in call assemblage can be significantly lower at wind farms compared to natural sites (Trowbridge 2020). Chronic noise exposure is also linked to increased physiological stress, reduced immune function, reduced reproductive success, and altered foraging behaviors in herpetofauna (Lovich and Ennen 2011; Ware et al. 2015; Maloney 2024; Trowbridge 2020).



Species-Specific Behavioral and Ecological Responses

Impacts on reptile species have been recorded at wind farms as well. The construction and use of infrastructure such as service roads, turbine pads, and transmission lines decrease habitat suitability and connectivity (Lovich and Ennen 2011). Research indicates behavioral avoidance and altered spatial ecology:

Turtles: Spotted Turtles occupying habitat within wind farms have been observed to discontinue the use of habitat situated near service roads (Delay et al. 2023). Spotted Turtles have been documented abandoning core habitat areas proximate to service roads. Other turtle species, like Midland Painted Turtles, were found to have shorter daily movements and a smaller home range when compared to individuals in a more natural habitat (Trowbridge 2020).

Amphibians and Fossorial Species: Ground disturbance during construction and maintenance, including soil compaction from heavy equipment, can directly crush individuals and collapse the burrows, rock crevices, and root channels used as refugia and hibernacula by salamanders, toads, and snakes (Lovich and Ennen 2011). Species that utilize subterranean sites like burrows or loose soils are at risk of compaction that occurs during the construction process and maintenance of wind farms (Lovich and Ennen 2011).

Operational and Post-Operational Considerations

A key consideration is the life expectancy of these facilities and long-term use and remediation following their decommission. Consideration of alternative landscape management, such as short grass prairies and meadows, while in operation provides



1. Several fossorial species of herpetofauna are negatively impacted from ground disturbance resulting from construction activities. Some impacts are temporary, while others including soil compaction can have more long-term effects. This is not only limited to construction, but also logging practices. Prior to initiation of projects consult experts in their respective field to help reduce or eliminate harm to species.

multiple functional values of a single landscape. Use of grazing species, such as sheep, can be used to help keep vegetation lower, reducing the need for mowers on these sites, to avoid additional impacts to herpetofauna. While goats are advocated for in other sections, given their propensity for climbing and jumping, they may inadvertently damage solar panels.

Mitigation Strategies for Renewable Energy Development

A hierarchy of avoidance, minimization, and mitigation must guide project development to protect herpetofauna.

Strategic Siting and Pre-Construction Assessment

The most effective mitigation is the avoidance of high-value herpetofauna habitat. Rigorous, multi-season baseline surveys conducted by qualified biologists prior to site selection are essential to identify critical habitats, movement corridors, and populations of conservation concern (Graeter et al. 2013; Andrews et al. 2006; Andrews and Jochimsen 2007; Brehme et al. 2024; Brehme et al. 2024; Andrews et al. 2015; Smith and Dwyer 2016).



Impact-Minimizing Design

Footprint Reduction: Minimizing the width and total length of service roads, using existing roadways where possible, and clustering infrastructure reduces habitat loss and fragmentation. Use of boring or directional drilling, where feasible, to reduce surface disturbance and avoid trench cutting.

Maintaining Connectivity

Designing and preserving vegetated corridors between infrastructure elements allows for animal movement. The use of wildlife-friendly culverts or bridges at road-stream crossings is critical.

Low-Impact Vegetation Management: Implementing an Integrated Vegetation Management (IVM) plan that avoids broad-spectrum herbicides and frequent mowing is crucial. Targeted grazing with sheep (noting that goats may climb and damage solar infrastructure) can effectively manage vegetation, reduce fire fuel loads, and create heterogeneous habitat structure while eliminating the noise and direct mortality associated with mechanical mowing (Johnston et al. 2021; Jones et al. 2009; Yayota and Doi 2020; Marchetto et al. 2026; Hart 2001).

Habitat Creation and Operational Co-Benefits

The land under and between solar panels and wind turbines can be actively managed as conservation habitat. Establishing native, low-growing prairie, meadow, or pollinator-friendly plant communities can provide high-quality foraging and basking habitat for herpetofauna, enhance landscape connectivity, and deliver additional ecosystem services (Macknick et al. 2013; Hernandez et al. 2015).

Decommissioning and Site Restoration

Project permits and agreements must include legally binding, fully funded decommissioning plans that mandate the removal of all infrastructure and the restoration of native plant communities and ecological function, returning the site to a condition supportive of wildlife (Lovich and Ennen 2013).

Illegal Collection and Overharvesting

Illegal collection for the national and international pet trade has reduced the



1. Incorporation of native seed mixes that provide a secondary and important benefit of provide pollinators with a food source helps create even greater quality landscapes post restoration.

1-2. Illegal collection of herpetofauna, especially turtles, has a significant impact on ecosystems. These long-lived species are difficult to recover and already face several threats. Education about threats to turtles from poaching is needed especially to state agencies and regulators. Most of this activity is done in coordination with people out of state and out of the country as part of a massive illegal trafficking syndicate.

viability (breeding) populations for some species in Michigan, such as the Wood Turtle, Spotted Turtle, Blanding’s Turtle, and Eastern Box Turtle (Lannoo 1998; Harding and Mifsud 2017). 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 et al. 1993; Congdon et al. 1994; Congdon and Keinath 2006; Harding and Mifsud 2017).

Poaching and illegal collection can be, and historically have been, a problem for herpetofauna in Michigan (Harding and Mifsud 2017). In addition, the high demand for turtles in overseas Asian markets (pet, food, and unsubstantiated medicine) has put pressure on the poaching of some Michigan turtle species for export (Hylton 2007). There have been multiple examples of arrests made for the trafficking of turtles and other herpetofauna in Michigan. Just across the border in Canada, 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). Unexplained declines in populations of Spotted Turtles are likely the result of poaching (Litzgus 2012). Although far more turtles are killed annually on roads than through illegal collection, illegal take is a real problem in Michigan and enforcement is required.

While illegal collection and poaching pose a significant threat to Michigan herpetofauna, legal take can also unintentionally contribute to overharvest and declining populations of long-lived, slow to mature species. Regulations have been enacted to prevent the overharvest of Eastern Snapping Turtles (Michigan Department of Natural Resources 2012), however, enforcement is limited and difficult. The Eastern Spiny Softshell is also at risk of landscape-wide population declines due to the selective harvest of large, sexually mature females (Convention on International Trade in Endangered Species of Wild Fauna and Flora 2022). Given the species natural history, bag limits (not possession limits) of no greater than two (2) Eastern Snapping turtles per season should be enacted, and Eastern Spiny Soft-shell turtles should be removed from the States legal harvest regulations (Government of Ontario 2017; International Union for Conservation of Nature (IUCN) 2012).

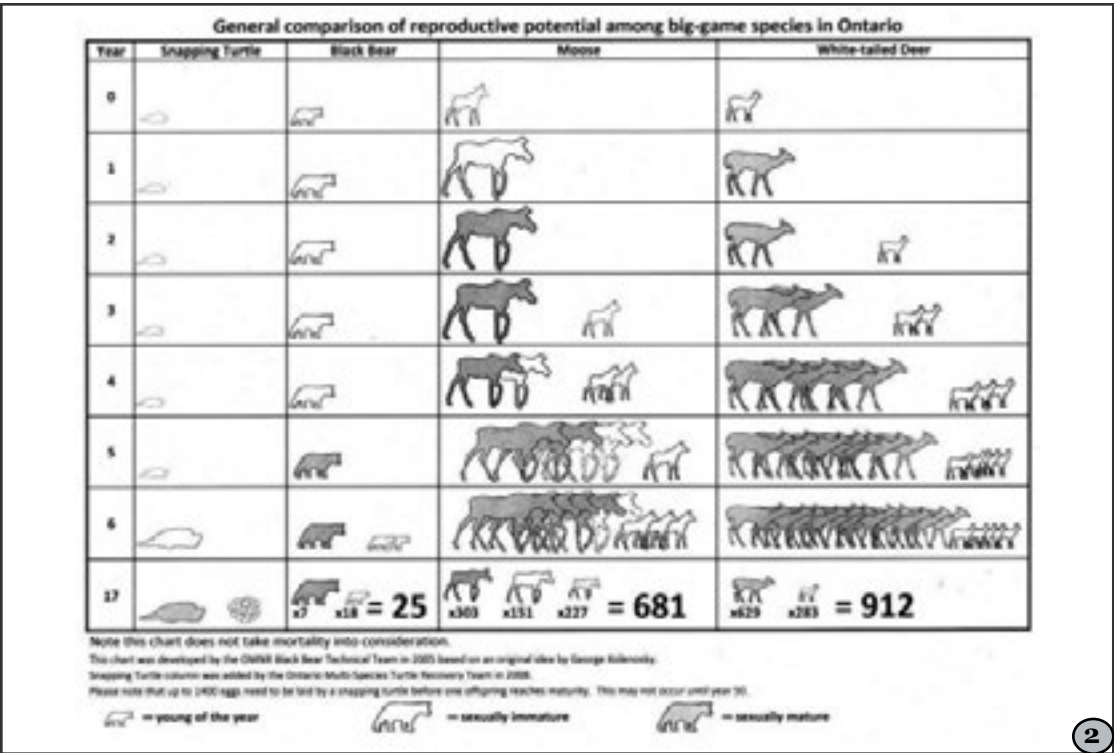


1. Eastern Snapping Turtles can be very long-lived including individuals like “T-rex” who is well known on the lake he lives. The protection and stewarding of the less charismatic species is just as important if not more, than those that are. Eastern Snapping Turtles serve as the kidneys of aquatic habitats helping keep them clean.

2. This diagram illustrates Eastern Snapping Turtle reproductive potential compared to commonly managed big game species. Due to delayed sexual maturity and low reproductive potential of Eastern Snapping Turtles and other turtle species, high adult survivorship is required to achieve population stability and sufficient recruitment. It is critical for management actions to take into consideration the significance of a singular sexual mature female in terms of population viability.

Persecution

Herpetofauna are 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 and Blue Racer, which mainly eat rodents, are more feared and therefore suffer greater persecution than smaller snakes. The Eastern Hog-nosed Snake and Eastern and Western Fox Snake are killed because they look similar to venomous copperheads or cobras. The only pit viper species in Michigan is the Eastern Massasauga Rattlesnake, which, due to its secretive and non-confrontational habits, is not usually encountered by humans. Fatalities attributed to Eastern Massasauga Rattlesnakes are incredibly



Ontario Multi-Species Recovery Team

uncommon due to the species’ non-aggressive nature and relatively short fangs that can only inject a small volume of venom (Klauber 1982; LeBer 1998). 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 with bullet holes, and purposefully hitting turtles and snakes with cars pose threats to these populations (Ashley et al. 2007). Eastern Snapping Turtles, in particular, face additional threats as this species defensively responds when approached on land. The Northern Mudpuppy and Eastern Snapping Turtle also are slain because people unjustifiably believe they affect fishing success and reduce the abundance of game species (Bosch 2003; Siebert 2008).

Invasive Species/Nuisance

1. Northern Mudpuppies are persecuted seasonally due to the false belief they compete with game fish and are a nuisance to ice fishing anglers. The are thrown on land or the ice to die. This species is a critical landscape species and important consumer of invasive species. In recent years, greater focus and protection has been observed especially on Lake St. Clair due to a collective effort by several organizations to educate anglers about the role this species plays and their protected status in Michigan.

Invasive plant and animal species are typically 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 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, once 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 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 et al. 2000).



Unfortunately, methods to control invasive species can also have negative effects on herpetofauna; for greater details on best practices regarding this topic, see Chemical Applications and Management in Section 7: Management Techniques.

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, 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, threatening wetlands throughout Michigan (Lynch and Saltonstall 2002; Tulbure et al. 2007; Tulbure and Johnston 2010). Although amphibians can 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 they restrict movements of turtles to upland nesting areas, movements of frog species to and from open water, and movements of herpetofauna from optimal thermoregulation (Mifsud personal observation 2026). 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 et al. 2007). *Phragmites* is predicted to expand as Great Lake water levels recede in response 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 causes mortality and deformities in larval amphibians (Sacerdote and King 2014). Due to the 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 aggressively growing invasives is strongly recommended. To reduce the risk of continued contamination, cut material should be taken offsite.

Autumn olive, honeysuckle (*Lonicera spp.*), garlic mustard, Japanese barberry, and multiflora rose (*Rosa multiflora*) are common invasive plants in upland areas (Borland et al. 2009). These dense invasive plants shade the ground, thus interfering with the



1

1. *Phragmites* and other invasives can be not only destructive to ecosystem quality, they can also choke landscapes making access across them difficult for low mobility species.

1. Non-native goldfish recovered from a wildlife clearance project. Over 80 large goldfish were rescued and now live in a large outdoor pond where no access to native habitats is present. Release of goldfish can be problematic and considered a kindness to these fish. They can negatively impact water quality and out compete native fish and eat amphibian eggs.

thermoregulatory behavior of herpetofauna and reducing the suitability of these areas as basking sites for snakes or nesting sites for turtles.

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).

The Mute Swan (*Cygnus olor*) is an aggressive exotic bird that may force native waterfowl off of water bodies and attack, injure, or kill wetland birds (Petrie 2002; Perry 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 et al. 1996; Bortolus et al. 1998; Allin and Husband 2003; Perry et al. 2004) and reducing water quality with the large quantity of feces they produce (Reese 1975; Weisner et al. 1997; Czezuga and Mazalska 2000; Perry et al. 2004; Bailey et al. 2008). Alterations of vegetation may make these water bodies unsuitable for omnivorous amphibians and reptiles.

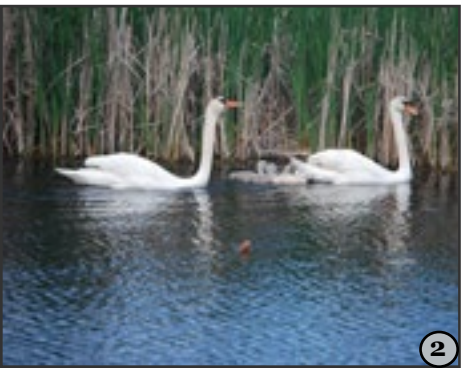
Raccoons (*Procyon lotor*), while a species native to Michigan, have become overabundant due to the alteration of available resources by humans. These unnaturally high densities of raccoons can result in 100% turtle nest mortality at some sites (Herpetological Resource and Management 2011b). Raccoons 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.

Wild Turkey (*Meleagris gallopavo*), another species native to Michigan, has recovered from its extirpation in the state to a point where the current population is higher than known historical levels (Bump 2022). Wild turkey possess a varied diet and are known to prey upon



1

2. Mute swans consume and dig up several pounds of aquatic vegetation daily. While arguably beautiful and “cute” their impacts to landscapes make their presence harmful to native wildlife.



2

1. Subsidized predators like the native raccoon have a tremendous impact locally on turtle populations and on other herpetofauna. They are nest predator specialists and incredibly intelligent. As a native species, they ARE an important part of ecosystems, however, historically they would have had populations of only a few per square miles.



2. Humans are directly responsible for high raccoon populations in Michigan. Historically, wolves, trapping, and large contiguous habitats helped limit their numbers. Today, that balance is reduced, and practices like trap and release can increase impacts on herpetofauna and other wildlife. Population management is needed to support healthier ecosystem function.

boats, and bait dumping have altered habitat for native species (Glassner-Shwayder 2000). The Rusty Crayfish, Round Gobies, 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 et al. 2000). However, some reptile species, such as the Northern Map Turtle, capitalize on the presence of these abundant non-natives as a food source and help control these undesirable species (Lindeman 2006).

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).

amphibians and reptiles (Fleenor 1976; Evans-Peters 2013). In areas of high turkey density, this bird may be deleterious to herpetofauna populations.

Feral Swine (*Sus scrofa*) have been known to damage native plant communities and wetland structures by digging, rooting, and wallowing (Campbell and Long 2009). Wallowing and rooting can lead to increased concentrations of phosphorus, nitrates, and total suspended solids, as well as a reduction in soil pH (Brown et al. 2015). These wetland alterations could make conditions unsuitable for wetland-dwelling amphibian and reptile species. Feral swine also are known to consume snakes, frogs and toads, lizards, and turtles and turtle eggs in large numbers (Lowe et al. 2000; Fordham et al. 2006; Jolley et al. 2010).

Zebra Mussels and other aquatic invasive animals transported via ballast water,

1. Feral and outdoor pets like cats can unintentionally result in considerable mortality of wildlife especially birds and herpetofauna. This also exposes them to greater threats and reduced overall life expectancy. Keeping cats indoors and if outdoor time is deemed "necessary" putting the cat on a leash or in outdoor cat enclosures to reduce unintended harm to wildlife.

Some non-native, invasive species, such as earthworms, have become incorporated into the diet of several amphibians and reptiles. Over time, these species adapted to consume 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 prey item and serve as a critical resource for this and other species of herpetofauna.

Feral and outdoor pet cats (*Felis catus*) and dogs (*Canis lupus familiaris*), 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 et al. 1997; Calver et al. 2007). Cats in Great Britain killed an estimated 5 million reptiles and amphibians in only a five-month span in 1997 (Woods et al. 2003). In Canberra, Australia, house cats were estimated to annually kill 29,700 reptiles and 5,940 amphibians (Barratt 1998). Cats may also impact the behavior of herpetofauna, increasing wariness and refuge-seeking behavior (Stone et al. 1994).

The impact of dog predation on wildlife in the United States is not well studied. However, feral dogs were the primary drivers of the extirpation of the Rock Iguana (*Cyclura carinata*) on Pine Cay Island in the Caicos archipelago (Iverson 1978) as well as the Marine Iguana (*Amblyrhynchus cristatus*) in the Galapagos Islands (Kruuk and Snell 1981). Further research is needed to assess their impact on herpetofauna in Michigan.

Non-native Herpetofauna in Michigan

Non-native or exotic species, while not considered to be indigenous to the specific area or region, do not always qualify as an invasive species. If the non-native species does not possess the ecological or economic harmful traits, including high reproduction rates or the ability to outcompete native species to a significant degree, it is not considered to be invasive (National Park Service 2023). Currently, three species of turtle found within Michigan are considered to be non-native, including the Eastern River Cooter (*Pseudemys concinna concinna*), Yellow-bellied Slider (*Trachemys scripta scripta*), and False Map Turtle (*Graptemys pseudogeographica*). While some urban Red-eared Slider populations within Michigan may be linked to individuals released as pets, the species most likely historically occurred throughout portions of the state, and is to be considered native (Terry 2015; Harding and Mifsud 2017). This species has been wrongfully vilified for decades and





1-2. The Red-eared Slider is a native species of turtle in Michigan. They have been introduced to a greater range within Michigan and often in urban and suburban landscapes these represent released pets. Similarly, the non-native River Cooter and Yellow-bellied Slider can be found in some urban parks. While they do not pose a direct harm to Michigan ecosystems, pet turtles should not be released.

has been part of the Michigan landscape for thousands of years.

Non-native species within Michigan, such as the Eastern River Cooter and Yellow-bellied Slider, are of little concern due to very few individuals present on the landscape and limited successful recruitment. The Red-eared Slider, while commonly classified as invasive in areas outside of its historical range, may provide analogous ecological functions similar to that of native species (Dupuis-Désormeaux et al. 2022). Non-native species also typically occur within heavily urbanized environments, oftentimes already lacking native species due to human disturbance (Dupuis-Désormeaux et al. 2022). Michigan’s non-native turtle species may fulfil similar ecological roles within human-influenced landscapes currently lacking native species. However, it is also still possible for non-native species to outcompete native species that are present and transmit infectious diseases (Dupuis-Désormeaux et al. 2022).

Disease

Disease has been implicated as a factor in the decline of amphibian and reptile populations worldwide (Blaustein et al. 1994; Berger et al. 1998; Daszak et al. 1999; Kiesecker 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 et al. 2001; Blaustein et al. 2003).

Disease can be spread by anthropogenic vectors, such as the collection and export of frogs for human consumption and use (Mazzoni et al. 2003; Schloegel et al. 2009; Bai et al. 2010; Schloegel et al. 2012), the pet trade (Une et al. 2008), and use as bait (Garner et al. 2009). Many of these pathogens are highly virulent and transmissible between vertebrate classes (Farnsworth and Seigel 2012; McGuire et al. 2012b). 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.



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

population decline of amphibians (Carey et al. 1999). Currently, 520 species of amphibians have been diagnosed with infectious *B. dendrobatidis* (Aanensen 2013).

Emerging Infectious Diseases (EIDs)

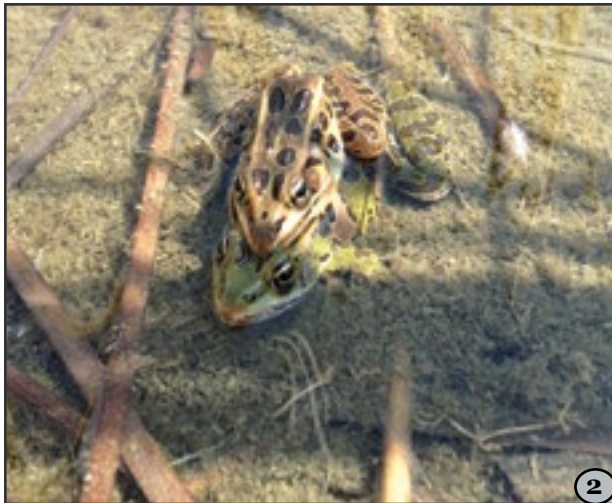
Ranavirus is an emerging and dangerous pathogen that poses potentially significant threats to Michigan herpetofauna. This EID infects multiple cell types, leading to organ necrosis and hemorrhaging, often leading to death from the ranavirus itself or from secondary invaders (Miller et al. 2011). Infection and subsequent die-offs have occurred in other states in species also common to Michigan (e.g. Marbled Salamanders, Small-mouthed Salamanders, Eastern Tiger Salamanders, Red-spotted Newts, Blanchard’s Cricket Frogs, Gray Treefrogs, Green Frogs, Northern Leopard Frogs, Eastern Box Turtles) (Bollinger et al. 1999; Docherty et al. 2003; Snyder 2007; McGuire et al. 2012; United States Geological Survey 2012; Davis et al. 2019), potentially facilitating the transmission of this disease to Michigan populations. In the last decade, ranavirus has been detected in Michigan Wood Frogs and is likely present in other species (Sauer et al. 2019), though testing for this pathogen is limited in the state since the procedure is expensive and time consuming (Stephens and McCurdy 2008). More tests are needed to determine the prevalence of ranavirus within Michigan herpetofauna. Transmission can occur between individuals of the same species, different species, and even between reptiles and amphibians, making this pathogen particularly dangerous (Brenes et al. 2014). Since this disease is easily transferred and typically affects the entire herpetofauna population of an infected site, if strict preventative measures are not implemented it is likely Michigan herpetofauna will suffer from this disease (Jancovich et al. 2010).

Snake Fungal Disease (SFD) is an EID known to cause mortality in snakes; however, population level impacts are not well known due to the cryptic nature of many snake species and a lack of long-term data. This disease, caused by the *Ophidiomyces ophiodiicola* fungus, creates skin lesions that, in severe cases, directly kill the host, or





1. SFD Symptoms on a Northern Water Snake. Strict decon was applied after handling.



2. 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.

can lead to death indirectly through complications (Lorch et al. 2016; Hileman et al. 2018). Recently, a relatively high prevalence of SFD in Michigan populations of the Federally Threatened Eastern Massasauga Rattlesnake has been observed (Tetzlaff et al. 2015; Allender et al. 2016; Allender et al. 2018). Additionally, SFD was detected in an Eastern Milk Snake in Michigan (Ravesi et al. 2016). This disease has also been found in neighboring states and provinces in species also common to Michigan (e.g., Northern Ring-necked Snake, Northern Water Snake, Eastern Fox Snake, Black Rat Snake, Western Fox Snake, Queen Snake, Northern Brown Snake, Northern Red-bellied Snake, Northern Ribbon Snake, and Eastern Garter Snake) (Lorch et al. 2016; Davy et al. 2021). As such, it is likely that this pathogen has already, or will in the near future, spread to Michigan populations of these species. The prevalence of SFD in the Midwest region is rapidly growing, and this disease poses a significant threat to Michigan snake populations (Dillon et. al 2024).

Turtle Shell Disease, also known as Pond Turtle Shell Disease, is a new EID caused by the fungus *Emydomyces testavorans* that afflict chelonians with ulcerative skin and shell disease (Woodburn 2019; Adamovicz et al. 2020). This disease was only recently discovered and has primarily been observed in freshwater aquatic turtles within the western United States and Illinois (Woodburn 2019; Adamovicz et al. 2020; Lambert et al. 2021). This fungus often proliferates in captive environments, which can lead to infections of wild populations when captive turtles are released as a part of headstarting programs

(Woodburn 2019; Hazemi 2020). The detection of this disease in Illinois Blanding's Turtles poses a risk to populations in Michigan given the close proximity of the two states (DeVore 2022). In addition to Blanding's Turtles, Michigan turtle species that have been infected with *Emydomyces testavorans* in other states include the Eastern Spiny Softshell and Red-eared Slider (Woodburn et al. 2019; Adamovicz et al. 2020). The conservation concerns posed by this disease in the regions of its proliferation (Lambert et al. 2021) are likely to recur in Michigan unless strict preventative steps are taken (Fredrickson et al. 2024).



1. Eastern Spiny Softshell Turtles are highly sensitive to aquatic habitat changes and are also susceptible to EID making them a good indicator species.

Bostwick 2012). Changes in habitat availability may affect amphibian survival, growth, reproduction, dispersal, and access to food (Blaustein et al. 2010). Due to variations 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 et al. 2013). For example, amphibian eggs and larvae may desiccate as a result of altered local climate patterns in extreme dry years, reduced pond depth increases the exposure of amphibian embryos to UV radiation, which could lead to pathogen outbreaks and population declines (Kiesecker et al. 2001). Climate change may also threaten the long-term viability of reptile and amphibian populations (Pounds et al. 1999; Kiesecker et al. 2001) as it may alter their development, spatial distribution, abundance, and species interactions (Pounds et al. 1999; Walther et al. 2002). Amphibians have been observed to call and breed earlier in years with warmer temperatures (Walther et al. 2002; Mifsud personal observation 2026). In the case of reptiles, shifting climates may affect nesting success and timing. Turtles may nest sooner, resulting in earlier nesting, providing a greater duration for young of the year to forage and grow. This can also influence multiple clutching in female turtles, increasing fecundity. Inversely, cooler weather results in insufficient time for incubation, resulting in reduced productivity of reptile nests (Sommer et al. 2009). Species for which the sex of individuals is determined by the temperature of incubation (e.g., Eastern Snapping Turtle) could experience skewed sex ratios (Janzen 1994; Ewert et al. 2004). This could be advantageous in Michigan, producing more females, helping to recover populations. However, analysis of long-term data reveals various responses among species (Blaustein et al. 2001).

Climate impacts may amplify current threats to herpetofauna populations and the landscape that support them. As environmental conditions change, previously occupied habitats may become unsuitable. The potential for dispersal is limited in areas with significant habitat fragmentation, thus making populations vulnerable

Climate Modification

Climate projections suggest that by the end of this century, Michigan's climate is predicted to resemble the current climate of central Missouri and northern Arkansas (Winkler et al. 2012). The predictions of various proposed climate models show potential shifts in plant communities and wetland conditions in Michigan and the United States (Hellmann et al. 2010; Nelson et al. 2011), which would affect amphibian and reptile populations. EGLE has acknowledged that wetland communities will play an important role in counteracting the negative effects of climate events, making it critical to protect and restore these ecosystems (Christie and

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; Angel et al. 2018).

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 may 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 et al. 2002).

Climate-driven species expansion will also be significantly limited and resultantly dangerous for a variety of taxa, especially herpetofauna, due to habitat fragmentation and bisection by roads (Coombs 2016). It is important to consider that all of Michigan's herpetofauna are relatively recent arrivals when viewed on a geological timescale (see Section 2 Amphibians and Reptiles of Michigan under The Ice Age and Herpetofauna in Michigan), and species are naturally expanding and moving northward. Conditions, as suggested, may be comparable to those of the hypsithermal, allowing for Michigan to significantly expand its herpetofauna richness. Caution must be given when presuming a species not previously documented is



1. Species like the Northern Spring Peeper are one of the first species to emerge and breed in Michigan. Shifts in climatic patterns and weather unpredictability can negatively affect their breeding efficacy and success.



2. The Northern Dusky Salamander has a known restricted range in Michigan and is a cool water stream specialist. Climate modification and habitat degradation can impact this species.

1. Amphibians require sufficient hydroperiods to successfully complete development. Vernal pools specialists like Wood Frog can lose entire reproductive cohorts resulting from insufficient seasonal hydrology due to drought and other factors.

“introduced” versus a possible northern migrant. Much of Michigan remains unsurveyed, and it is irresponsible to presume that all is already known in terms of species and their distribution.

Projected Climate Trends and General Impacts

Global climate projections suggest changes in mean annual temperatures and modified precipitation patterns across broad geographic regions. These changes have the potential to disrupt natural ecosystem processes through shifts in temperature, precipitation anomalies, and the cascading effects that follow. For Michigan and the broader Great Lakes region, modeling suggests a continued trajectory of warming, alongside an increase in climatic variability and the frequency of extreme precipitation events throughout this century. Such changes could influence native species through pathways including thermal stress, altered hydrology, habitat transformation, and phenological mismatches. Michigan is expected to continue warming and see these anomalies increase throughout the next century. Alternatively, other scenarios suggest the Great Lakes region is a potential “climate refuge” due to its immense supply of fresh water.



Hydrological Extremes: Drought and Flooding

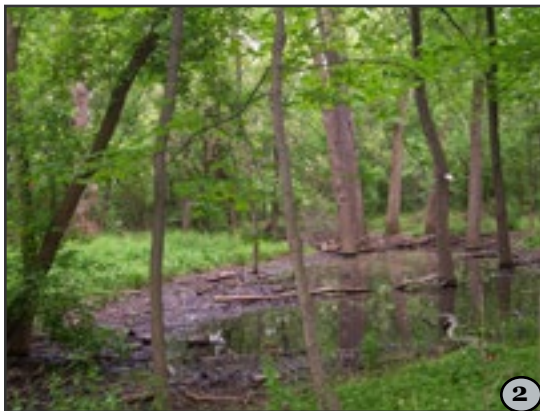
Altered precipitation patterns are expected to amplify hydrological extremes, posing distinct and interconnected threats to Michigan's herpetofauna. Prolonged drought conditions can have devastating impacts on amphibian and reptile populations by reducing aquatic habitat availability, increasing dispersal distances, and ultimately leading to recruitment failure and overall population declines (Walls et al. 2013). As surface water diminishes, aquatic habitats contract and the distances between remaining wetlands increase, reducing foraging opportunities, eliminating critical refugia, and fragmenting populations. These effects are particularly pronounced for aquatic and riparian-obligate species (Walls et al. 2013). The combination of decreased precipitation and higher surface temperatures, especially in urban centers, further lowers water levels and reduces overall aquatic habitat area, posing a significant threat to at-risk turtle species found in riverine systems and their associated riparian habitats.

2. Drought and lack of hydrology not only impact amphibians, but can have considerable effect on turtle species. During drought conditions turtles will seek refugia often traveling considerable distances to find adequate aquatic habitats.





1. Drought or drier conditions impact turtle nesting success and can result in restricted nesting areas or dessication of eggs.



2. Altered or shifted weather patterns can affect hydrology of wetlands especially small seasonal ones. Reduced hydroperiod can result in these seasonal nurseries drying before wildlife have a chance to finish developing

For riverine specialists like the Wood Turtle, diminished stream flows directly correlate with increased mortality as lower water levels reduce available refugia and severely limit foraging opportunities (Kamm et al. 2024). Drought conditions also impact nesting success by reducing egg viability in dry soils, and lowered soil moisture can desiccate turtle and reptile nests, decreasing hatchling success (Refsnider et al. 2013a; Refsnider et al. 2013b; Geller et al. 2022; Beard and Powell 2023). While the specific habitats may vary across their range, the underlying threats warrant concern and continued observation.

The absence of spring flooding further compounds these impacts by reducing the hydrology delivered to floodplain forested wetland communities, thereby shortening hydroperiods and limiting the developmental window for amphibian larvae (Harding and Mifsud 2017; Chandler et al. 2016). When hydroperiods are truncated, larvae may be forced to metamorphose at smaller body sizes, increasing their vulnerability to predation post-metamorphosis and reducing overall juvenile survival. This cascade of effects can result in reduced size at transformation, increased predation pressure, and higher rates of desiccation.

Conversely, extreme precipitation events and increased hydrological flashiness present an inverse but equally consequential set of threats. Intense storms can cause flash flooding in riverine systems, with high-velocity flows scouring stream substrates, washing away amphibian eggs and larvae, and eroding the riparian banks where turtles nest (Brooks et al. 2019a; Brooks et al. 2019b; Ocock et al. 2016; Walls et al. 2013). When heavy storms occur after breeding has commenced, eggs and larvae from frogs and salamanders can be displaced downstream, resulting in significant mortality.

Beyond direct physical disturbance, rising water levels can create ephemeral connections between isolated wetlands and permanent water bodies, introducing fish predators into what were once safe amphibian breeding sites and transforming them into ecological traps (Babbitt 2005; Hamer and Parris 2013). Many Michigan amphibian species, including the Wood Frog, actively avoid breeding in wetlands containing fish, meaning that increased hydrologic connectivity can functionally reduce the availability of suitable breeding habitat across the landscape (Holbrook and Dorn 2015). When fish become established in floodplain wetlands, the resulting avoidance behavior by amphibians diminishes overall breeding site availability and community diversity.



1. Species like Blanding's Turtles may benefit when compared to other species potentially facilitating multiple clutching increasing the fecundity rate for females. While this is a best case scenario, longer seasons would provide many species a greater duration of activity to develop and grow.

Phenological Shifts and Life History Responses

Warmer temperatures associated with climate change are altering the timing of biological events, or phenology, with species-specific consequences that may benefit some taxa while posing significant challenges for others. For turtles, shifting temperatures appear to be affecting nesting phenology in Michigan. Warmer spring temperatures may trigger earlier nesting activity, and studies on Blanding's Turtles indicate a trend toward earlier nesting initiation (Byer et al. 2020). A longer active season could theoretically benefit some species by allowing extended foraging opportunities for juveniles, increasing growth rates, and potentially enabling double-clutching, the production of two clutches in a single

season, in species where this behavior is currently rare. While the full effects are not yet understood, earlier nesting has the potential to provide emerging hatchlings with a longer active season to forage, grow, and identify suitable nesting areas. Double-clutching is already documented in some Michigan species, including the Midland Painted Turtle and Eastern Musk Turtle (Harding and Mifsud 2017). An extended active season, particularly in early spring, could even result in double-clutching for species like the Spotted Turtle (Ernst and Lovich 2009) and Blanding's Turtle (Lee 2009, Litzgus 2003), which have been documented exhibiting this behavior in southern captive environments. However, the fitness benefits of earlier nesting may be offset by increased nest predation or lethal incubation temperatures if soil moisture proves insufficient during the extended incubation period (Telemeco et al. 2013).

While turtles may experience certain benefits from phenological shifts, amphibians that rely on vernal pools for breeding face more precarious outcomes. Earlier spring warm spells can cue vernal pool-breeding amphibians to emerge from hibernation and migrate to breeding sites prematurely. If these warm periods are followed by a return to freezing temperatures, air-breathing salamanders can become trapped under ice, resulting in widespread mortality (McCaffery and Maxell 2010). Species may emerge and travel to breeding ponds only to find themselves caught by subsequent cold weather, unable to escape before ice melts.

Warmer and drier conditions present an additional threat by causing vernal pools to dry before amphibian larvae have completed their development. When pools desiccate prematurely, the result can be reduced size at metamorphosis, increased predation pressure, and direct mortality from desiccation. In some cases, entire cohorts may be lost when pools dry too early in the season, eliminating annual recruitment entirely. This variability makes annual reproductive success unpredictable and threatens the long-term population viability of species such as the Blue-spotted Salamander and Spotted Salamander (Newcomb Homan et al. 2003). Over time, the cumulative effect of repeated recruitment failures can significantly alter community composition and lead to local population declines.



1. Altered water regimes can impact herpetofauna even on riverine landscapes. Reduced hydrology exposes more area and consolidates animals to a more consolidated landscape. Animals that attempt to migrate to other habitat can also be harmed from exposure to predators and roads where habitat is bisected.

2. Eastern Newts have a unique natural history and utilize a range of habitats seasonally and throughout their life which can extend for over 20 years. Their presence and understanding of their natural history as part of assessments help to understand the health of a ecosystem and the connectivity of a landscape.

The Great Lakes as a Potential Climate Refuge

The immense thermal mass and freshwater volume of the Great Lakes may moderate local climate extremes, potentially making the region a relative “climate refuge” compared to areas facing more severe drought or wildfire (Wuebbles et al. 2017). This is due to the presence of the Great Lakes, which can buffer Michigan, as opposed to other states and other parts of the globe. However, this moderation does not come without cost. The lake effect can also intensify precipitation on land, contributing to extreme storm events that threaten herpetofauna through flooding and habitat scouring (Notaro et al. 2015). This can, however, result in more extreme precipitation events with greater energy being generated as storms move across the Great Lakes.

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



1. Education and training are foundational necessities for better management and conservation. Dispelling ignorance and proactively engaging in productive dialogue is critical for moving the bar in the positive direction for conserving these herpetofauna species.

2. Engaging and supporting the next generation of biologists, enthusiasts, and stewards must come from an early age. Education and support of young people is essential. “In the end, we will conserve only what we love; we will love only what we understand; and we will understand only what we are taught.” Baba Dioum

in Michigan is well documented. However, the loss of programs like the State of Michigan Frog and Toad survey and the continued loss of funding and support for other monitoring efforts, makes understanding the status of not only the rarest species but also incredibly important generalist species so vital. 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.





4. Conservation Efforts

1-2. Though locally abundant, Blue-spotted Salamanders and Black Rat Snakes are listed as Species of Greatest Conservation Need, with the Black Rat Snake also considered a species of Special Concern. Habitat loss and fragmentation have significantly impacted these populations.

Over the past several decades, all species of Michigan herpetofauna have experienced declines. Even species once considered abundant have faced losses in parts of the State. The Eastern American Toad, formerly common across Michigan, has experienced regional and local die-offs over the last 50 years, particularly within the past decade. Conservation and protection must strive to **keep common species common** while concurrently working 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 the impacts from these activities. The 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



4. Conservation Efforts



Chris Hoving

1-3. Eastern Red-backed Salamander consuming an invertebrate(1), Riverine ecosystem in northern Michigan(2), and Kirtland's Snake (3) are State Endangered species.

(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 habitats 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 restoration, management, and development practices are to:

- Maintain and enhance healthy environments that support a diverse assemblage of amphibians and reptiles.
- Protect and create sufficient habitat and area essential for project activities.
- Maintain and improve habitat quality and connectivity.
- Maintain natural processes and develop methods for improvement and restoration.

Existing Conservation Guidelines

The Michigan Amphibian and Reptile BMP manual serves as an effective, all-encompassing document regarding the conservation of amphibian and reptile species in Michigan, with considerable application abroad. The manual provides important information regarding the challenges Michigan's

herpetofauna communities face and extensive guidelines that can be implemented to promote their conservation across a wide variety of restoration, management, and development projects to promote their conservation.

The MDNR created the Michigan Wildlife Action Plan to provide a comprehensive framework and information source to coordinate statewide wildlife management and conservation efforts (Clark-Eagle et al. 2005; Derosier et al. 2015). Wildlife Action Plans cite the need to prioritize conservation actions for wildlife with "low or declining populations." These documents support the urgency to conserve Michigan herpetofauna as they identify approximately 60% of Michigan's species as Threatened, Endangered, Special Concern, or as Species of Greatest Conservation Need.



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 that was developed for EGLE. 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. The report, “Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II”, prepared by the U.S. Global Change Research Program (Reidmiller et al. 2017), aims to help inform decision-makers, public health officials, emergency planners, and other stakeholders by providing a thorough examination of the effects of climate change on the United States (Angel et al. 2018). “Changing Climate, Changing Wildlife: A Vulnerability Assessment of 400 Species of Greatest Conservation Need and Game Species in Michigan” (Hoving et al. 2013) was developed by the MDNR Wildlife Division to assess 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.



1. Refer to the yearly Michigan Fishing Guide for current limits and regulations regarding the take of amphibians and reptiles.

2. The Bullfrog is a relatively commonly harvested herpetofauna species for consumption. Maintaining stable amphibian and reptile populations is critical for continued recreation opportunities and for their conservation.



In addition to Michigan, other states and regions have also developed herpetofauna management and conservation resources that reflect their own regional species assemblages, ecological priorities, and regulatory frameworks. These are often developed by state wildlife agencies, natural heritage programs, universities, and nonprofit organizations to provide both land managers and private property owners with detailed guidance tailored to local amphibian

1. Eastern Fox Snake using a pile of limestone intended for dyke armoring. This species is known to utilize Riprap.
2. Forestry management practice must consider the impacts to herpetofauna.
3. The Copper-bellied Watersnake is a Federally protected species. Observations should be reported to the Michigan Herp Atlas.

and reptile communities (Edgar et al. 2010; Baker et al. 2011). Resources commonly include species-specific information, habitat and landscape management recommendations, survey and monitoring protocols, threat mitigation strategies, and conservation planning tools to address issues such as habitat fragmentation, road mortality, as well as invasive species and disease. Documents like this typically contain information varying from recommended methods for maintaining suitable herpetofauna habitat to creating microhabitat features like nesting sites and hibernacula that support key life-history requirements. For example, “Restoring and Managing Habitat for Reptiles and Amphibians” is a detailed document developed



by the Iowa NRCS that encompasses a wide range of herpetofauna specific best management practices (Iowa NRCS 2005). More locally, colleagues and collaborators in Ontario, Canada, contribute to the broader conservation of herpetofauna, pioneering resources to local reptile and amphibian best management practices (Eastern Foxsnake Recovery Team 2010; Gunson et al 2016; Ontario Ministry of Natural Resources and Forestry 2016a). The need for binational conservation efforts is especially significant because many of the species found in Michigan also occur in Ontario. Coordinated protection and management of species across borders helps to enhance herpetofauna, ultimately strengthening the conservation outcome for shared herpetofauna communities.

Many states will also implement outreach and education materials designed to improve public understanding of herpetofauna ecology and to promote the stewardship of local landscapes. Collectively, these state-level efforts contribute to a broader national framework for amphibian and reptile conservation, helping to ensure that management actions are informed by local ecological conditions while remaining aligned with regional and national best herpetofauna management practices.



Jim Harding

1. The Four-toed Salamander is in decline and a habitat specialist. While not as rare as other species of herpetofauna, their designation as Species of Greatest Conservation Need helps identify this and other species as needing additional study and management to avoid declines and greater need for protection.

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 (224.16) and Part 365, Endangered Species Protection, of the Natural Resources and Environmental Protection Act.

The MDNR Fisheries Division Order (224.16) sets limits and regulations regarding take methods, acceptable species, seasons, minimum size, daily possession limit, and total possession limit for all herpetofauna within Michigan (Michigan Department of Natural Resources 2016). An all-species fishing license is required to take non-protected amphibians and reptiles, and take must abide by the limitations outlined by the MDNR in the latest Michigan Fishing Guide (Michigan Department of Natural Resources 2022). The sale of amphibians and reptiles, including commercial trade, is not permitted. Commercial harvest of Eastern Snapping Turtles in Michigan ended in 2008 thanks to the efforts and proactive actions of the MDNR Fisheries Scientific Collector Permit coordinator and other MDNR Fisheries staff and members of the Amphibian and Reptile Technical Advisory Committee (ARTAC).

All State Threatened and Endangered herpetofauna species are protected from take in accordance with MDNR fisheries Division Order (224.16). Cultural or Scientific Collector's Permits can be applied for through the MDNR Fisheries Division to allow for the collection of amphibians and reptiles not covered under a State of Michigan Fishing License. While most Special Concern



2. Eastern Box Turtles are listed as State Threatened and a regulated species in the commercial trade by CITES. It is illegal to collect this species without appropriate permits.

1. Recently rediscovered in Michigan and a range expansion documented, the State Threatened Marbled Salamander is an example of our need to better document herpetofauna and not presume a species is extirpated or introduced due to lack of information.



2 While the six-lined Racerunner has a currently limited range in Michigan, this species likely occurs across much of Michigan's prairie peninsula. Additional surveys are needed to determine if relic populations are present or if this species has recolonized in Southwest Michigan.

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 (Michigan Department of Natural Resources 1994). This law prohibits the collection or "take" of Threatened and Endangered species, including Eastern Box Turtles, Spotted Turtles, Wood Turtles, Copper-bellied Water Snakes, Eastern Fox Snakes, Eastern Massasauga Rattlesnakes, Kirtland's Snakes, Six-lined Racerunners, Blanchard's Cricket Frogs, Small-mouthed Salamanders, Marbled Salamanders, and Western Lesser Sirens. 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 ESA, administered by the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS), protects all Federally Threatened and Endangered species by prohibiting take, including harassing, harming, hunting, shooting, wounding, killing, trapping, capturing, or collecting individuals (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1973). The ESA also provides protection for any Critical Habitats of listed species on public and private lands (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1973). Critical Habitat is defined by the USFWS as specific areas within the species' range, occupied by the species at the time it was listed, that contain the physical or biological features that are essential to the conservation of the species and that may warrant special management or protection



species in Michigan are not protected under this legislation, reptiles and amphibians designated as Special Concern are afforded protection under MDNR Fisheries Division Directors Order 224.16. This order prohibits the removal of such species from the wild for possession, or "take" without authorization by a Scientific Collector's Permit (Michigan Department of Natural Resources, 2016).

Part 365, Endangered Species Protection, of The Natural Resources



1. Eastern Massasauga Rattlesnake is both State and Federally Threatened with Michigan being a stronghold for this species. Conservation of land and maintaining connecting corridors as well as protection of chimney building crayfish species should be a priorities to help protect this species.



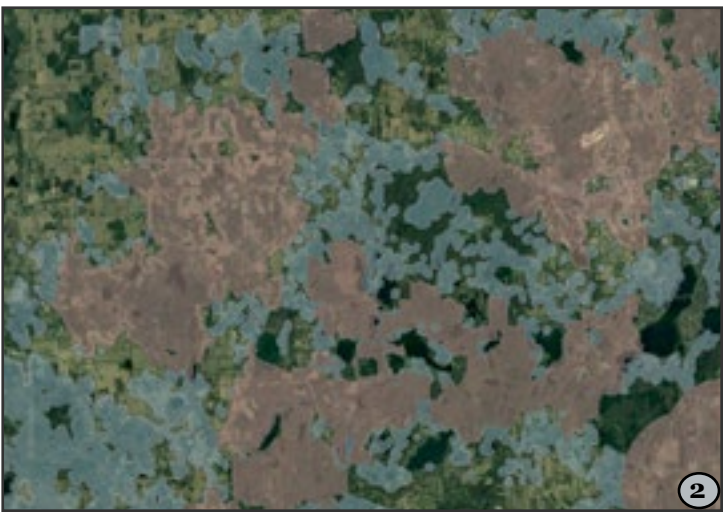
(U.S. Fish & Wildlife Service 2017). There is currently no Critical Habitat designated for the two species of Federally protected Michigan herpetofauna: the Eastern Massasauga Rattlesnake and Copper-bellied Water Snake. While there is no defined Critical Habitat for either species, the USFWS Information for Planning and Conservation (IPaC) developed Tier 1 and Tier 2 habitat areas for use as screening tools for the

Eastern Massasauga Rattlesnake in Michigan (U.S. Fish and Wildlife Service 2017). Tier 1 habitat is defined as habitat that is known to support the species, while Tier 2 habitat is defined as areas that have landscape features known to be present in habitats suitable for the species.

The ESA 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. **For a comprehensive**

discussion of these threats, including detailed information on specific impacts and contributing factors, see Section 3: Threats to Amphibians and Reptiles.

International regulations regarding herpetofauna include the Convention on International Trade in Endangered Species of



2. Eastern Massasauga Rattlesnake Tier I and II habitat designations. This spatial model is an important tool and is largely accurate. On-the-ground view validation is necessary in situations of models expanding into active agriculture areas or where habitat is not present.

Wild Fauna and Flora (CITES), an international agreement between governments to protect endangered species by imposing trade restrictions. While CITES plays a critical role in controlling the transnational movement of listed amphibians and reptiles, the agreement does not provide in-country habitat or management regulations and restrictions (CITES 2022). Eastern Box Turtles, Blanding’s Turtles, and Spotted Turtles, actively exploited for the international pet trade, are currently listed in CITES Appendix II, indicating that there are population level concerns for these species, but that regulated commercial trade is still allowed with proper permitting.

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 Appendix A for more information regarding current State and Federal status designations for each species of Michigan herpetofauna.**

1. High quality fen habitat can support several species of rare and declining herpetofauna. Care must be taken to limit habitat disturbance and protect hydrologic regimes both surface and subsurface permits. It is also important for agencies and conservancies to not promote the location of rare species at these sites to prevent poaching and potential spread of disease.



1. Herpetofauna-focused surveys often utilize visual encounter, meander transects to document amphibian and reptile presence in addition to other methodologies. Assessments are a necessary and critical aspect to understand the potential impacts and measure to mitigate them.



Herp HAT: the Herpetofauna Habitat Assessment Tool for Michigan

The need for the development of indicators of ecosystem health for the Great Lakes region was recognized at the State-of-the-Lakes Ecosystem Conference in 1998. Following this recognition, ecosystem health monitoring protocols have been developed to evaluate wetland integrity, including bioassessments of fish, crayfish, anurans, plants, macrophytes, macroinvertebrates, zooplankton, and birds. EGLE also created the Michigan Rapid Assessment Method for Wetlands (MiRAM) to quantify wetland integrity by surveyors with significant knowledge of wetland plants, fish, and wildlife species and their ecological wetland roles. However, no methods had yet been developed that incorporate reptiles or non-vernal pool associated amphibians.

As recognized indicators of environmental health, herpetofauna are ideal candidates for integration into a wetland functional assessment tool. Incorporating a system that considers reptile and amphibian communities would provide a stronger, holistic approach to quantifying wetland value and function. The goal of this effort was to create a standardized herpetofauna-based habitat assessment tool, structured as an Index of Biotic Integrity (IBI), specifically for application in Michigan wetlands.

The Herpetological Habitat Assessment Tool, or Herp HAT is a scientifically supported



2. Community engagement is an essential part of overall conservation and species protection. Efforts such as this in Oceana County are an important step in educating the public about the role herpetofauna play and the benefits of contributing data to programs like the Herp Atlas.

1. Surveys for herpetofauna are not only limited to high quality habitat but rather any place where these species may occur. Surveys along this reach of highway showed several species of rare herpetofauna present helping guide MDOT to minimize impacts and develop mitigative measures. Incorporating programs like HerpHAT also allows for comparison of site condition pre-construction to post construction.



conservation and management tool. It primarily focuses on Michigan's aquatic and terrestrial habitats and assesses the ecological health of wetlands and uplands by evaluating the amphibian and reptile community occupying the site. The tool uses several metrics, including species richness, rarity, and tolerance to disturbances, to gauge habitat quality and guide conservation and best management efforts for Michigan's herpetofauna populations. It is a reliable, rapid method to assess the health of an ecosystem through a focus on detected species. The Herp HAT incorpo-

rates species-specific Coefficient of Conservatism Scores (C-Scores) ranked by Michigan herpetologists with expertise in their field and relevant taxa, species, along with observational herpetofauna data, and optional MiRAM Scores, to create an overall

2. Surveys of deep water and submergent aquatic habitats sometimes necessitate the use of watercrafts to effectively determine species composition and spatial distribution.



1. Sampling for herpetofauna can and often include the use of artificial cover objects to increase detection of fossorial and cryptic species. Surveys should incorporate several techniques to optimize detection, life stages, and spatial distribution.

Habitat Score.
To implement the Herp HAT tool, a herpetofauna habitat quality assessment incorporates:

- Site selection based on project needs and landscape sensitivity.

- A preliminary desktop review, utilizing publicly available satellite imagery, MiENVIRO, the Michigan Herp Atlas, and other heritage databases, to assess historical habitat and species composition prior to visiting the sites.

- A minimum of three site visits during the active herpetofauna season, including early (April-May), middle (June-July), and late season (August-September), to optimize the probability of detecting species present. Implementation of visual encounter surveys, transect surveys, amphibian call surveys, rapid habitat assessments, dip netting, baited hoop traps, funnel traps, and artificial cover objects are utilized to maximize detection probability in a rapid assessment framework.

- A Survey 123 application has been created to simplify data collection and analysis. This can be found on both the HRM and EGLE websites.

2. Surveys should always include the use of spatial reference documentation of data. Use of high-end GPS equipment preferable with a 1-3 ft accuracy is preferred. Use of programs like Survey 123 and the Herp HAT use cell towers to ping locations to record locations. The MI Herp Atlas also has this integrated into their data collection system of use with phones.

C-Scores for species were calculated based on a list of metrics that attempt to consider all associations that might be correlated with wetland functional value. Species C-Scores were developed through a rigorous expert assessment process evaluating each species against 8 critical metrics correlated with ecosystem functional value including: (1) Current State Regulatory Status; (2) Rarity; (3) Fragmentation Tolerance; (4) Generalist or Specialist; (5) Life History Traits; (6) Probability of Detection; (7) Required Hydroperiod; and finally, (8) Need for Fishless Wetlands. These metrics have been fully assessed and finalized by a panel of 13 experts and are embedded directly within the Herp HAT tool. To ensure the continued accuracy and relevance of these conservation metrics, it is recommended that C-Scores be reevaluated every 10 years. This periodic review accounts for dynamic changes in habitat conditions, spe-



1. Documentation of herpetofauna with GPS equipment is ended to properly document species occurrence. Some devices integrate with GIS increasing the utility and functionality of spatial reference data and data collection.

cies populations, distributions, and other ecological factors, guaranteeing that habitat assessments are always conducted using the most current and accurate metrics available.

The Herp HAT protocol scores based strictly on species presence or absence (detection/non-detection), which eliminates bias introduced by fluctuating seasonal abundance. The Herp HAT Score represents the conservation value of a habitat to herpetofauna based on this presence/absence methodology.

The Herp HAT tool is a valuable resource for regulators, natural resource practitioners, private sector biological and natural resource organizations, and environmental stewards on projects that encompass Michigan wetlands. The Herp HAT tool allows users to determine the functional value of habitats for herpetofauna in an accurate, rapid manner. These time-constrained surveys are beneficial in providing valuable data without extensive sampling effort.



How to Calculate Raw C-scores

Rarity	= 2
Fragmentation Sensitivity	= 4
Specialist or Generalist	= 2
Fecundity	= 4
Life Expectancy	= 6
Probability of Detection	= 1
Required Hydroperiod	= 5
Need for Fishless Wetlands	= 2

1. Estimate a score from 0-10 for each metric for each species

2. Average all metrics across each species

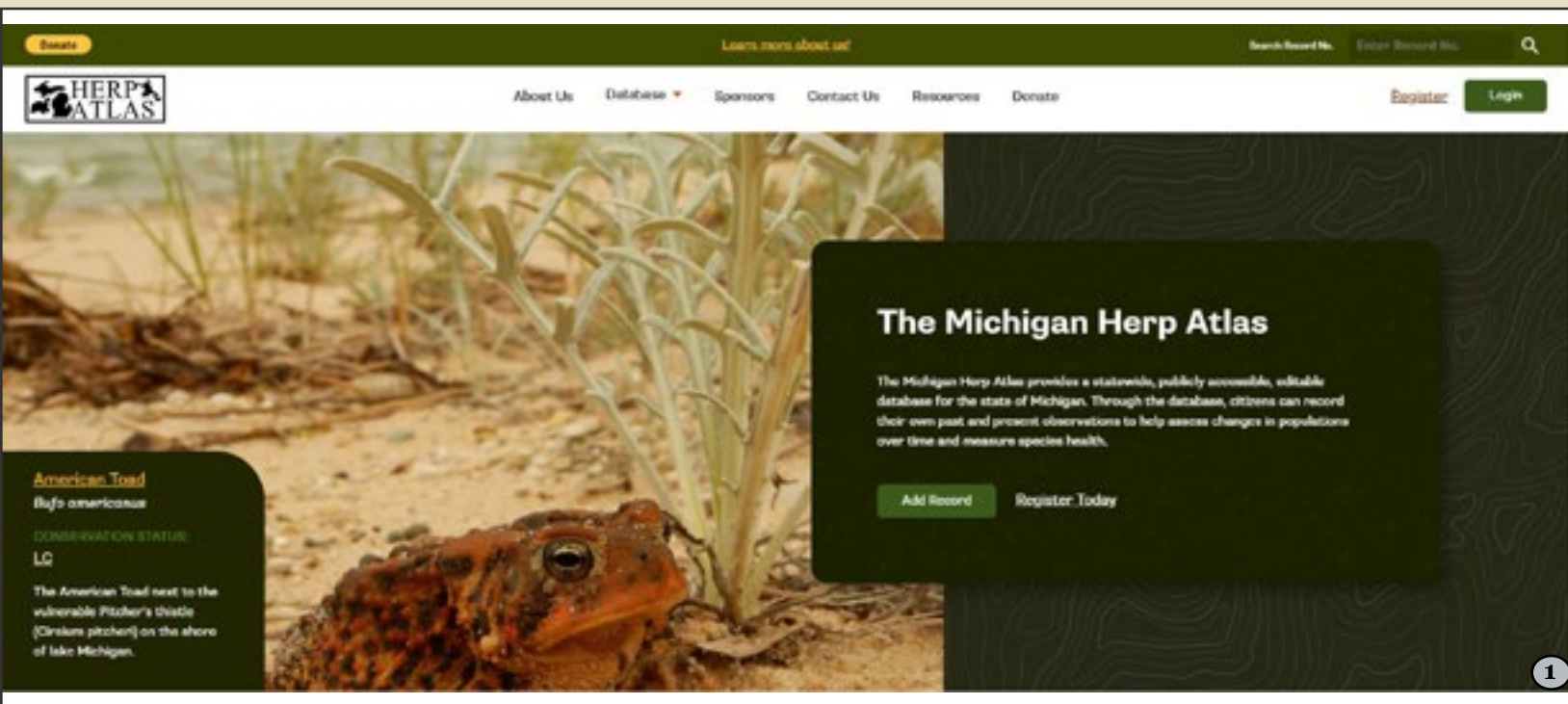
3. Average the C-score for each species submitted by each professional

Average of metrics for 1 professional = 3.25

Metric averages for other professionals = 3.0, 3.5, 3.75

Average raw C-score = 3.375





The Michigan Herpetological Atlas

Originally initiated in 2004 to address data gaps in our understanding of Michigan’s amphibian and reptile distributions, the Michigan Herp Atlas has been administered by HRM since its acquisition in 2010, where it serves as an inclusive, public-private collaboration that maintains a comprehensive database of herpetofauna observations within the state of Michigan. The program goal is to keep common species common and to better understand the spatial distribution of Michigan species. The Atlas has grown to include over 500,000 observations and over 10,000 members to date. Current and historic partners and data contributors/users, include USGS, USFWS, USEPA, National Parks Service (NPS), MDNR Fisheries Division, MDNR Wildlife Division, MNFI, Friends of the Rouge, City of Ann Arbor, Eastern Michigan University, Central Michigan University, Michigan State University, University of Michigan Museum of Natural History, Oakland County Park and Recreation, Washtenaw County Parks and Recreation, Ottawa County Parks and Recreation, Oceana County

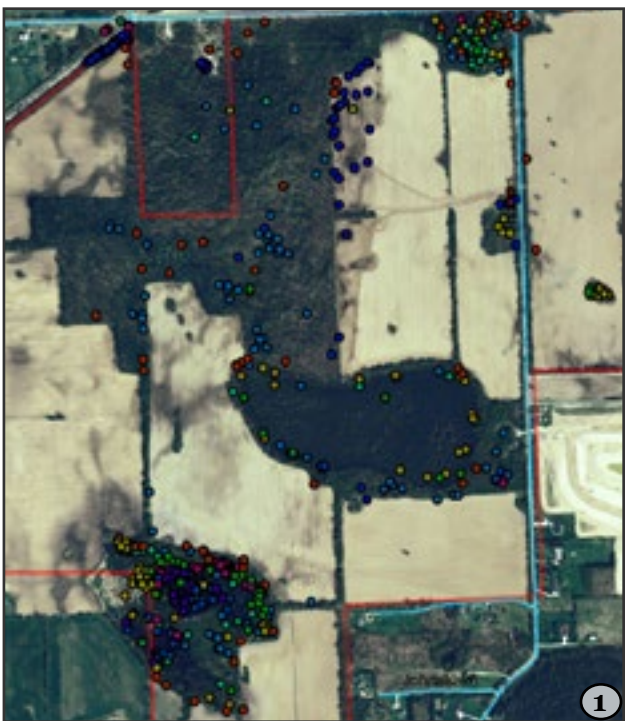


1-2. Everyone can submit observations of amphibians and reptiles to the Michigan Herp Atlas. Training events are a great way to not only educate, but also document herpetofauna to contribute to conservation.

1. Spatial data allow for better interpretation of impacts and natural resource conditions and limitations. Knowing the species, the age classes, and where they occur and when on a landscape allow for better understand of site needs and potential impacts.

comprehensive and up-to-date accounts of Michigan herpetofauna. Integrating Herp Atlas data into analyses can:

- Provide innovative tools for assessing habitat conditions and health, such as the Herp HAT.
- Determine important ecological hotspots and potential corridors for wildlife movement.
- Identify locations of data gaps and population declines to prioritize conservation efforts.
- Help evaluate the response of herpetofauna to invasive species control and other management actions.



The Michigan Herp Atlas also promotes a culture of responsible observation and interaction with herpetofauna. Finding and observing reptiles and amphibians in the wild is often referred to as “herping,” and it can be a valuable way to better understand the animals you share your habitat with. However, it is very important to consider the well-being of the animals we encounter. To support this, the Michigan Amphibian and Reptile Conservancy (MARC) developed the acronym R.I.D.E. as a simple framework for determining when handling is appropriate. The handling of wild reptiles and amphibians should only be conducted in situations where the R.I.D.E. principles apply.

2. Always be mindful of you actions and behavior when surveys or “herping” and always display integrity in the field. Consider R.I.D.E with every decision and always adopt good decon procedures.

R.I.D.E., which stands for Relocation, Identification, Documentation, or Education, serves as a helpful reminder that animals are only to be handled with purpose and intent, rather than for the entertainment or challenge of it. Observing herps without handling will minimize stress on the animal and ultimately keep it safer. For times when the handling of an animal is required, refer to the simple guidelines below to ensure that handling is performed in a manner that is safe for both the animal and the handler.



1. Always leave the landscape better than you found it and contribute data to programs like the MI Herp Atlas. Everyone can submit observations of amphibians and reptiles to the Michigan Herp Atlas. Also be mindful of sharing locality data in forums and groups as this can harm species and their landscape.

2. Engaging children as part of management such as headstarting helps create future conservation minded adults who appreciate natural resources and the species in them.



When handling is necessary, follow these guidelines:

1. What is your goal in handling the animal? Think of the acronym **R.I.D.E.** Animals should only be handled with purpose and intent. Limit the time you are handling the animal to minimize stress. Avoid catching every animal, like frogs, that you encounter. Once you have observed a particular species in an area, it is not necessary to handle all the other specimens that you encounter. Be sure to put animals back where you found them, with the exception of animals found beneath logs or boards.

In these cases, replace the log or board and then place the animals at the edge of the object; they will find their way back underneath and not be crushed. Threatened or endangered species should never be handled unless you have proper federal and/or state permits to do so. The exception to this is when moving an animal off the road to prevent road mortality. In these instances, be sure to only using proper relocation techniques to move the animal to the side of the road it was initially heading. Also submit this data to the Michigan Herp Atlas.

2. How sensitive is the animal you are handling? Amphibians: frogs, toads, newts, and salamanders have absorbent skin. This is a defining characteristic of amphibians and what makes them key indicators for ecosystem health. Salts, oils, and chemicals on your hands, like lotions, hand sanitizer, sunblock, and insect repellents, can all be absorbed by an amphibian's skin and seriously harm them. If handling amphibians is necessary, be sure that your hands are clean and wet. The use of Nitrile gloves is also approved if the gloves have been rinsed before and are wet during handling. If you recently applied sunblock or insect repellent, the handling of an amphibian could be fatal to that animal.

3 How can You help prevent the transmission of EIDs? Clean your gear. Your gear, such as boots, walking or snake sticks, can transport pathogens like Snake Fungal Disease (SFD), Chytrid, and Rana Virus from one habitat to another. You can prevent this by cleaning your gear between sites. Keep a spray bottle containing a solution of 10% bleach and water to decontaminate the bottom of your shoes or boots. This can be very effective at mitigating the spread of pathogens. Washing and bleaching your gear also helps to reduce the spread of invasive plant species. It is imperative that we all do our part to minimize the impact on our ecosystems.



1. Handle animals only when necessary. Here an adult female Spotted Turtle was crossing the road and nearly hit by a car. This provided an opportunity to save the turtle and educate individuals attending a herp conservation workshop.

4. How can I best observe herpetofauna? Be respectful of the habitats you are enjoying. Be mindful of where you are stepping and what you might be damaging (e.g., avoid stepping into sensitive vernal pools). One way to find reptiles and amphibians is by flipping over logs, man-made cover objects like boards or tins, and rocks. Be careful to replace these objects once you are done inspecting under them, to ensure that animals will still be able to use the cover. Take photos and notes if you like, but NEVER remove an animal from its habitat. Even if an animal is not threatened or endangered, it is a vital part of a functioning ecosystem and should never be taken to be kept as a pet, study specimen, or any form of captive animal. Observe the animal where it is meant to be in its natural habitat and think about all the roles it may play in its ecosystem. This includes eggs and egg masses; even if you find hundreds of Eastern American Toad egg masses, each of those eggs is important to ensure the future success of that population.

5. How can I help contribute to population's viability? Stay discreet to save the species. While individuals often want to share their observations with friends and family, on social media, and on citizen science sites like the Michigan Herp Atlas and broader-reaching sites like iNaturalist, it is important to stay discreet about your favorite herping locations. It is not advisable to disclose the exact location(s) of animals that you find, especially when that information can be found and accessed across large platforms (e.g., Facebook or Instagram posts). Providing your discoveries at the county level, or a more generic level, is a way to share your findings without putting locations or species at risk of collection, stress from too many observers or handlers, habitat damage from too many visitors, and even persecution or killing, as is often the case for many snake species. The Michigan Herp Atlas only provides data to the public at the county level to preserve the integrity of the observers' submissions and the species found. Additional detailed data requests require a data use agreement to protect species and locations.

We encourage you to save these guidelines on your phone for reference when you are herping. The Michigan Herp Atlas presents an opportunity for everyone to contribute to the 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 consider contributing to the Michigan Herp Atlas at www.MiHerpAtlas.org.





5. Project Planning

1-3. Before beginning any project, 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 actively managing natural

resources or developing new construction, your decisions and actions influence 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. **See Appendix B for a recommended project action timeline to minimize impacts to herpetofauna.**



Obtain the Appropriate Permits

Before any land clearing, construction, or other activities can begin on a site, permits from regulatory agencies may be required. Permits are issued by several 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 the USFWS, EGLE, MDNR, as well as County and local municipality websites. Ensure to apply for permitting well in advance of the proposed work to account for delays in the permitting process.



5. Project Planning

Evaluating the Site

Although habitat destruction, degradation, and fragmentation are the main reasons for the decline of amphibians and reptiles (Dodd et al. 2003; Marchand and Litvaitis 2004; Weyrauch and Grubb 2004), land use planning and pre-construction planning can help mitigate these problems (Calhoun 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 types 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. When possible, site visits should be timed to coincide with optimal observation windows based on the species' natural histories.

Assess habitat connectivity – All areas of wildlife habitat cannot be preserved; the restore, the importance of preservation of habitat areas should be prioritized 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

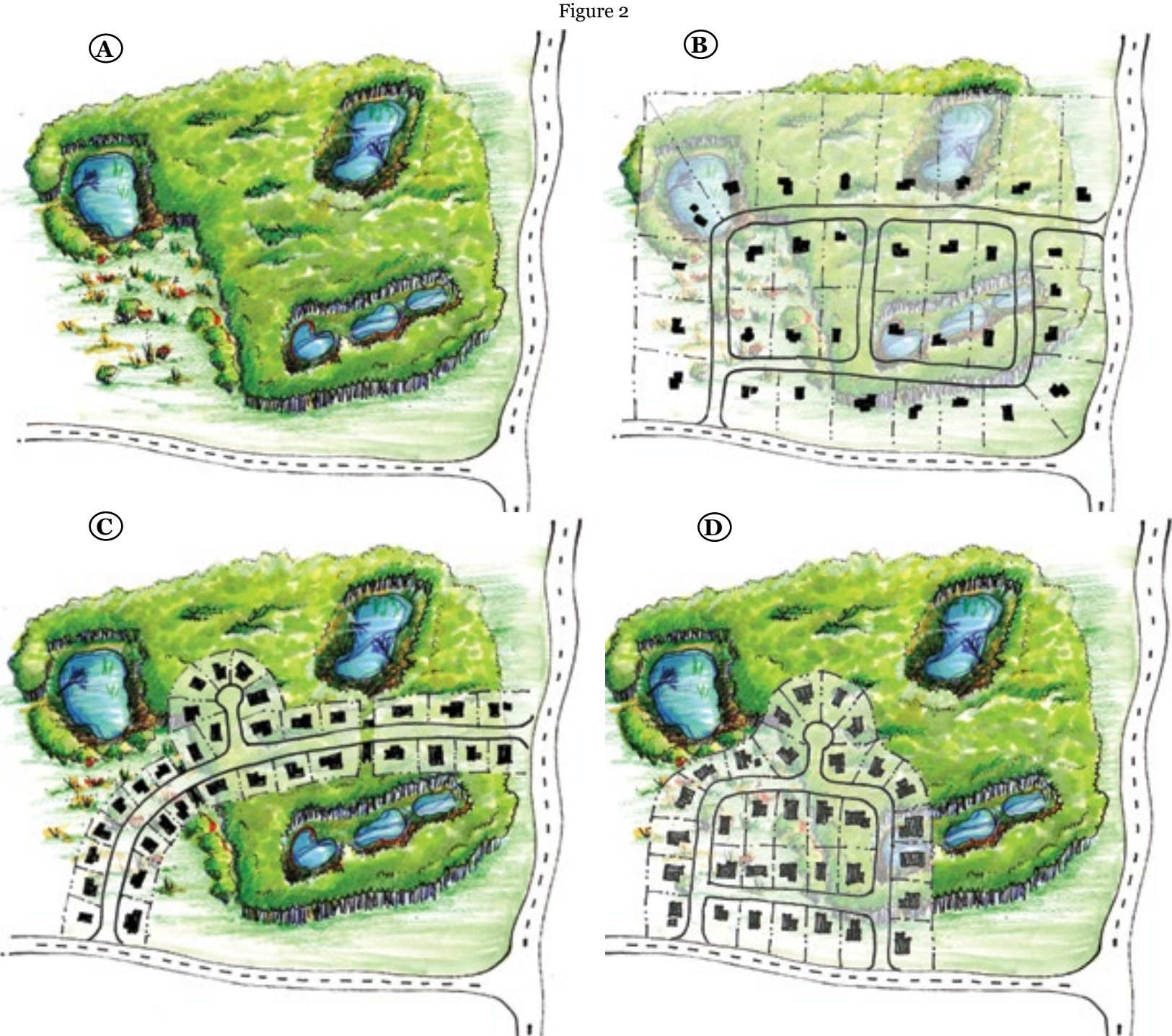


1. Visual encounter surveys help detect species like Wood Turtle in their aquatic habitat. Based on morphological characteristics you can often also determine sex of the animals without needing to capture or handle. This passive survey method allows for animals to have minimal stress and still facilitate documentation.

2. To reduce threat of harm from construction baseline survey are important to guide best management practices. Failure to incorporate such measure can result in harm or death to animals and loss of future generations.



Figure 2. Thoughtful and creative design approaches can significantly minimize impacts while still meeting project objectives. The following designs, demonstrate how thoughtful planning can still preserve critical habitats and connectivity. Pre-development (A). Typical development (B). Fragmented site (C). Loss of some high quality wetland to maintain greater connectivity (D).



1. Pickerel Frogs are a cold water stream associated species and indicator of high quality habitat.

2. Four-toed Salamanders are a habitat specialist and their presence indicate overall habitat connectivity and wetland health.

3. Northern Red-bellied Snakes are worm and slug specialist and their percent and abundance in a forested landscape is indicative of overall ecosystem function.

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 because of the project. These threats should be addressed and mitigated when possible.

The presence of rare and protected species, breeding species, and the ability of the area to support reproduction should be considered when evaluating the ecological value of a site (Calhoun 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 an important 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 (Harding and Mifsud 2017). However,

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 functions and value, as well as support a rich diversity of herpetofauna.

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 Geographic Information Systems (GIS), or other spatial data analysis and mapping software, by a wildlife or environmental professional may be helpful in this process.





1. Wetland complexes provide the greatest value to herpetofauna and can support multiple life stages. This coupled with critical contiguous upland habitat provide the ideal conditions for amphibians and reptiles.

2. Mapping of habitat communities provides a spatial explicit reference with acreage to best manage and restore landscapes.

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. 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-

GIS spatial data and 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). The USFWS IPaC website provides Tier 1 and Tier 2 habitat areas for use as screening tools to determine if a project occurs within habitat that is protected for the Eastern Massasauga Rattlesnake. 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 created to aid in the development of landscape and long-term planning perspectives for conservation activities. The United States Geological Survey (USGS) supports Earth Explorer, an online database that



1. Gradients of wetland habitat provide for more structural complexity creating a more diverse landscape.

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



Conservation Resource Alliance

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 the ecological functions of a landscape can also benefit the conservation of amphibians and reptiles. Large-scale decisions and general guidelines regarding management activities, earth moving, siting developments, and construction materials can affect habitat quality and connectivity, hydrologic processes, and wildlife conservation.

Weigh potential costs and benefits of various restoration, management, and development 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.

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.

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



- Figure 3.
- A. Basking Logs provide critical thermal regulatory opportunities for turtles.
- B. Logs provide critical refugia and cover from predators as well as places to forage.
- C. Riparian habitat with porous soils can support a variety of native berries providing food for several semiaquatic turtle species like Wood Turtles and Eastern Box Turtles.
- D. Eastern Hog-nosed Snakes rely on cover and travel corridors to ambush prey. They require sandy soil conditions to construct burrows which they use their shovel-like snout to construct.
- E. Several species Like Wood Turtles require large blocks of contiguous habitat exceeding greater than a mile.
- F. Turtles along river corridors look for sand banks as nesting beaches. They depositional landscape features are critical for these species reproductive success.
- E. Where roads bisect habitats, use of culverts, crossing and wing walls reduce mortality.

Figure 3



1. Impoundments and dyked wetland can alter ecosystem function and community composition. The seasonal alterations of these habitats also can negatively affect herpetofauna living in these wetlands.

sediment transport, and temperature regimes.

Threats, including damming, shoreline development/hardening (seawalls, bulkheads, riprap), urbanization, and contamination, negatively impact riverine ecosystems and degrade their functional value to herpetofauna and other organisms. The use of management techniques to help mitigate these negative impacts can help to conserve herpetofauna and continue their persistence and occupancy across these landscapes. Consequently, the implementation of science-based BMPs is imperative to mitigate these impacts, conserve herpetofauna biodiversity, and maintain ecological resilience within Michigan's riverine networks. **For a detailed overview of these threats, see Section 3: Threats to Amphibians and Reptiles under Dams and Riverine Alterations.**

Maintaining vegetated buffers of native grasses, shrubs, and trees along watercourses is a fundamental practice in forestry and agriculture. Streamside Management Zones (SMZs) filter runoff, stabilize soils, moderate water temperature, and provide essential terrestrial habitat, cover, and dispersal corridors for herpetofauna. Wider, more structurally complex SMZs support greater herpetofauna diversity and abundance (Foley 1994; Semlitsch and Bodie 2003). For species like Wood Turtles and Eastern Box Turtles, maintaining open canopy areas within the riparian zone for foraging and nesting is critical. Management should aim for a mosaic of conditions within the SMZ, balancing shade with necessary solar exposure. Maintaining wide, undisturbed forested buffers along watercourses is the single most effective practice for protecting aquatic and riparian-associated herpetofauna. These buffers filter sediment, regulate water temperature, and provide essential terrestrial habitat.

Herps and Riverine Impacts: Dams

Dams represent one of the most severe and pervasive threats to riverine herpetofauna, inducing impacts through physical fragmentation, hydrological alteration, and geomorphic change. As summarized in Section 3, these structures act as physical barriers that fragment aquatic landscapes and disrupt natural flow regimes. The





1. Impacts from the fragmenting of habitat such as roads, limit connectivity and increase the risk of road mortality of low mobility species increasing risk of local declines of population or extirpation.

following provides a comprehensive overview of these impacts and their consequences for herpetofauna populations.

Physical barriers can also isolate populations and fragment habitats that herpetofauna utilize. Dams fragment the landscape not only by acting as a barrier, but also by causing changes to the timing and intensity of natural flooding events (Magilligan and Nislow 2005). This disruption can be detrimental to species that have adapted to depend on seasonally inundated floodplains and can lead to reproductive loss and decreased gene flow. Landscape disturbances caused by dams can displace native species by creating site conditions favorable for invasive species colonization. This results in homogenous vegetative communities that provide limited benefit to herpetofauna (Bateman et al. 2014; Hunt et al. 2013). The cumulative loss of foraging, breeding, and migratory habitat are deleterious to current and future populations that inhabit these waters throughout the dam's lifecycle (Alla and Liu 2021; Bárcenas-García et al. 2022; Lin 2011; Wang et al. 2018).

Dams act as physical barriers, fragmenting once contiguous aquatic landscapes and reducing flood-dependent wetland connectivity. This fragmentation bisects populations and can result in a cascade of ecological impacts for herpetofauna. Alteration and regulation of natural river system flows are associated with dramatic abiotic and biotic changes to rivers. These changes can increase the potential for invasive species like Zebra Mussels and Mystery Snails (*Cipangopaludina sp.*). An evaluation of the diets of Northern Map Turtles showed marked differences from those examined directly downriver of the dam in a previous study that preceded Zebra Mussel establishment (Richards-Dimitrie et al. 2013). While Northern Map Turtle consumption of Zebra Mussels may benefit freshwater ecosystems, given the negative impact this species has had on native mussel fauna, it is unclear what impact this obligate dietary shift may have on long-lived species such as turtles (Gacheny et al. 2021). Increased habitat degradation from issues associated with damming can increase population vulnerability, as reliance on specific nonnative food sources becomes more obligate.

Dams significantly alter river ecosystems by impeding natural hydrologic regimes, flow rate, increasing water temperatures, lowering dissolved oxygen levels (hypoxia), and creating impoundments that alter natural system function. This disruption has cascading negative impacts on downstream species. For example, amphibians that depend on flowing rivers for breeding purposes are often absent from downstream habitats and have reduced breeding population sizes compared to populations devoid of dam impacts (Kupferberg et al. 2011). Species like Wood Turtles, which are a riverine associated species in Michigan, rely on pools and associated high-oxygenated water in rivers for hibernation. When landscapes are altered, these and other species are more susceptible to stress or may relocate (when possible) to nearby suitable



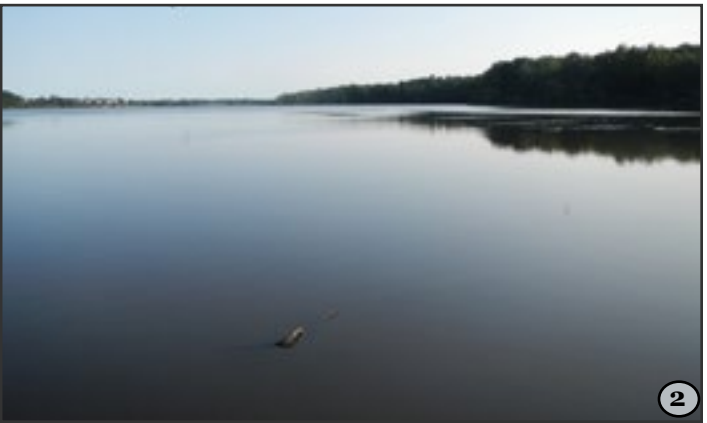
1. Dams alter hydrology, flow rate, temperature, nutrients, and connectivity of landscapes.

2. Dams can result in large impoundments shifting from lentic to lotic systems and community composition. These relatively homogenous systems often support reduced community composition when compared to natural lakes. With time they can function to support a range of herpetofauna and care must be taken if a dam is proposed for removal.

habitat and left behind a more uniform, simplified environment (VanDeWalle and Christiansen 1996).

Building an impoundment transforms a flowing river (a lotic system) into a still or slow-moving waterbody (a lentic or semi-lentic system). This shift changes the physical habitat and disrupts the ecological community that developed under river conditions. Forcing a sudden change from one community type to another can lead to widespread mortality (Alho 2011). The shorelines formed by reservoirs do not replicate the riparian habitats that once bordered free-flowing rivers. Reservoir construction also damages or removes important habitat features for aquatic turtles that use riverbanks and nearby upland areas. In addition, these reservoirs limit the movement, dispersal, and migration of animals through the river system and the surrounding uplands (Alho 2011).

Dams can severely degrade riparian habitat by causing changes in water quality. This can occur through disruptions to sediment movement. Sediment, including sand and silty material, is naturally carried by flowing water and is essential for building healthy meandering riverbeds and turtle nesting beaches. Organic material flowing



habitats.

The construction of upstream reservoirs creates uniform environments that can reduce habitat diversity. This loss of variation affects species that depend on complex habitat mosaics, such as the Blanding's Turtle (VanDeWalle 1993). VanDeWalle and Christiansen observed that stream alteration appeared to reduce the species richness of riverine turtles by removing intolerant species. Turtles like the Northern Map Turtle, Blanding's Turtle, and Smooth Softshell Turtle were absent when river modification removed their



1. The impacts of fragmenting to long-lived species that travel long distances and use large habitat block result in a high degree of likelihood of mortality and decline of species locally and regionally.

downstream provides important nutrients for riparian and floodplain wetlands, which help sequester these nutrients, improving water quality. Dams block this natural flow, trapping sediment in the impoundment behind them. This starves downstream areas of the materials needed to maintain habitats, shorelines, and nutrient cycles. The impounded waterbody created by a dam can result in a variety of issues such as eutrophication, hypoxia, altered water temperatures, the accumulation of contaminants from runoff, and increased water acidity. These changes can lead to the widespread loss of submerged aquatic vegetation, which plays a critical role in nutrient cycling and oxygen regulation. These impacts can also affect aquatic organisms, especially in winter, resulting in anoxia, which results in die-offs fish, aquatic turtles, submerged amphibians like Northern Mudpuppies and frog larvae, as well as mussels and other aquatic invertebrates. The subsequent decomposition of this vegetation under anoxic conditions promotes mercury methylation, a microbial process that converts inorganic mercury into methylmercury, a highly toxic and bioaccumulative compound that poses significant risks to aquatic food webs and higher trophic levels (Bárcenas-García et al. 2022).

The hypoxia of the environments behind dam walls can also cause ammonia, iron, manganese, and mercury to be reduced and released from vegetation and soils into the surrounding environment (Alla and Liu 2021; Lin 2011; Wang et al. 2018).

Excessive nutrients like nitrogen and phosphorus enter water bodies and cause explosive and dense vegetative growth, often associated with a decrease in water quality, and can lead to mass mortality from hypoxia. This process can impact riverine herpetofauna that utilize water bodies as it can lead to changes in their physiological stress levels and bactericidal capacities compared to individuals who are not in these harmful algal blooms (HABs). It was found that animals in these HABs are often more stressed and are more likely to have compromised immune functioning (Refsnider et al. 2021). Compromised immune functioning can increase infection rates and associated disease introduction, especially in virulent herpetofauna diseases like chytridiomycosis or SFS (Jacinto-Maldonado et al. 2023).

Avoid essential habitat – Essential habitat includes areas such as vernal pools, wetlands, adjacent uplands, potential hibernacula, and identified breeding areas. Construction and management activities should be planned to preserve essential habitat for species potentially present on site and avoid possibly killing large numbers of amphibians and reptiles with earth-moving equipment and machinery. 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. For development projects such as natural gas pipelines, fiber-optic cable, or transmission lines, consider utilizing horizontal directional drilling (HDD) or boring installation to avoid



1. Roads bisecting high quality habitat, especially aquatic and terrestrial ecosystems result in areas of high mortality for herpetofauna that migrate between aquatic and terrestrial habitats.

2. Blanding's Turtles travel long distances and often get hit on roads.

direct impacts to essential habitat areas, when possible.

For a comprehensive discussion, see Section 8. Development Techniques under Horizontal Direction Drilling.

Reduce habitat fragmentation – Creating wildlife habitat corridors and buffers around essential habitat areas and reducing the number of roads, fences, and other barriers can help to increase and/or 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 limiting disturbance of natural areas to only areas directly around a building footprint 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.

Maintain landscape mosaic – A range of natural communities, including 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, Blue-spotted Salamanders, Spotted Salamanders, and Marbled Salamanders. 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.

Cluster development and disturbances – Where possible, focus work in areas far from wetlands and high-quality herpetofauna habitat to minimize 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 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



1. Logs are a simple and effective habitat feature that can be incorporated as part of restoration.

areas that avoid impacting habitat (Bengston 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 2021). Preserved green space is considered an asset by many potential property owners who are willing to pay a higher price for this valuable amenity (Andrews et al. 2015). 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 the 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.

Provide appropriate habitat structure – Each herpetofauna 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. Planning to provide for species’ needs at all life stages for restoration can significantly influence community health and diversity. **For a comprehensive discussion: See Section 6. Ecological Restoration, Mitigation, and Habitat Design.**

Engage 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 educated constituents who are positively engaged in the conservation and preservation of amphibians and reptiles. Consider implementing signage at restoration sites to inform and engage patrons on the sites’ importance to wildlife and the environment.

Plant native and diverse vegetation communities – Select native flora seed mixes appropriate for a habitat community type that provides forage, shelter, and habitat for herpetofauna in addition to insects and other wildlife.



2. Control of subsidized mesopredators and reducing their access to food can significantly help reduce turtle nest predation and help recover species.

1. Monofilament soil erosion control products are well documented as negatively impacting herpetofauna and other wildlife. They entangle animals leading to death. Avoid these products and use wildlife friendly products.

2. Wildlife barrier fencing is an effective tool for minimizing construction-related mortality of amphibians and reptiles when paired with focused rescue and relocation efforts. Incorporation of signage about the potential or known species helps to create a sense of awareness and consideration on job sites.

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. **For a comprehensive discussion; See Section 6. Ecological Restoration, Mitigation, and Habitat Design.**

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

- Herpetofauna community composition, species distribution, and presence of multiple life stages indicating the successful recruitment of new individuals into the population.
- Target species, such as sensitive herpetofauna species or those that require specific habitat types, as indicators.
- The presence of plant communities or habitat features that provide the necessary structure and services to meet the species’ needs.





Implement Herp-friendly Work

Construction activities can have long-term impacts on wildlife communities and habitat, and should be planned to minimize impacts to herpetofauna and other wildlife.

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

1. Post project implementation monitoring is an effective way to gauge the success of restoration and help to better inform future management actions. Use of HerPHAT can also quantify the efficacy numerically of the restoration results.

2. Engaging those involved with the project on a day-to-day, boots-on-the-ground perspective can have a tremendous impact on the conservation of wildlife.

Conduct work when risk to wildlife is less – By evaluating which species are present at and near a work site, along with their annual movements and habitat needs, specific construction tasks can be timed to reduce impacts to these animals. Construction should be timed to avoid active seasons, migrations, and management activities, such as herbicide application, which should be timed to avoid sensitive larval stages of amphibians in nearby wetlands. **See Appendix B for more information regarding generalized project timing recommendations.**

Engage work crews – Work crews should be alerted to the potential 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 the 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 positive identification was possible (to the best of the worker's 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. Workers should only handle and relocate herpetofauna under the guidance and permits of a herpetologist or wildlife biologist with demonstrated expertise with herpetofauna.



Rescue and relocate wildlife (Wildlife Clearance) – If the proposed project activities are deemed to directly impact herpetofauna populations within essential habitat areas, a professional herpetologist or wildlife biologist with demonstrated experience and expertise working with herpetofauna should be present on-site to conduct relocation or translocation efforts. Relocation and translocation, often referred to as 'wildlife clearance' or 'site walk-downs', is the act of rescuing or removing wildlife from the area of impact before and/or during project activities and relocating the individuals to nearby suitable habitat outside of the project area. **For a comprehensive discussion: See Section 7. Management Techniques for more details.**

1. Turtles and other herpetofauna can get trapped in holes and pits constructed as part of construction activities. Recovery of these animals can be difficult, if you are even aware they are in them. Care should be taken to always cover pits and prevent wildlife from accessing them. In some cases, a board covering a whole could in fact encourage an animals to use it.

Prevent wildlife from entering the workspace – Soil erosion control, silt fencing, or dedicated wildlife barrier fencing (WBF), when properly utilized, can be an effective proactive measure for protecting herpetofauna and other wildlife through reducing the risk for species to be physically injured or killed by excluding animals from active impact areas. Additional specialty products have been created targeting wildlife movement avoidance and abatement. **For a comprehensive discussion: See Section 7. Management Techniques for more details.**



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 wildlife-friendly, natural products are available and should be used as the standard soil erosion control product. **For a comprehensive discussion: See Section 6. Ecological Restoration, Mitigation, and Habitat Design.**

Percolation test holes – Holes dug to measure the rate at which soil absorbs water for septic system suitability—along with 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 a 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, when not removed after final site cleanup, can be unintended barriers for herpetofauna, sometimes trapping them within a construction site. These barriers must be removed after the site has been adequately vegetated, and equipment or vehicle use within the workspace has completed to reduce mortality. Bonds can be help until these and other potentially hazardous soil erosion control measures have been removed as a guarantee of completion. In some cases, if equipment is used for removal, wildlife clearance may be necessary to avoid injury or death to an animal located along the fence.

Herpetofauna-Safe Construction Along a Linear Corridor

Case study: Balancing Energy Infrastructure and Herpetofauna Conservation

Consumers Energy has demonstrated a long-term commitment to integrating wildlife conservation into natural gas pipeline infrastructure projects. Through two major pipeline replacement projects—the Saginaw Trail pipeline (2017-2020) and the Mid-Michigan Line 100A pipeline (2020-2025)—the company worked collaboratively with their herpetological consultant, the USFWS, EGLE, and MDNR to develop Best Management Practices that minimize impacts to rare and protected herpetofauna while meeting critical energy infrastructure needs.

The Projects

Saginaw Trail Pipeline (2017-2020)

This 95-mile pipeline replacement through Saginaw, Genesee, and Oakland counties required extensive pre-construction surveys, which documented suitable habitat for the federally Threatened Eastern Massasauga Rattlesnake and other rare species. The project herpetologist developed BMPs emphasizing avoidance of “take” through horizontal directional drilling, wildlife barrier fencing, rare species signage, environmental training, and focused rescue and relocation.

Mid-Michigan Line 100A Pipeline (2020-2025)

Building on this success, Consumers Energy undertook a 55-mile pipeline replacement across Clinton, Livingston, Shiawassee, Ingham, and Washtenaw Counties. This project included two years of pre-construction assessment, two years of construction clearance, and three years of post-restoration monitoring. An Eastern Massasauga Rattlesnake-targeted Low-Effect Habitat Conservation Plan was developed to comply with the Endangered Species Act.

Conservation Outcomes

- Collectively, across both projects, over 41,000 individual amphibians and reptiles were rescued and relocated, representing dozens of species, including state Special Concern Blanding’s Turtles, Butler’s Garter Snakes, Eastern Fox Snakes, and Fowler’s Toads.
- BMP measures successfully prevented any take of Eastern Massasauga Rattlesnakes throughout the duration of both projects.
- Headstarting programs incubated and released 51 Blanding’s Turtles, 183 Eastern Snapping Turtles, 11 Midland Painted Turtles, and 9 Blue Racers from the Saginaw Trail project. An additional 59 Blanding’s Turtle hatchlings as well as several dozen Eastern Snapping Turtle and Midland Painted Turtles were incubated and released from the Line 100A project. A total of 110 juvenile Blanding’s Turtles were incubated, hatched,



Herpetofauna-Safe Construction Along a Linear Corridor

and released back to their habitat, helping offset mortality in other parts of their range in Michigan.

- Post-restoration monitoring at a subset of sites along Line 100A project documented 1,897 amphibian and reptile observations comprising 25 species within restored target areas.
- The presence of 25 species, including all life stages for most of the identified species, indicates that these areas provide high-quality, functional habitats post-construction.

A Benchmark for Species Protection

These projects establish a new industry benchmark for how energy infrastructure development can coexist with species preservation. The integrated strategy of pre-construction assessment, habitat avoidance, adaptive construction, targeted species rescue, and active restoration provides a replicable model for minimizing impacts on imperiled wildlife.

The methods and BMPs developed through these projects are readily transferable to other infrastructure initiatives and linear projects, offering a proven pathway for balancing human infrastructure needs with the preservation of Michigan’s rich herpetofauna heritage. This work exemplifies that with proper planning, commitment, and expertise, industrial progress and species conservation can successfully coexist.

Consumers Energy and their herpetological experts have set a forward-looking standard that should serve as a model for other energy companies, transportation companies, organizations, regulatory agencies, and conservation practitioners. By weaving ecological responsibility throughout the project lifecycle, this collaboration proves that large-scale development does not need to come at the expense of our most vulnerable species. Continued monitoring will further validate the long-term efficacy of these recovery measures and the ecosystem, ensuring this benchmark continues to guide future conservation efforts.



6. Ecological Restoration and Mitigation and Habitat Design

1. Training workshops and field visits are an important part of building support and educating agencies, managers, consultants, and citizens about the threats and measures to mitigate these impacts.

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 Sections 7 and 8 are also applicable to restoration and mitigation projects. Consult Section 5 to minimize potential impacts to amphibians and reptiles at the planning phase of site restoration, 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.

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 be as successful as possible, the following recommendations, specifically regarding the restoration and mitigation planning process, should be considered. Wetland and stream mitigation requirements in Michigan are imposed by the State on specific permits, under statutory criteria, and when involving stakeholders for mitigation design it is important to include EGLE.

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



1

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.



1

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 an ecologically, economically, and socially sustainable project. Involving these groups early on is often necessary to gain community support, which is 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 requires support from qualified government or non-governmental organizations or have considerable local community support.

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

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.

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, the 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.



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.

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.

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 (Hychka & Druschke 2017; The Nature Conservancy 2011). It is important to share the knowledge gained through adaptive



Kathy Evans

Kathy Evans

management implementation with the broader community of restoration practitioners and land managers to advance restoration techniques.

Structural Complexity – Small scale habitat improvements can be achieved through placement of logs, leaving no-mow areas, retaining leaf litter, creating brush piles, utilizing natural materials including wood and rocks when landscaping, and encouraging the growth of native plants (Helping Wildlife U.S. Fish & Wildlife Service 2021). Other beneficial actions include the planting of native plant species, with an emphasis on pollinator plants, to encourage the regrowth of natural vegetative communities. Performing these simple changes can create suitable micro-habitats that can further contribute to providing complex habitat structure.

Incorporating structural diversity mimics natural habitat and provides essential life-history resources for herpetofauna. The arrangement and composition of physical features within a landscape directly influence microclimate conditions, availability of refuge sites, and foraging opportunities. Key features that enhance structural complexity include:

- **Brush Piles and Logs:** Providing critical cover, hibernacula, and foraging substrate for snakes, lizards, salamanders, and turtles. Decaying wood also supports invertebrate prey communities and retains moisture, creating favorable microhabitats for amphibians.
- **Rock Piles and Stone Walls:** Offering thermoregulatory opportunities by retaining heat for basking while simultaneously providing cool, moist retreats beneath the surface. These features are particularly valuable for reptiles such as snakes and lizards that require both warm basking sites and secure shelter.
- **Leaf Litter Beds:** Essential for fossorial (burrowing) salamanders, including the Eastern Red-backed Salamander, as well as the invertebrates that serve as their prey (DeGraaf & Rudis 1986; DeGraaf and Yamasaki 2001). Leaf litter helps maintain soil moisture, moderates temperature fluctuations, and provides foraging grounds for numerous species.

1-2. Salamanders, such as the Southern Two-lined Salamander (1) and the Northern Dusky Salamander (2), can only live in areas with high humidity, such as under logs, and leaf litter and near wetlands. They are also dependant on first order headwater streams for breeding. Maintaining moist, forested upland areas and protecting headwaters help maintain habitat specialist species.



- **No-Mow Zones and Native Plantings:** Allowing native grasses and forbs to establish provides cover for amphibians and reptiles while supporting pollinator insects, which serve as a crucial food source for many herpetofauna species. Native plant communities are better adapted to local conditions and support higher arthropod diversity compared to non-native ornamental plantings (Tallamy 2009; Helping Wildlife U.S. Fish & Wildlife Service 2021).

Incorporating these natural materials and structural elements into landscape management plans, restoration projects, and residential developments can significantly enhance habitat quality for herpetofauna. Even small-scale additions of structural complexity within otherwise simplified landscapes can create critical refuge patches, support foraging opportunities, and increase overall biodiversity. Land managers, landowners, and developers are encouraged to integrate these features into site designs and maintenance practices as cost-effective measures to support native amphibian and reptile populations.

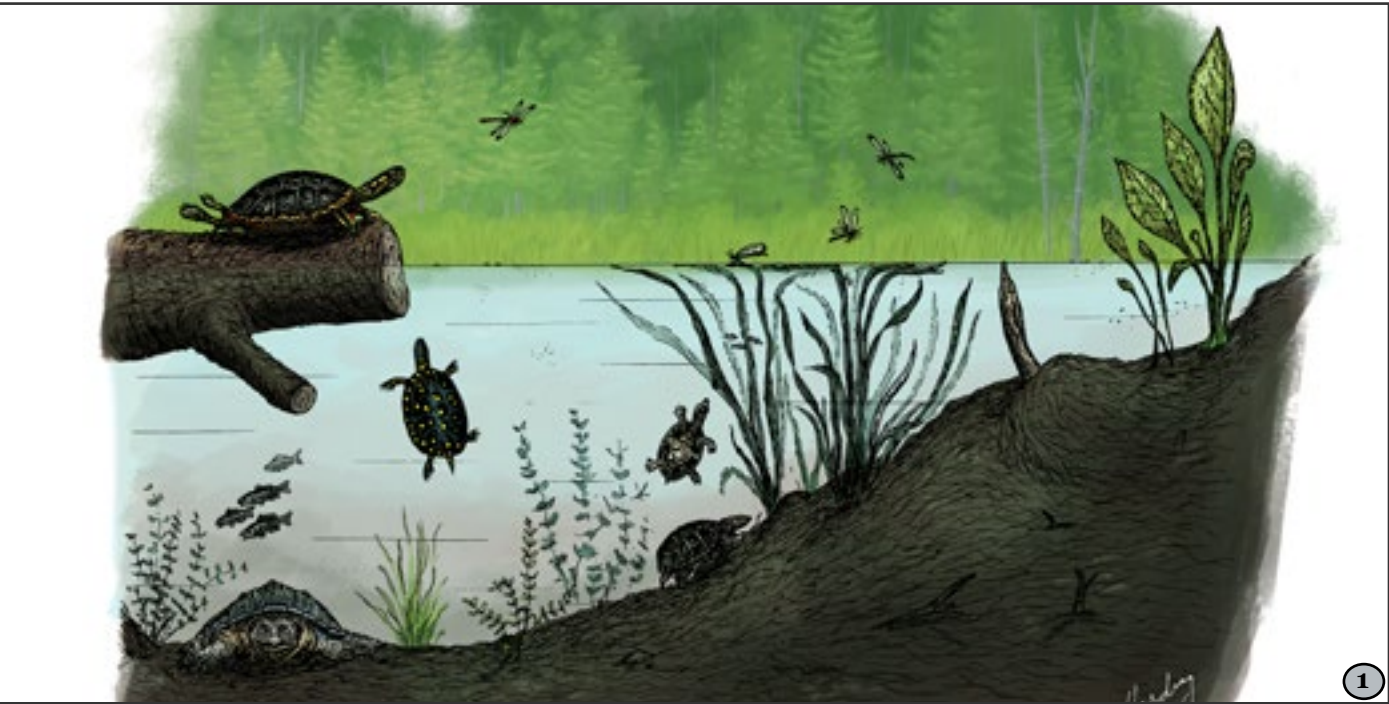
Wetland Mitigation and Restoration

Over half of the wetlands in Michigan have been destroyed or degraded from their pre-settlement condition (Dahl et al. 1990; Fizzell 2014). Wetland restoration and creation can have large-scale benefits, including improved social welfare, greenhouse gas mitigation, and recreation opportunities (Jenkins et al. 2010) and can enhance population sustainability and connectivity of wildlife habitat (Petranka et al. 2007). Although there are substantial gains associated with wetland restoration, the exact outcome of any wetland restoration is difficult to predict (Burrow & Lance 2022; Kentula 2000; Wenner et al. 2025; Zedler 2000). Following some basic guidelines/

1. Placement of habitat structures, including trees and limb along a shoreline, provides several ecological functions for herpetofauna and other wildlife, including basking opportunities, shelter, and adhesion points for amphibian eggs such as Northern Mudpuppies.



Jim Harding & Hailey Brown



1. Habitat complexity helps create and maintain a rich assemblage of amphibians and reptiles. Variable topography and hydrologic regimes benefit the greater number of species.
2. Maintaining a mosaic of habitats within a wetland as well as upland habitats helps secure herpetofauna population viability.

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.

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 more quickly and at lower cost. 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 lack 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 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





1. Habitat complexity including microhabitats like basking logs, branches, rock piles, help to create a robust and diverse community of amphibians and reptiles as well as other wildlife.

a wetland complex with several wetlands of different configurations and depths within a few hundred feet of each other can 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 – 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 Turtles and Eastern Spiny Softshells utilize deeper waters. At the same time, Midland Painted Turtles and Blanding's 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).

Restore and protect critical zones 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 et al. 2005). Management or development actions within this critical zone should not impact greater than 25% of the area to reduce the 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 critical area cannot be protected, at least the first 100-150

feet of upland area adjacent to a wetland should be preserved as a buffer, as this is where most pool breeding amphibians live their first year and where many species of freshwater turtles occur (Bodie 2001). Land conversion and habitat disturbances

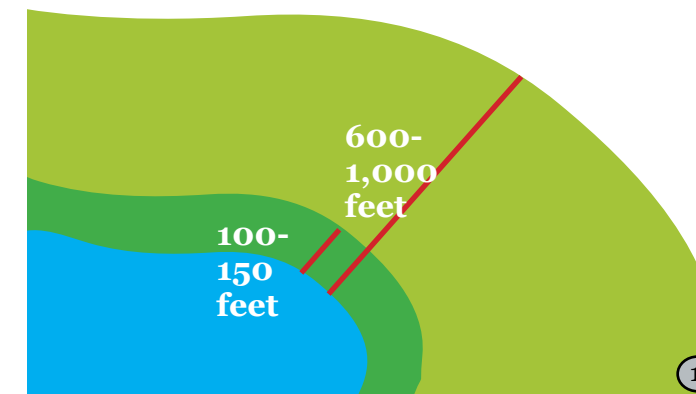
within 1.25 miles of a wetland can have a significant effect on the biodiversity of the respective wetland, and the protection of “herp hot spots” and where essential habitat is present should be included in wetland policies (Findlay and Houlihan 1997). If creating a wetland buffer, plant native species that provide cover, foraging and hunting areas, and a safe breeding habitat for amphibians and reptiles while maintaining interstitial spaces for basking and herpetofauna movement. The establishment of dense vegetation and tall grasses should be avoided.

Design for a diversity of animals –

Creation and restoration must take into

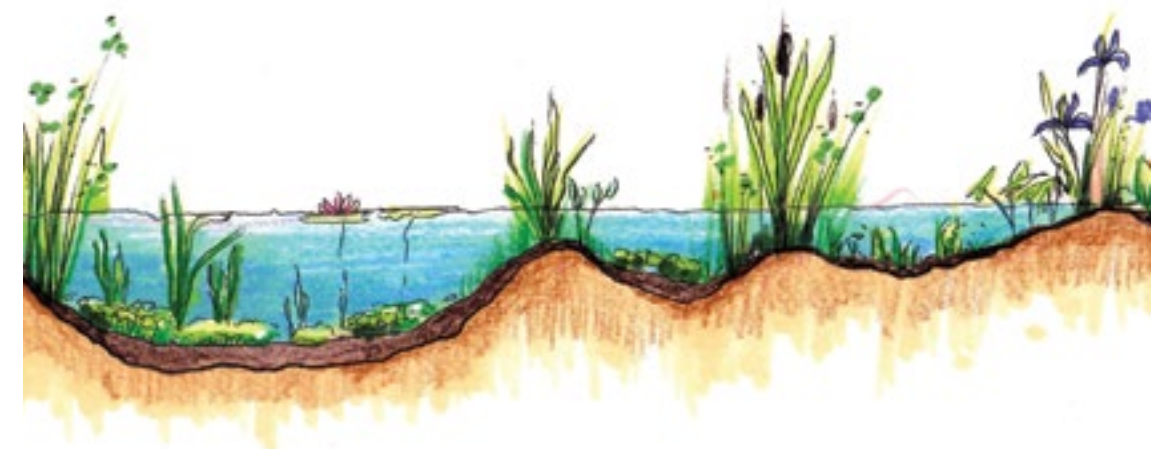
consideration the needs of all wildlife, including herpetofauna, birds, mammals, and macroinvertebrates. A diversity of native plants can contribute to habitat structure for several wildlife species. In general, a design based on herpetofauna and aquatic macroinvertebrates will have ecosystem benefits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

Time construction and earth moving for the warm season – Grading and earthmoving should be conducted during the warm seasons. This is because herpetofauna are more active during the summer months and are therefore more likely to avoid equipment. Rescue and relocation surveys and exclusion fencing can



1. Disturbance within 1.25 miles of a wetland can impact amphibians and reptiles associated with the wetland, although the closest 500-1,000 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.

2. Variable wetland topography provides for a diverse and complex ecosystem and helps support the greatest number of life stages of species.



also be implemented as BMPs during the active season. Conversely, if earthmoving activities are carried out during the cold seasons, herpetofauna hibernating below ground will be at risk of being crushed, and because some overwintering sites are used by many individuals, disturbances could result in a mass-mortality event. 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 wildlife 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 in conducting translocations. 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. **For comprehensive details on wildlife barrier fences, see Section 7: Management Techniques under Wildlife Barrier Fencing as well as Section 8: under Road Crossing Structures.**

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 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 also significantly reduce project costs 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



1. Wetland creation and enhancement should consider the herpetological goals of the site and plan for those species as part of an overall landscape.



1. Woody debris serves as critical habitat for wetland dependant species.

2. Terrestrial root wads and logs provide nesting habitat for lizards, snakes, and salamanders as well as shelter.

3. Wildlife clearance is paramount to reduce unnecessary wildlife mortality on projects.



improve water quality, provide foraging sites, and help increase dissolved oxygen in the water.

Translocate animals from construction areas – Trapping and relocation efforts are important, especially in the 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 – Long-term stewardship and/or monitoring is required as part of wetland mitigation banking or wetland creation as mitigation. Invasive species management, water manipulation, and design adjustment may be necessary to ensure long-term 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 to provide reliable feedback. This feedback cycle helps to improve techniques used for sites with a specific set of conditions and drives





1. Baseline inventories and monitoring are paramount to creating and assessing successful restoration and habitat creation projects. Understanding species composition allows for better understanding of the current function features and those needing aid.

2. Incorporate multiple habitat structures including basking and submerged logs, partially submerged root wads, and stones (including flat pieces for nesting and shelter) help create diverse adaptive landscapes and supports greater community composition.



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. Use of the MI Herp HAT tool is recommended where applicable to the monitoring needs. Data should be submitted to the Michigan Herp Atlas for archiving and use for future conservation and management needs.

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 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.

Shoreline Hardening and Habitat Loss

Shoreline hardening is a practice where natural shorelines are removed and replaced with constructed man-made features to minimize wave action and prevent erosion. Constructed features include seawalls, bulkheads, riprap (rock armoring), and revetments. This transformation fundamentally modifies habitat structure and ecological function. Natural shorelines

1. When feasible incorporate connective corridor between aquatic and terrestrial habitat where seawalls are present. The use of small rocks can increase access for the greatest number of species.



2. Avoid large rocks with gaps as part of restoration. Where necessary integrate egress ramps and shallow sloped areas with VFR to direct species like turtle to use those areas to access upland habitats. Integrating pocket habitats like vegetated swales provide hatchling and juvenile turtles, amphibians and snakes habitat.



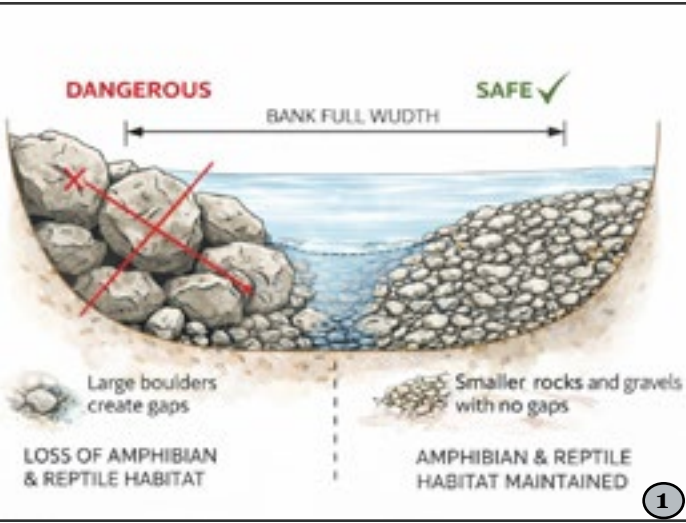
are characterized by gentle, undulating slopes, organic-rich soils, and complex vegetation that support diverse invertebrate communities and facilitate critical biogeochemical processes like organic matter decomposition (Wensink and Tiegs 2016). Natural shorelines contain greater amounts of debris and organic material and support larger invertebrate community composition (Wensink and Tiegs 2016). In contrast, hardened shorelines are typically

steeper, drier, and biologically impoverished, with simplified structure and reduced capacity to support native riparian food webs.

For riverine herpetofauna, shoreline hardening presents three primary threats: loss of critical nesting habitat, creation of movement barriers that prevent access to essential terrestrial areas, and entrapment hazards within loose riprap that can trap small turtles and hatchlings (Kolbe and Janzen 2002; Paterson et al. 2012). **For a comprehensive discussion of these threats, including species-specific impacts and supporting citations, see Section 3: Threats to Amphibians and Reptiles under Shoreline Hardening.**

Project Improvements for Turtle Habitat: Where shoreline hardening is unavoidable, design modifications can partially mitigate impacts. A way to mitigate this is by creating small pockets of natural shoreline within the riprap to allow for increased connectivity between aquatic and terrestrial habitats. If a seawall is present, a gently sloped ramp containing a texturized surface for grip can be installed. Specific measures include:

- Pocket Habitats:** Integrate small, intentional pockets of natural, gently sloped shoreline and suitable nesting substrate within hardened segments.
- Egress Ramps:** Install gently sloped ramps ($\leq 3:1$ slope) with textured surfaces (e.g., grooved concrete, embedded aggregate, coarse geotextile) on seawalls to allow safe passage between aquatic and terrestrial habitats.
- Void-Filled Riprap (VFR):** A specific best



1. Gaps in rock can pose threats to many species of herpetofauna. While snakes and Northern Mudpuppies can utilize such features others are negatively impacted.

2. Butler' Garter Snakes use riprap along rivers and marsh habitats.



practice involves filling the interstitial voids in conventional riprap with well-graded, compactible material (e.g., gravel, sandy soil). This creates a stable, traversable surface for turtles while maintaining erosion control. Native vegetation can also be planted within these crevices to further increase habitat suitability for a wider range of herpetofauna species. VFR can be implemented in strategic, spaced corridors to create safe upland access points. This process does not have to be implemented to the full extent of a riprap revetment, but can be done in small, spaced-out segments that create a path from the water to upland habitat.

Creating small embankments along the sides of the VFR path can further assist in ensuring turtles do not venture off the path. These corridors can be bordered with low-profile stone or log barriers to funnel hatchlings and adults safely to and from the water. At the upland terminus of a VFR corridor, a formal, protected nesting site with southern or southwestern exposure to maximize solar gain can be established and safeguarded with predator-exclusion cages. These nesting areas can also be protected with nest protectors to reduce predation pressure. Not only will the nest protectors protect the developing turtles from predation, but their placement and proximity to the pathway will also act as a funnel that will direct hatchlings to enter the water through the VFR pathway and not accidentally wander into the riprap, where they may become trapped in the gaps. Low profile path barriers made from stones or branches can also serve to reduce meandering and direct them to aquatic habitats safely.

Riprap Management and Habitat Enhancement

Riprap and other hardened shoreline structures present a unique management challenge, as they pose significant threats to turtles while simultaneously providing critical surrogate habitat for several snake species. The management goal should maintain a balanced approach that retains or enhances the value of riprap for snakes while eliminating its entrapment hazard for turtles. **For a comprehensive discussion of these threats, including species-specific impacts, see Section 3: Threats to Amphibians and Reptiles under Shoreline Hardening.**

Ecological Value for Snakes

Riprap functions as a surrogate for natural historic shorelines, which once included limestone shelves with fractures that provided natural gaps for refugia and egg deposition. These



1. 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.

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.



natural rocky habitats are now largely lost across the landscape, making existing riprap a critical habitat alternative for species such as the Eastern Fox Snake, Butler's Garter Snake, and Northern Water Snake. Riprap offers these species thermoregulatory basking sites, refuge from predators, and egg-laying opportunities (Harding and Mifsud 2017). Telemetry studies have documented Eastern Fox Snakes selecting riprap habitat over 80% of the time when available, underscoring its conservation value (Kucher and Seldon 2009).

Streambank Stabilization and Erosion Control

In agricultural, forested, and urban settings where erosion threatens riparian integrity, stabilization is necessary. The chosen method must reconcile erosion control with ecological function for herpetofauna.

Natural Stabilization Methods:

•**Gully Erosion Control:** In agricultural landscapes where erosion is problematic, stabilization of active gullies is necessary and can be accomplished by reducing water velocity, trapping sediment, and encouraging vegetation growth through the use of gully erosion control structures like drop pipes. These can be built by constructing an earthen dam across a gully and embedding an L-shaped drop pipe within the dam to move water from the field level to the level of an adjacent stream. The installation of these drop pipes was incidentally found to help improve and replace gullied areas with riparian habitat. The creation of riparian habitat from previously eroded areas can help land managers to enhance the landscape and provide areas for herpetofauna colonization (Smiley et al. 2009).

•**Large Woody Debris (LWD):** Large woody debris can be used in a variety of contexts depending on the project. Factors like stream size, channel stability, flow, depth, and availability of already occurring LWD can determine how to best utilize natural methods to achieve management goals. Strategically placing logs, root wads, and log jams can mimic natural river processes. LWD reduces flow velocity, traps sediment, promotes pool formation, and creates basking structures, cover, and complex foraging habitats for amphibians, turtles, and aquatic snakes (Marrow and Fischenich 2000). LWD can be used to create natural features like pools, reproductive and hibernacula habitat,





1. Use of live staking as part of shoreline restoration is an effective tool to reduce erosion and increase habitat structure. This should be conducted as part of a holistic approach to help provide access to shoreline from low and moderate mobility species. If too dense and spans long distances species like turtle can not access upland habitats.

streambanks across the project while creating critical habitat.

•**Live Staking and Bioengineering:** Live staking can also be incorporated as part of a stabilization plan. This process involves planting live woody hydrophytic vegetation stakes, typically of Willow (*Salix spp.*) and Dogwood (*Cornus spp.*), into the soil along a river where they will eventually sprout and spread roots to further stabilize the banks. Live staking can also be implemented in combination with other organic erosion control methods such as fascines or brush mattresses to promote rapid root growth that binds the soil. This “soft engineering” stabilizes banks while regenerating native riparian vegetation, improving habitat complexity, and enhancing insect prey bases (Polster 2021). It is imperative that connectivity between aquatic and terrestrial habitat be maintained when vegetation becomes too dense along the bank. This can be achieved by establishing groomed pathways that provide a clear route from the water onto the bank.

•**Streamside Management Zones (SMZs):** Streamside management zones, also known as riparian buffer zones, are another commonly used method to reduce erosion in riparian habitats that are prone to experiencing disturbances like timber harvests. Maintaining vegetated buffers of native grasses, shrubs, and trees along watercourses is a fundamental practice in forestry and agriculture. These SMZs are like filter strips seen in agricultural settings, which are constructed to naturally collect and prevent soil material from negatively impacting water quality. SMZs filter runoff, stabilize soils, moderate water temperature, and provide essential terrestrial habitat, cover, and dispersal corridors for herpetofauna. These SMZs can also provide sanctuary for herpetofauna species which can improve the diversity and complexity of local herpetofauna communities (Foley 1994). Wider, structurally complex SMZs support greater herpetofauna diversity and abundance (Foley 1994; Semlitsch and Bodie 2003). For species like Wood Turtles and Eastern Box Turtles, maintaining open canopy areas within the riparian zone for foraging and nesting is critical. While

cover, and foraging opportunities while also providing necessary erosion control (Fischenich and Morrow 2000). Designs must ensure that LWD placements do not create impassable barriers; ensure structures are spatially arranged to maintain gaps or ramps for turtle passage to uplands. This method of restoration was recently utilized in southwestern Michigan with a river re-wilding construction project funded and completed by the Pokagon Band of Potawatomi Indians in Cass County. Within their construction planning, the group utilized natural streambank stabilization methods such as live staking and burying LWD beneath the constructed banks with the root systems facing the river’s flow (Pokagon Band of Potawatomi Indians 2021). Alternating layers of LWD allowed for the construction of naturally stabilizing

1. Monofilament soil erosion material can trap turtles that have nested prior to installation resulting in entrapment and death.

Lauren Schirtzner



to avoid erosion or damage to the landscape. Management should aim for a mosaic of conditions within the SMZ, balancing shade with necessary solar exposure.

Hazardous Materials and Urban Challenges:

•**Erosion Control Netting:** As previously discussed, care must be taken when using artificial means to control erosion. Commercially available erosion control mesh netting is often used to maintain water quality, especially in construction settings. While often the easiest to install and marketed as photodegradable, this material can have detrimental impacts on local herpetofauna. Photodegradable or biodegradable plastic mesh netting, commonly used on construction sites and newly seeded slopes, poses a severe and often overlooked threat. Snake species are the most affected since they can easily become entangled in the material and suffer severe injuries or die from overheating, desiccation, and predation (Walley et al. 2005). Depending on timing of placement, these products can also entrap hatchling turtles resulting in desiccation and death.

•**Best Practice:** Avoid plastic netting entirely in known herpetofauna habitat. Use alternative soil stabilization methods such as tackifiers, coconut fiber (coir) blankets, or dense native seeding without mesh.

•**Urban Riverine Restoration:** Urban riverine restoration of eroded riparian zones presents a unique challenge to managers. This is due in part to impervious surfaces and flashiness coupled with increased velocity. Urban streams suffer from hydrologic flashiness due to impervious surfaces, leading to severe bank erosion, especially if floodplain connectivity is not present. Increasing floodplain connectivity in an

2. UV degrading plastic soil stabilization mesh is dangerous for herpetofauna as well as birds and should not be used on any restoration or other projects where wildlife may be present.

Lauren Schirtzner



Lauren Schirtzner



1. Species including the Queen Snake benefit from installing a variety of habitat features during stream restoration. Materials typically removed during a project such as logs or large rocks can be utilized for basking or cover. Reusing these materials can also reduce the cost of a project, sometimes significantly.

entrenched system can not only help to reduce the energy that may be causing bank erosion but can also improve herpetofauna access to the riparian zone. When considering stabilization and restoration of these habitats, it has been found that increasing the structural complexity of vegetation within the riparian zone and adding woody debris to the site can assist in stabilizing the soil (Banville and Bateman 2012). Increasing riparian vegetation structural complexity and strategic placement of Large Woody Debris are effective for stabilizing banks and improving habitat (Banville and Bateman 2012). This not only prevents erosion but also helps

improve the surrounding habitat and site conditions for herpetofauna. In high-energy locations where some armoring is unavoidable, the VFR technique described above should be the standard, as it combines structural integrity with ecological connectivity.

In both examples, consideration must also be given to the ability of these materials to allow for herpetofauna like turtles to navigate them to access upland habitats including nesting sites. Frequently, the desire to fortify and secure the shoreline comes at the expense of accessing habitat. Depending on the landscape and river type, this can also reduce the movement of sediments. This can prove to be detrimental since the downstream deposition of sediments like sand is critical for the creation of nesting areas for species like Wood Turtles.

Stream Restoration Design Elements

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 be excavated to the side of a river channel to provide additional areas to facilitate breeding, nesting, feeding, hibernation, and basking.

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 on 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 and other riverine

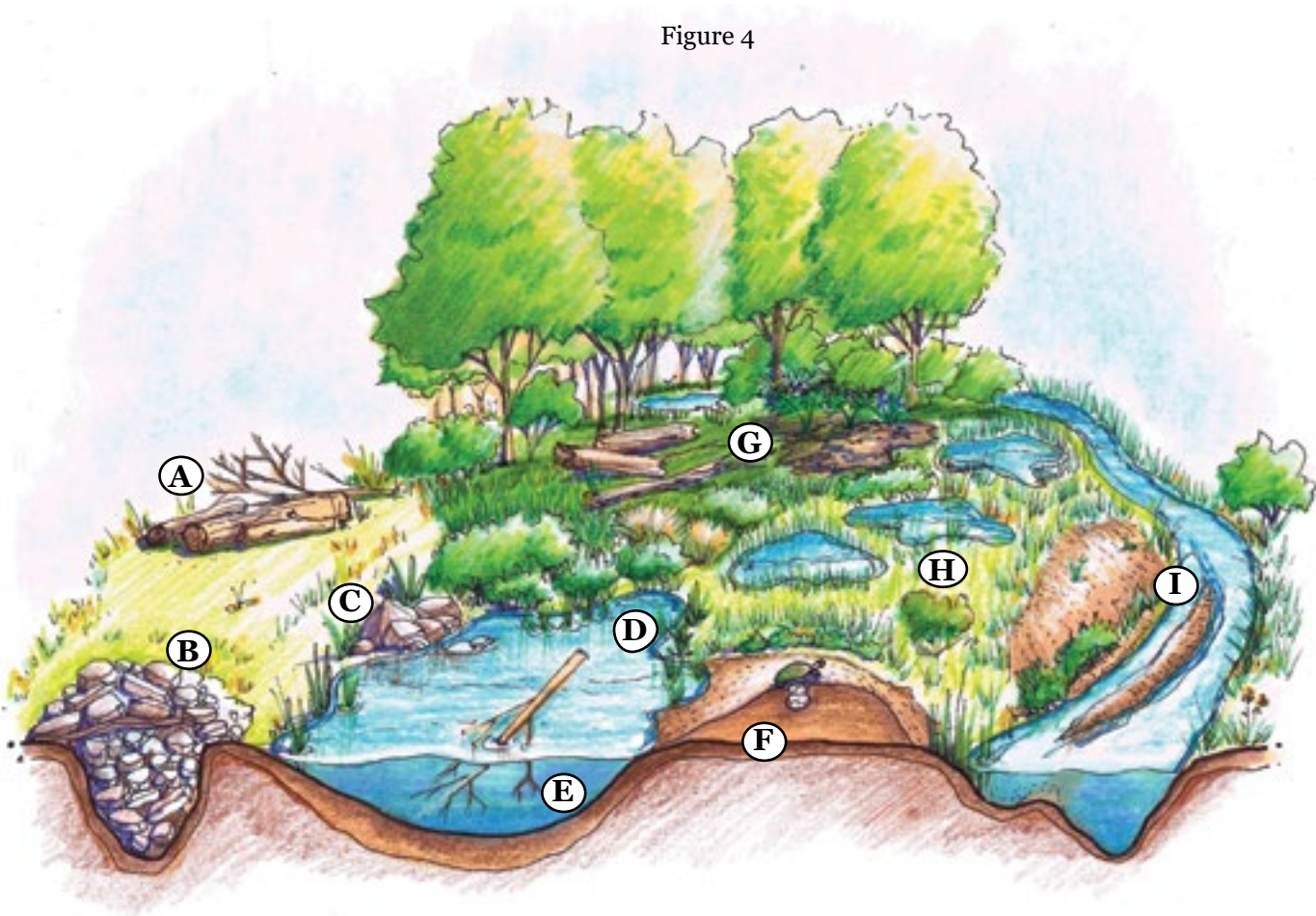


Figure 4

Figure 4. 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).





1. This open-bottom arch culvert allows species like the Wood Turtle to follow stream corridors safely while reducing the risk of road mortality. For an additional illustration of this structure, see Figure 15 in development techniques.

Figure 5. Sandy, sparsely vegetated banks along a river provide turtle nesting habitat (A and B).

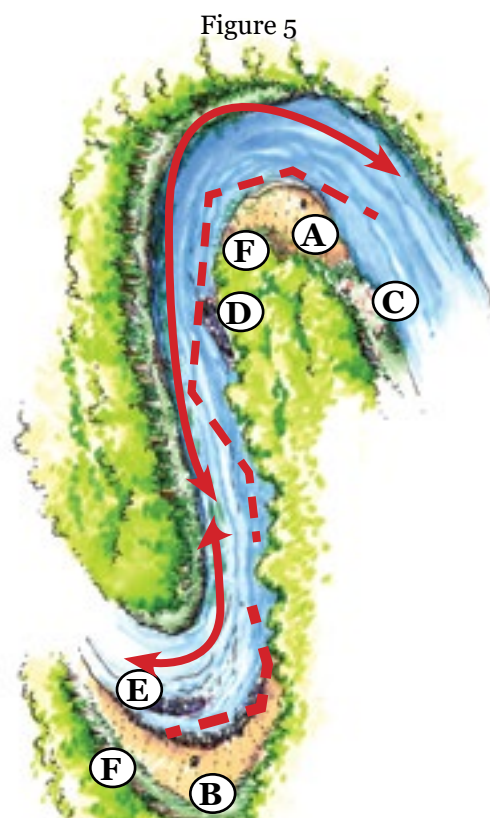
Cutbanks which are prone to erosion (A) can be protected while maintaining access for turtle nesting. Rocks in the channel deflect stream velocity (C) and the toe of the slope is stabilized by small rocks filled-in with gravel or sand (D).

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.

Depending on the species' use of 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. 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.

Wildlife Passages and Culvert Design



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 installing 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 floodplain area can be created along the sides by placing rocks. It is important that when culverts larger than bankfull are installed, stable banks are constructed within the culvert that will not become mobilized (i.e., eroded, displaced, or washed downstream during high-flow events). 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 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. Alternative options, in order of preference, include 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 the movement of a greater number of amphibians, reptiles, and other wildlife. Wing walls or barrier fences leading to both openings of crossing structures can direct wildlife through the passage and prevent them from crossing roads. Consult a professional herpetologist or wildlife biologist to provide conditions the target species will need. **For a comprehensive discussion on implementing crossing structures that best accommodate amphibian and reptile movement, see Section 8: Road Crossing Structures.**

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, set at the same slope as the streambed measured from a riffle upstream and downstream 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 subsequently 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 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

1. To improve stream crossing function and reduce road related mortality, prioritize structures that optimize hydrologic and ecological connectivity.





1. Preserving or restoring natural stream morphology and sinuosity can increase the overall habitat function by providing greater microenvironments to support a greater community composition and system function.

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

Wildlife Passages

When designing wildlife passages, consideration must include the target species’ natural history and type of mobility. These include low mobility, moderate mobility, high mobility, and high openness herpetofauna-species that thrive in, prefer, or are specialized for habitats with low canopy cover, minimal vertical obstruction, and high light penetration, such as grasslands, savannas, or cleared areas. Each group has certain best management techniques for use and design that vary from substrate, the dimensions of the passage, lighting, and how far apart they should be spaced. Designs that include open bottom bridges, culverts, shelves, and fencing function for different wildlife guilds and vary in size and placement; therefore, these different designs should be used in conjunction with one another. Generally, herpetofauna tend to be categorized within the low and moderate mobility categories (Berdweg et al. 2019; Flego et al 2025; Younquist and Boone 2014).

Constructed passages that are placed near high traffic locations help to drastically reduce road mortality. In Vermont, wildlife underpasses resulted in an 80%

Figure 6. Dams typically bisect and fragment landscapes and alter community composition and connectivity disrupting genetic flow. Measure can be taken proactive and retroactively to mitigate these impacts.

A. Creating a natural tributary bypass allows for passive movement around the dam and can result in the creation of critical habitat for rare species like Pickerel Frogs Blanding’s Turtles, and Eastern Massasauga Rattlesnakes.

B. Bypass systems have been created that provide riverine herpetofauna the ability to move between dam segments. These incorporate natural materials including stones and logs for structure. Species like the Northern Mudpuppy and Wood Turtle can benefit from this design.

C. More traditional systems can be converted and elongated to account for Eastern Snapping Turtles and Northern Water Snakes which could use these structures.

reduction in amphibian mortality, with non-arboreal amphibian mortality decreasing by 94% (Marcelino et al. 2025).

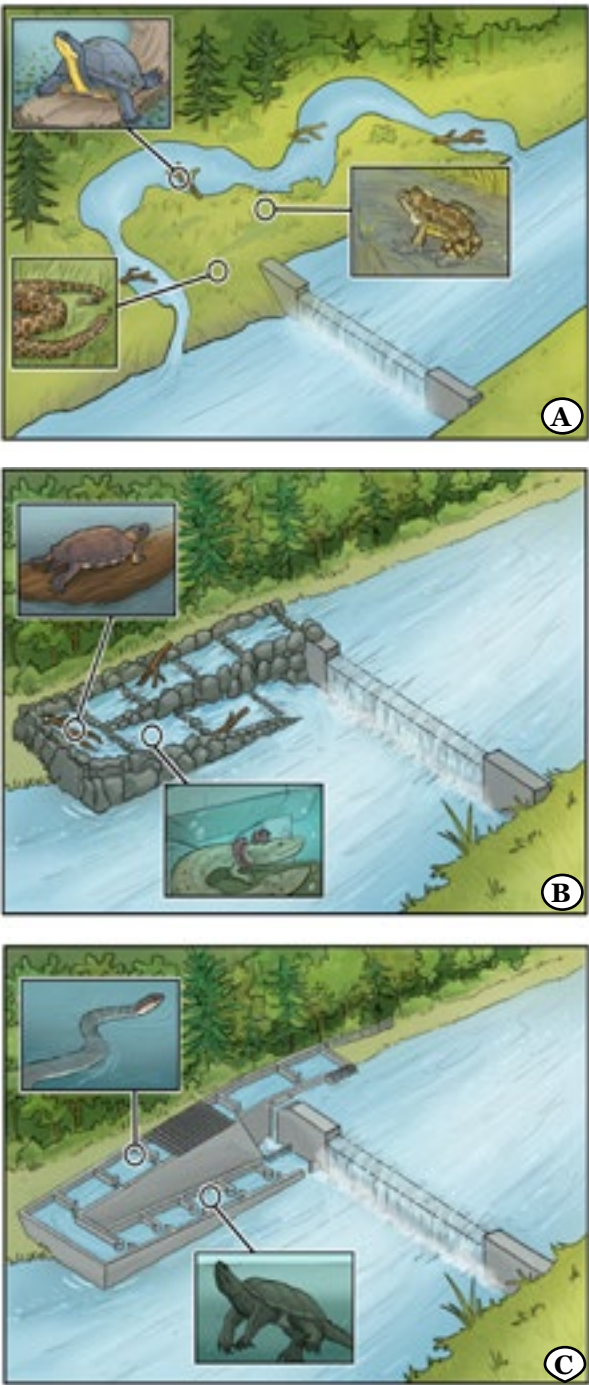
Dam Bypasses and Fish Ladders

Dam bypasses, commonly referred to as fish ladders, are structures designed to restore aquatic connectivity by allowing passage around barriers such as dams. While these structures are primarily engineered for fish, observations have demonstrated that amphibians and reptiles can also utilize them. For instance, a Northern Water Snake has been documented ascending an eel ladder to bypass a dam (Welsh and Loughman 2015). Such findings highlight the potential for adapting existing passage designs to benefit herpetofauna, including species like the Northern Mudpuppy. Targeted modeling and testing are recommended to develop effective passage solutions that reconnect populations fragmented by dams. **For detailed design specifications, engineering considerations, and additional best management practices related to dam bypasses and fish ladders, see Section 8: Development Techniques under Dam Bypasses and Fish Ladders.**

Turtle-Specific Passages

Innovative wildlife passage systems designed specifically for riverine turtles have been developed internationally, including a structure in Queensland, Australia, that provides upstream and downstream passage for endangered turtle species (Pratt et al. 2025). These designs incorporate textured ramps, resting pools, and shaded areas to facilitate movement and reduce thermal stress. While such structures may require modification to accommodate Michigan’s turtle species, they offer a promising model for mitigating barrier effects on imperiled populations.

Figure 6





For comprehensive guidance on design, slope requirements, and implementation strategies for turtle-specific passages, consult Section 8: Development Techniques under Turtle-Specific Passages.

Shoreline Access Ramps

Steep shorelines can limit access to critical nesting habitat for turtles, including Painted Turtles, Musk Turtles, and Northern Map Turtles. The installation of textured ramps with slopes not exceeding 40 degrees can provide safe passage from the water to upland nesting areas (Scott et al. 2023).



For additional information on ramp construction, materials, and placement, see Section 8: Development Techniques under Shoreline Access Ramps.

Wetland Mitigation and Banks

Wetland mitigation banks are large-scale (10-300 acres, though some are much larger) restored or created wetland areas used to compensate for permitted impacts to other wetlands. These landscape level habitat replacements can provide ecologically significant benefits by using a consolidated approach compared to the often small, fragmented, or poorly performing wetland mitigation projects. These larger, more sustainable, and functional ecosystems provide a greater overall functional value when designed and constructed in a holistic and ecologically minded approach. Wetland banks can improve water quality, provide critical habitats for biodiversity, facilitate flood control, and support carbon sequestration, resulting in higher quality, better-managed habitats compared to small, isolated mitigation projects. Care must be given to replicate all hydrologic cycles and habitat needs for

1-3. Variable stone size can affect the extent of shoreline use where wave abatement and erosion control measures are incorporated. Depending on the materials, turtles can use all or a portion of the shoreline habitat. In some cases with large stones, turtles can get injured on the rock or succumb to dessication if they fall between them.



1. Submerged logs can be a simple and essential landscape feature for aquatic herpetofauna such as Northern Mudpuppies or Northern Map Turtles. They serve as refugia, nesting sites, and foraging grounds.

2. Sand can be used in restoration sites to create nesting areas. Knowing what species occur locally will help guide type of substrate selection.



the greatest species richness and community composition. Designing systems to target a singular hydrological regime can negatively impact the overall value of a site and is ecologically limiting.

Design Considerations for Herpetofauna:

Wetland banks often have a variety of habitat structures as part of their design, including root wads, basking logs, brush piles, and occasionally a turtle nesting area (sand piles). Historically, many mitigation sites were designed to provide largely open water habitats. More modern designs in Michigan have shifted largely to incorporate hydrologic regimes that are designed to dry seasonally. While some locations have more gentle slopes surrounding the site, several can have steep banks to optimize the usable area for wetland acreage. The most effective and desirable mitigation banks are those that provide a habitat mosaic, including variable topography with a gradual, gentle gradient (1:5 or greater) that transition into deeper, more permanent wetlands. An open water system encourages fish colonization and reduces the community composition for several species, while seasonally inundated systems provide little value to most turtle species and several amphibian species that require a longer period of hydrology for development and as part of their natural history. Such species include Bullfrogs, Green Frogs, Tiger Salamanders, and Eastern Newts. Ideal mitigation banks provide the greatest ecological habitat complexity with areas supporting permanent water and portions that are only seasonally inundated.

Habitat structures such as basking logs are often undersized or limited in number compared to the potential density a site can support, making them a limiting resource. Logs should also be placed along shorelines to provide shelter and refugia for herpetofauna. Small multibranched tree segments should be incorporated to provide amphibian egg adhesion sites during nesting. Turtle nesting areas should be placed only on southern and southwestern exposures to optimize solar gain and to increase nesting site thermal mass during the incubation period.



Monitoring and Assessment:

Traditional monitoring efforts often exclude herpetofauna. When such species are recorded, reports typically note observations of frogs, snakes, or other taxa in general terms, but lack detailed accounts of species, age class, and spatial data. These elements are neither consistently included or required.

As part of monitoring mitigation sites, whether at the bank or individual site level, the amphibian and reptile community should be considered equally important as botanical richness. These areas present ideal opportunities to incorporate the Herp HAT as a standardized assessment tool.



Timelines and Conservation Considerations:

In general, wetland mitigation banks can provide similar functional value to natural wetlands. In some cases, they have increased value when compared to isolated wetlands. The timeline for replacement value and community composition varies, especially for forested wetlands and vernal pools. In general, the time for a replacement forested wetland to be viable for herpetofauna is measured in decades and not feasibly studied in the limited 5 years of monitoring. Preservation should be a priority consideration for such landscapes over mitigation. When vernal pools and forested wetlands are destroyed, these sites should be strongly considered for wildlife clearance and relocation where feasible. Cost can also be a factor, often exceeding \$100,000 per acre to purchase mitigation credits. For sites like forested wetlands (including vernal pools) or difficult to replace systems like fens and wet meadows, preservation should be strongly considered over mitigation, even if outside of the watershed, to preserve these habitats where feasible and warranted.



1-3. Inventory and monitoring should focus both on rare species as well as our more abundant generalist species. Northern Ribbon Snakes, Northern Spring Peepers, and Painted Turtles are some of the foundational species within ecosystems and they protection is essential for continued habitat function and integrity.



Habitat Design

Wildlife habitat is comprised of everything that contributes to the presence or abundance of wildlife (Cooperrider et al. 1986; Hall et al. 1997). This means that flora, fauna, 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,

1. Creation of hibernacula can incorporate already available on site materials or inexpensive items. These structures can often be colonized within days of completion even in the active season as seasonal refugia. Within the Detroit River, Eastern Fox Snakes actively seek these structures out on multiple islands where this restoration measure has been incorporated.

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 the restoration of large-scale landscape processes. 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 also helping construction and management plans move through regulatory approval. General amphibian and reptile habitat design considerations are listed below and contain details pertaining to the creation of habitat structures that benefit specific groups of herpetofauna.

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 (Porej et al. 2004; Attum et al. 2008; Attum et al. 2009; Harding and Mifsud 2017). 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. Maintaining clusters of pools that support a variety of hydroperiods help to support vernal-pool dependent amphibian populations (Nagel et al. 2021). Larger pools within

1. Materials such as this pile of limestone left over from another project has become a regionally significant landscape feature providing Eastern Fox Snakes, Eastern Garter Snakes, Butler's Garter Snakes, Northern Brown Snakes, Northern Red-bellied Snakes, and Eastern American Toads critical habitat. Removal or presumption this has no value can significantly impact local species and threatened population viability.

a wetland will make the system less vulnerable to drying and when combined with small pools that form in these microtopographic depressions. These provide sources of water over a larger portion of the landscape and allows for better accessibility for herpetofauna. The irregular topography also enables a greater variety of community types and facilitates 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 at a cost, may be reused to create hibernacula, refuges, basking sites, or nesting sites. The money is saved when removal costs are eliminated and materials do not have to be purchased to create habitat features. Care should be taken to reduce the amount of crushed concrete material that enters aquatic systems since pH can increase from concrete leachates (Van Dam et al. 2011).

Create habitat for prey species – Providing habitat for the food source of 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 prey for each target species should be identified and checked for included in restoration plans. This can be especially important for species, such as Queen Snakes, which have a specialized food source, feeding almost exclusively on crayfish (Wood 1949; Harding and Mifsud 2017). In this case, meeting the habitat requirements to maintain a healthy population of crayfish is necessary to ensure a food source for Queen Snakes.

1. Nesting areas should be maintained to reduce the growth of vegetation. Places like farm fields serve as sinks for turtle nesting. The loose soil and limited early season vegetation attack turtle to nest in them. Creating dedicated nesting areas with elevation will entice turtles to nest in those areas, though care should be take to avoid heavy predation from raccoons in a limited area. Protecting nests from predators will increase nest and hatchling success.

Agricultural Habitat Mitigation

In Michigan, agricultural landscapes represent a significant land use type , and their interaction with herpetofauna is complex. Agriculture is a source of habitat loss and chemical contamination, however, agricultural lands themselves, when managed holistically with considerations to wildlife, they can provide valuable habitats for amphibians and reptiles. Implementing mitigation strategies within agricultural operations can reduce impacts on herpetofauna while maintaining productive farmlands.



Mitigation Strategies for Chemical Use in Agricultural Landscapes

To mitigate concerns associated with chemical use in agricultural landscapes, several strategies can be employed. Application of pesticides should be conducted in accordance with consideration of species movements in spring and fall. The migration of herpetofauna from their overwintering habitats back into agricultural areas in the spring increases the risk of contamination to herpetofauna species. This risk increases again in the fall when species return to their overwintering habitats. While not every herbicide may be toxic, considerations must be in place. The toxicity can vary depending on the LC50 of any specific pesticide and the life stage of the herp in question (Fryday and Thompson 2012). **Aligning pesticide application schedules with herpetofauna phenology is a critical mitigation step.**

•**Application Timing:** Aligning pesticide application schedules with herpetofauna phenology is a critical mitigation step. Avoid spraying during peak spring and fall migration periods, as well as during amphibian breeding seasons, to drastically reduce direct exposure (Lenhardt et al. 2015).

•**Buffer Zones and Drift Reduction:** Increasing no-spray buffer zones around aquatic habitats and field margins, and using low-drift application technologies (e.g., shielded sprayers), can minimize chemical ingress into critical refugia (Reichenberger et al. 2007).

•**Adoption of Integrated Pest Management (IPM):** A variety of alternatives to pesticide applications exist, such as integrated pest management (IPM) strategies. IPM involves the facilitation of natural predators of certain pests to reduce the impact of their damage to agricultural systems. IPM strategies reduce reliance on



1. Pesticides used adjacent to wetlands or where run-off enters wetlands can have deleterious effects on amphibian communities. The absence of amphibians in otherwise suitable aquatic habitat can be linked to runoff and products applied to agricultural landscapes.



broad-spectrum chemicals by incorporating biological control, crop rotation, and pest monitoring. Examples of an IPM would be the installation of bird houses in fields, encouraging the nesting of raptors in hedgerows, or releasing native beetles to eat invasive plants. The use of herpetofauna in an IPM system is an underexplored option for producers. Encouraging herpetofauna as part of an agro-ecosystem is a promising, under examined component of IPM.

Amphibians and reptiles are

prodigious consumers of agricultural pests; a single adult frog or toad can consume thousands of invertebrates per season. The integration of herpetofauna can help save billions in farming losses as amphibians can consume millions of pests in a growing season that may otherwise give unnecessary pressure to crops. Actively managing field margins to support herpetofauna populations can provide a sustainable, natural pest control service, helping to mitigate losses caused by common agricultural pests (Amphibian Conservation Action Plan a Status Review and Roadmap for Global Amphibian Conservation IUCN SSC Amphibian Specialist Group, n.d; Smalling et al. 2021; Wanger et al. 2010).

Operational Modifications to Reduce Impacts

Agricultural operations can pose direct physical threats to herpetofauna through the use of machinery. Mowing, tilling, harvesting, and other mechanical operations can cause direct mortality to amphibians and reptiles, with snakes, frogs, toads, and turtles being particularly vulnerable due to their low profile and use of agricultural fields for foraging, basking, or nesting (Saumure et al. 2007; Humbert et al. 2009). Additionally, soil compaction from heavy machinery can cause direct mortality to individuals burrowing or hibernating below the surface (Bol 2007). **For a detailed discussion of these threats, see Section 3: Threats to Amphibians and Reptiles.**

The following mitigation strategies can be adopted by farmers to significantly reduce machine-related mortality in



2. Turtles and other herpetofauna can be harmed or killed by direct contact with agricultural equipment. Burrowed turtles can be killed via disking and animals can be run over by equipment especially in mid-summer during turtle nesting. Here a female Blanding's Turtle was run over by a tractor while seeking a nesting site. This loss of genetic material and of an adult female can significantly impact a populations viability.

1. Nesting areas should be maintained to reduce the growth of vegetation. Accessibility can also be a factor. Consider the size and proximity to the ground of turtles when restoring or enhancing landscapes to facilitate their ease of movement. Do not mow nesting areas after mid-may in Michigan to prevent the risk of harm to turtles until after the nesting season conclude typically in early July.

agricultural landscapes. Turtle movements are driven by periods of high river or stream flow and high temperatures, which can also cause turtles to disperse into areas undergoing active farming operations. To resolve this issue, farmers can consider adjusting the timing of their practices to account for periods of peak turtle movement.

•Seasonal Timing Adjustments: Delaying the first cutting of hayfields until after peak turtle nesting and hatchling emergence (e.g.,

mid-July or later in northern states) can dramatically improve survival. Similarly, adjusting tillage schedules to avoid periods of high surface activity (e.g., warm, humid nights for amphibian migrations) is beneficial (Bentrup and Shi 2025).

•Modified Mowing Practices: When mowing is necessary in potential habitat, employing flushing bars (conservation devices mounted to the front of tractors during haying or mowing to protect wildlife) on equipment, raising the cutting heights, and mowing from the field center outward can allow animals to escape. The use of a sickle bar mower can also reduce suction and increase the likelihood of herpetofauna survival.

•Habitat Management for Safe Nesting: Providing and maintaining designated, protected nesting habitats (e.g., gravel beds or sandy plots in uncultivated field margins) can attract nesting turtles away from dangerous cultivated areas (Paterson et al. 2012).

•Monitoring and Avoidance: Being aware of local herpetofauna activity, particularly during periods of high temperature or following flood events that may displace animals into fields, allows for temporary avoidance of specific field sections during sensitive operations.



Backyard Habitat

Figure 7. Thanks to their ability to withstand below freezing temperatures, Wood Frogs can overwinter on the soil surface.

A. Eastern Newt Eft.

B. Northern Leopard Frog along ponds edge.

C. Gray Treefrog feeding at porch light.

D. Treefrog condo habitat.

E Toad house with toad present along pond edge.

F. Juvenile Green Frog on water lily.

G. Spotted Salamander deposition eggs.

H. Adult male Eastern Newt in breeding condition and second year larval Tiger Salamanders living in the created pond.

I. Juvenile Midland Painted Turtle foraging in pond.

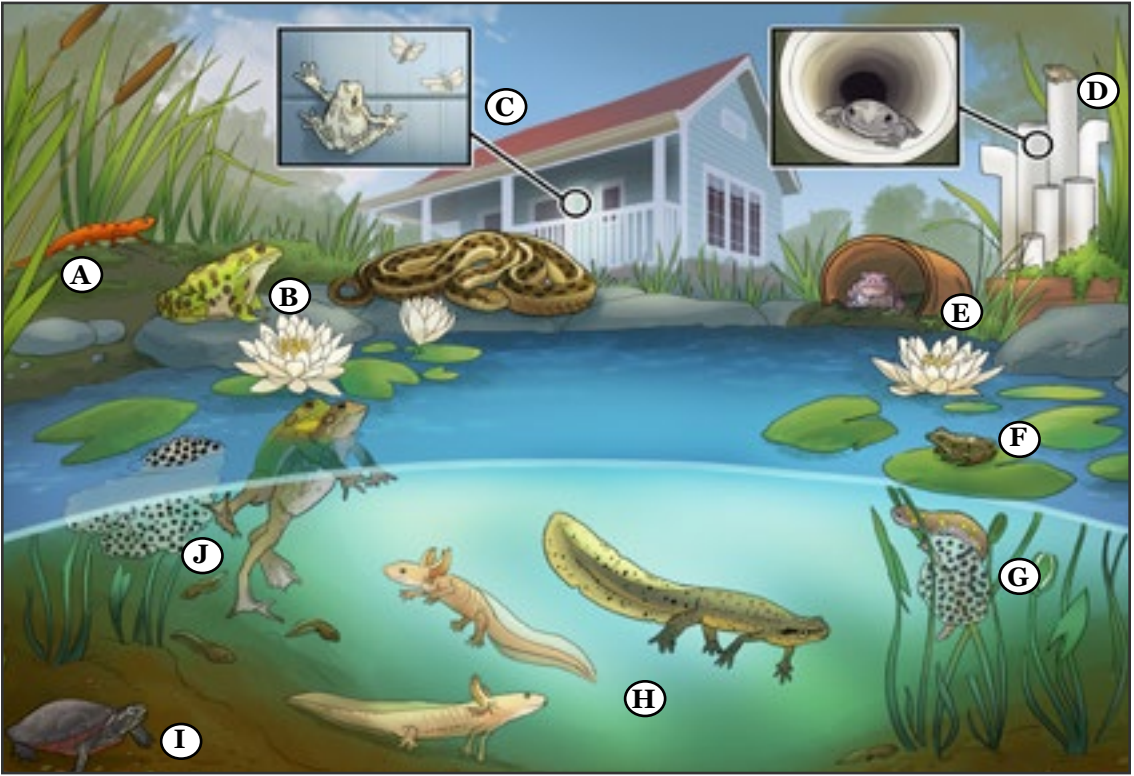
J. Adult pair of Green Frogs breeding and nesting in pond.

The management and stewardship of herpetofauna populations is not solely the responsibility of natural resource professionals; private landowners and community members also play a critical role in species persistence. Anyone can take actions that support the continued persistence of herpetofauna on the landscape with just a few simple backyard modifications. Cumulative small-scale habitat improvements across residential landscapes can create essential refuge, breeding, and foraging habitat, effectively forming a network of micro-reserves that counter habitat fragmentation (Bradley and Altizer 2007; Scheffers and Paszkowski 2011). Simple, intentional modifications to yard management can significantly enhance local biodiversity and support the recruitment of amphibian and reptile populations.

The Role of Private Landowners in Herpetofauna Conservation

Private landowners hold significant potential to contribute to herpetofauna conservation through habitat stewardship within their own properties. Residential yards, gardens, and undeveloped portions of private land can serve as valuable habitat components, particularly in landscapes where natural areas have been diminished. By adopting wildlife-friendly practices, landowners can create refuge sites, enhance connectivity between remaining natural areas, and support local populations of amphibians and reptiles.

Figure 7



Core Habitat Features for Backyard Implementation

Aquatic Habitat: Backyard Ponds

Ecologically functional herpetofauna habitat can be easily created by the implementation of a variety of critical habitat features. An example of such a feature would be the addition of a backyard pond, which can greatly aid species colonization and improve localized recruitment. The creation of a backyard pond is one of the most impactful actions for supporting herpetofauna at the local level. These artificial wetlands serve as colonization hubs, breeding sites, and aquatic refugia, particularly in urban and suburban matrices where natural wetlands are scarce. Creation and enhancement of habitat, including backyard ponds, have the potential to also restore species to parts of their historic range that lacked suitable habitat (Baker and Halliday 1999; Chovanec 1994; Pechmann et al. 2001). Research indicates that constructed ponds can restore localized amphibian communities and function as stepping-stone habitats that support metapopulation connectivity and potentially support range expansions (Baker and Halliday 1999; Brand and Snodgrass 2010; Chovanec 1994).

Design Considerations: The materials and techniques for pond construction vary. It is the resulting creation of aquatic refugia and potential spawning sites for herpetofauna that is significant. In order to preserve existing habitat and prevent harmful effects, ponds should only be created in non-wetland areas and isolated from streams. In order to preserve existing habitat and prevent harmful effects, ponds should only be created in non-wetland areas and isolated from streams. For optimal herpetofauna use, ponds should have:

- Variable Depth:** Include shallow, gently sloping edges (beach areas) for easy entry and exit, and deeper zones (≥ 24 inches) for overwintering.
- Complex Structure:** Incorporate native emergent (e.g., sedges, rushes) and submerged vegetation (e.g., elodea), as well as logs and rock piles to provide cover and basking structures.

1-2. Logs along the edge of the forest can serve as important habitat for a variety of herpetofauna including Eastern Milk Snakes (2).



•**Fish-Free Environment:** To maximize amphibian breeding success, ponds should be designed to exclude predatory fish (Knapp et al. 2007; Hamer and McDonnell 2008).

Supplemental Artificial Habitat Features

In addition to aquatic features, private landowners can incorporate a variety of terrestrial habitat enhancements that provide critical refuge, thermoregulatory opportunities, and foraging grounds for herpetofauna. Supplemental artificial habitat features, such as artificial cover objects (ACOs), can also be incorporated to provide additional cover. ACOs are purpose-placed materials that provide shelter and thermoregulation sites, facilitate monitoring, and enhance, habitat value. The following are simple examples of easily implemented habitat feature that can be created from backyard and household items. When utilizing ACOs, it is important to consider species-specific microclimate and thermoregulatory requirements.

•**Brush and Rock Piles:** Creating piles of branches, logs, and rocks in sunny locations provides shelter, basking sites, and hibernacula for snakes, lizards, salamanders, and small mammals that serve as prey. These features are particularly valuable in yards lacking natural ground cover.

•**Leaf Litter Retention:** Allowing leaves to accumulate in garden beds and beneath trees creates essential microhabitat for fossorial salamanders, toads, insects, and other invertebrates. Leaf litter helps maintain soil moisture, moderates’ temperature, and supports the foundation of the food web.

•**Native Plantings and No-Mow Zones:** Replacing areas of maintained lawn with native grasses, wildflowers, and shrubs provides cover, supports insect prey populations, and reduces disturbance from mowing. Native plant communities are better adapted to local conditions and support higher arthropod diversity compared to non-native ornamental plants (Tallamy 2009). Designating unmown areas of refugia within backyards can create safe havens for amphibians and reptiles during routine maintenance activities and serve as corridors for dispersal.

•**Snake ACOs:** Pieces of corrugated sheet metal, plywood boards, or rubber mats placed on the ground in sunny areas can attract snakes for basking and shelter. Studies show that ACOs can significantly increase detectability and local occupancy of species like Garter Snakes and Eastern Massasauga Rattlesnakes (Liberman et al. 2024; Ochs et al. 2024). However, this type of cover can be less effective for other herpetofauna such as toads and frogs.

•**Terrestrial Amphibian ACOs:** “Toad-a-tats” are an

easy method for creating functional toad and frog hides that can be made by making a hole in the bottom of a terra-cotta planter pot and then flipping it upside down so that the top lip is flush with the ground (Wild Ones 2024b). These inverted, buried terra-cotta pots provide cool, moist refuges for toads and frogs.

•**Arboreal Amphibian ACOs:** If applicable, arboreal habitat for tree frogs can also even be enhanced through the construction of “tree frog hotels” from PVC and a few other simple materials. Although relatively more sophisticated in design and requiring more maintenance, “tree frog hotels” can be assembled by first situating pieces of PVC into a tub or bowl so that they are standing upright. Then fill the tub with gravel or small stones to support the PVC tubing in place and add water to the tub and to each tube so that there is standing water at the bottom (Betcher 2003; Little et al. 2020). This is an example of a very basic tree frog hotel design; however, they can be much more intricate with some containing aquatic vegetation or lights to attract insects at night. By implementing these simple modifications, private landowners can transform their properties into valuable habitat patches that support herpetofauna persistence across the broader landscape. These efforts, when multiplied across neighborhoods and communities, contribute meaningfully to conservation outcomes and foster a culture of stewardship for Michigan’s native amphibians and reptiles.

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) across upland areas to locate an acceptable nesting site (Standing 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

1. Salamanders and other forest associated herpetofauna rely on organic material, including leaf litter, for habitat and to thermoregulate.



1-2. Turtle nest success depends on adequate habitat, suitable substrate, correct solar orientation, and lack of predation pressure. The greatest threat to turtle recruitment is surviving development. Most nests are destroyed within 72 hours of construction. Those that are successful produce the future of these species.



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

2. Nesting areas should be maintained to reduce the growth of vegetation and remain open to optimize thermal gain to the surface.

Jim Harding



turtle species are likely to be present and their nesting requirements when creating turtle nesting areas. Various turtle nesting area creation and maintenance techniques are listed below.

Locate a site – Turtle nesting areas are typically located on Southern facing slopes to ensure the nest is warmed 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 the water on a Southern-facing slope can serve as 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. Fresh wood chips can produce heat through the decomposition process that when exposed to full sun can become hot enough to bake turtle eggs. If utilizing mulch, use old mulch or place mulch at the site well before nesting season (e.g., fall of the previous season) to allow for sufficient decomposition to take place. These areas can also provide snake nesting sites.

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 et al. 2010).

Mitigate predator damage – In several areas throughout Michigan, artificially high populations of subsidized mesopredators (a medium size predator that often increases



Figure 8

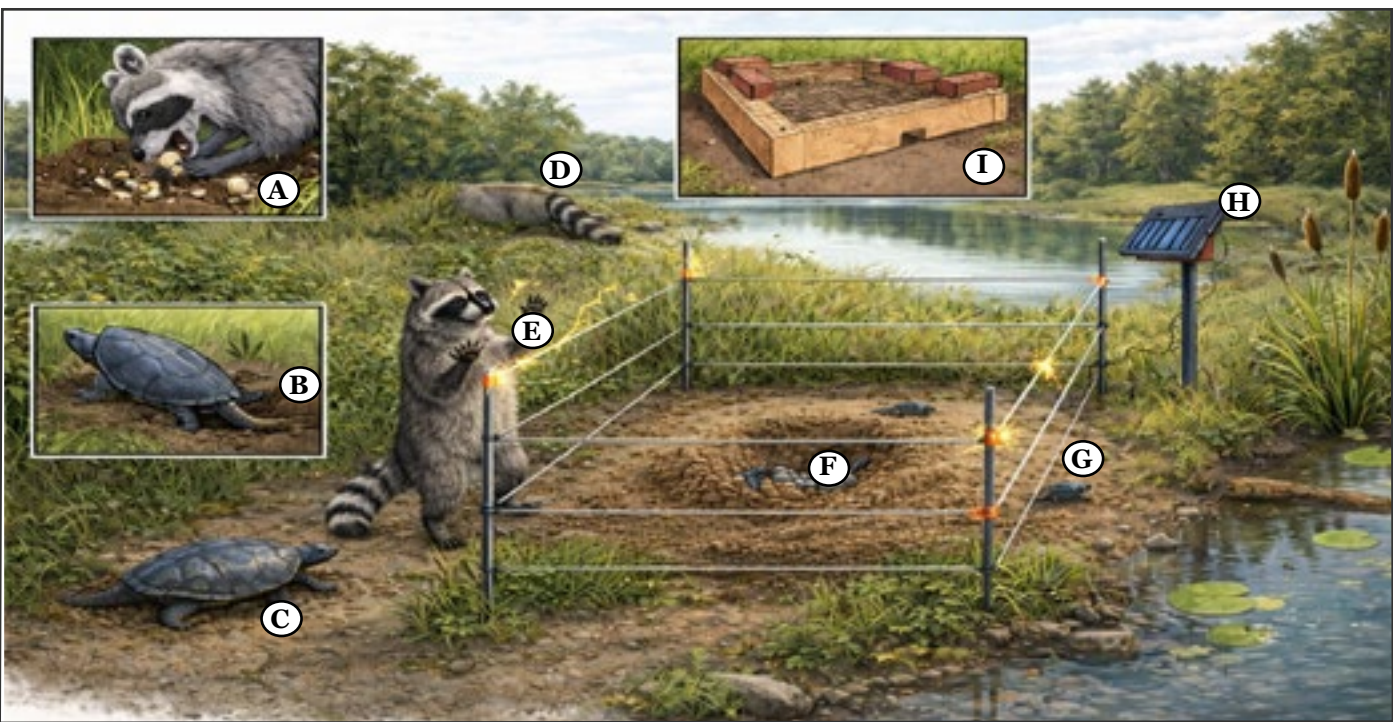


Figure 8. Turtle nest protection is a critical tool in species recovery.

A. Raccoon predating turtle nest.

B. Turtle nesting.

C. Turtle seeking nesting site.

D. Raccoon looking for nests.

E. Raccoon trying to access turtle nests.

F. Protected nest

G. Hatchling turtles emerge from protect nesting area.

H. Solar power supply to fence.

I. Simple less high-tech nest protector design.

in abundance when larger predators are eliminated), like raccoons, can result in devastatingly high turtle nest mortality. In landscapes with high mesopredator densities (e.g., raccoons, skunks), nest predation often exceeds 90%, making recruitment nearly impossible without intervention (Marchand and Litvaitis 2004). This is particularly apparent in suburban and urban locations where mesopredators such as raccoons, skunks, foxes, and crows are present in greater densities. **For a comprehensive discussion of these threats, see Section 3: Threats to Amphibians and Reptiles under Invasive Species/Nuisance**

Exclusion Devices: Protective structures placed over nests after egg-laying are a proven, low-cost conservation tool. Turtle nest protectors are an effective and relatively low-maintenance method to improve nest success for local turtle populations. A variety of designs exist, including metal cages, plastic screens, nest boxes, or larger fenced enclosures placed over entire nesting areas, all intended to reduce predation on vulnerable nests (McElroy et al. 2024; Herpetological Resource and Management 2011b; Herpetological Resource and Management 2012). When constructed and implemented correctly, these devices have been shown not to negatively alter incubation temperatures, hatchling morphology, hatchling success, or hatchling carapace length, making them an important tool for mitigating high nest mortality (Refsnider et al. 2022; Riley and Litzgus 2013; McElroy et al. 2024). However, exclusion devices are not universally effective, as predators such as raccoons and chipmunks have been documented breaching or excavating beneath improperly installed structures to access nests, highlighting the importance of proper installation, maintenance, and site-specific application.

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.



Nest Boxes: Nest boxes are simple structures, consisting of a wooden frame covered with hardware mesh (1/4-1/2 inch), and are highly effective at allowing rainfall and sunlight through while excluding predators. It is the preferred choice for nest protection, with nest boxes resulting in lower depredation rates of around 8% compared to nest cages at 30% or electric fencing at around 35% (Bougie et al. 2022; Bougie et al. 2024; Brewer 1969).

Predator Management: 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 proven to successfully reduce mammalian predation on ground nesting birds and on sea turtles (Lokemoen et al. 1982; Bennett et al. 2009). Control of these predators on islands where turtles nest has been effective at reducing predation pressures (Garmestani and Percival 2005; Engeman et al. 2010) but to date there has been limited effort and success conducting similar control measures in inland areas. The removal of predators in general can help increase nest survival, especially in localized areas. In localized areas of extreme predation, targeted, legal removal of nest-raiding raccoons can complement physical exclusion, significantly improving hatchling recruitment (Urbanek et al. 2016; Rutter et al. 2023). Targeting raccoons in areas with high nest predation through both lethal and non-lethal methods can improve the success of nests (Urbanek et al. 2016; Rutter et al. 2023).

Public Participation: Nest protection is an accessible conservation tool that can engage both the public and professionals in hands-on stewardship. A variety of guides and designs exist to assist with constructing nest protection structures and safeguarding nest



3. Turtle nesting areas should be created with a geotextile barrier to prevent vegetation from growing and a minimum of 1 foot of sand as nesting substrate. Orientation should be south to Southwest facing.

sites (Canadian Wildlife Federation n.d.; Turtle Nests–Road Shoulder Maintenance Best Management Practices: A Guide for Municipalities 2017; Toronto Zoo Adopt-a-Pond Habitat Stewardship, 2026). These efforts can be highly effective for education, outreach, and fostering community investment, particularly as nest protection and observing hatchling emergence are visible and rewarding activities. However, nest protection should not be viewed as a universal solution. Due to the slow life history of turtles, increasing hatchling survival alone will not result in population recovery if adult mortality remains high. As with any conservation strategy, nest protection is most effective when applied to clearly identified threats, such as high nest predation in urban or suburban areas with elevated predator densities and should be implemented alongside broader measures that address adult survivorship.

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 otherwise cause death (Packard and Packard 1993). Aquatic turtles and terrestrial turtles have different hibernation requirements, both of which can be provided through 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 along 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, the 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



1. Basking logs are a simple cost effect habitat improvement critical for turtles and other wildlife. Females such as this Northern Map Turtle spend considerable time basking especially prior to nesting.





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.

as these provide an important insulating layer. Providing areas of leaf litter at least one foot deep is ideal to ensure Eastern Box Turtles 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 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 of 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 location, 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 to 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/

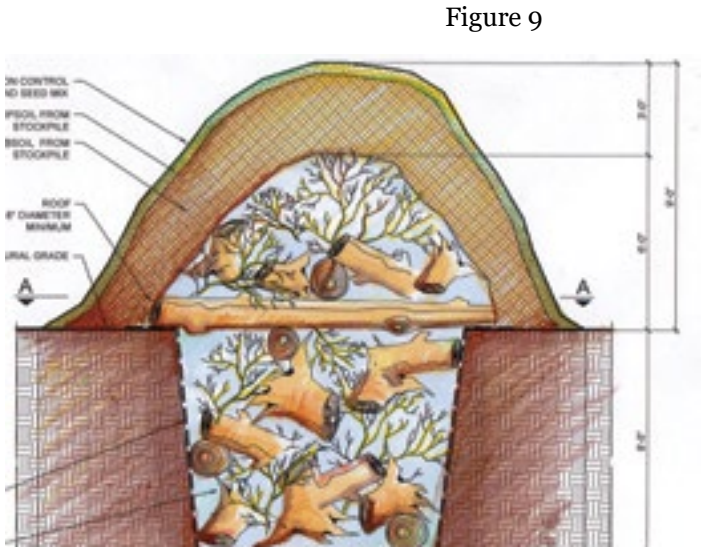


Figure 9. Hibernacula structures containing logs, stumps, and stones with several access openings allow snakes and other animals to find an ideal niche in the hibernacula.

1. Constructed hibernacula with multiple small access points between Southern facing stones.

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.

Snake Nesting Structures

Similarly, snake habitat features and nesting structures can be built and placed in areas where habitat conditions may be declining or absent. These designs work in the same manner as other habitat features that can be constructed in backyards or implemented across landscapes (Laurence et al. 2025; Wild Ones 2024). Purpose-built structures can support oviparous (egg-laying) snake species where natural nesting sites (e.g., decaying logs, compost piles) are lacking.

Design and Function: These are typically insulated, subterranean or ground-level chambers filled with moist, organic substrate (e.g., peat moss, shredded leaves) to maintain stable humidity and temperature for egg incubation. Implementing snake breeding structures is another method that can be used to greatly improve backyard herpetofauna habitat. When employed, these structures can assist in enhancing local snake populations by providing suitable habitat for gravid snakes to deposit their eggs while also offering protection from predation.

Limitations: It is critical to note that these structures will only benefit oviparous snakes (e.g., Eastern Milk Snake, Blue Racer), while viviparous (live-bearing) snake species may not benefit as greatly. Viviparous snakes (e.g., Garter snakes, Eastern Massasauga Rattlesnake) require different habitat features, such as undisturbed, well-drained hibernation sites (e.g., crayfish burrows, rock fissures) (Laurence et al 2025).



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





1. Lizard habitat involves sand to loamy substrate that is well draining and woody material, including decomposing logs, to provide areas species such as Five-lined Skinks can hide and protect their nests.

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, 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 a portion of snakes and all Michigan lizards 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 structure (Harding and Mifsud 2017). 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.

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) lay their eggs in water or over water, and several species mate in water. Some amphibians deposit their eggs on sticks, branches, and submerged 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



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

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 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.

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 nearby cover where they can hide from attack.

Vegetation - Sunny areas in shallow



water or at the edge of a water body are ideal for basking. Southern 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 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 the 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 Northern Mudpuppies and breeding phase Red-spotted Newts, live in the water during their adult life.

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.

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

1-2 Simple structures, such as repurposed segments of concrete or sidewalk, mimic natural Northern Mudpuppy habitat in addition to habitat for aquatic invertebrates and fish.



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.

invertebrates. The creation of rocky shoals in rivers and lakes can provide excellent habitat for Northern Mudpuppies.

Upland Conditions for Reptiles

Upland areas managed for reptiles or those suitable for reptiles are generally dry and relatively open with gaps in the 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 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 strawberries (*Fragaria*), raspberries and blackberries (*Rubus*), and grapes (*Vitis*), 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.

Upland Conditions for Amphibians

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

Relocation, Translocation, and Rescue

When conducting a restoration or any other management or development activity that may disturb or threaten wildlife communities temporarily or permanently, relocation or translocation (also known as wildlife clearance), 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 herpetologist or wildlife biologist with demonstrated experience and expertise in conducting these activities for amphibians and reptiles must 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. Due to many herpetofauna species’ limited mobility and likelihood of being injured or killed during project activities, amphibians and reptiles greatly benefit from wildlife clearance efforts.(Griffiths and Pavajeau 2008; Germano and Bishop 2009; Bodinof 2010).

1. Species documentation is essential, and for species like salamanders, larvae can be challenging to identify. Photo documentation and office review can help key out species without harm or undue stress in the field. It also provides developmental information and timing for monitoring and planning analysis.

Relocation or recipient 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 connectivity 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 from EIDs.

Habitat – The conditions should be similar to the 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.

Size – Recipient 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

1. Headstarting and population supplementing can be an effective tool when coupled with addressing the causes of decline to help facilitate species recovery at the local and metapopulation level. Here, Blanding’s Turtles headstarted for 8 months are being released. They grow in this time to the equivalency of a 4-6 year old wild turtle providing a “headstart” in life and reduces the number and type of predators.

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 2012a). Measures such as the placement of wildlife barrier fencing 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 (Rimple et al. 2024; Tuberville et al. 2005; Alberts 2007; Parker et al. 2008; Attum 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 recipient 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.



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

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



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 SGCN in the MDNR Michigan's Wildlife Action Plan and Special Concern or Threatened by the MDNR (Derosier et al. 2015; Michigan Department of Natural Resources 2016). The Spotted Turtle, Blanding's Turtle, Wood Turtle, and Eastern Box Turtle are all protected and regulated as rare in Michigan and throughout their ranges. In addition, at the time of publication, Blanding's Turtles, and Wood Turtles are being evaluated for Federal protection under the ESA (U.S. Fish & Wildlife Service 2015). 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.

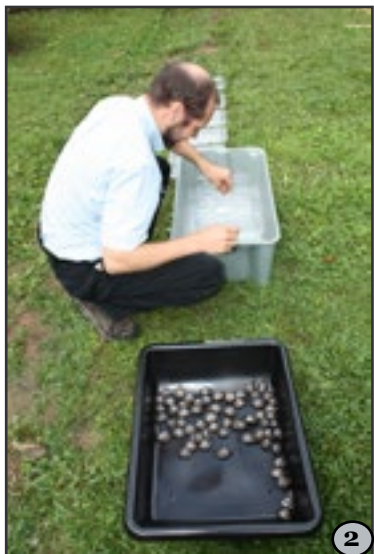
For rare species, pressure on populations can be offset through headstarting programs: eggs are collected, juveniles raised in captivity, and the individuals are released once they have reached a larger, less vulnerable body size. Turtles are generally long-lived animals, with some species known to surpass 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.

Headstarting as a Population Augmentation Tool for Turtles

Definition and Rationale

Headstarting is a targeted conservation technique wherein eggs or hatchling turtles are collected from wild nests, reared in a controlled captive environment for a period (typically several months to a few years), and then released back into their natal habitat at a larger body size, thereby reducing their vulnerability to a wide array of predators (Cann et al. 2023; Golba et al. 2022; Heppell et al. 1996; Richter et al. 2024). This practice is commonly used in turtle conservation and provides many benefits such as ensuring youth survival and allowing the individual to grow to a larger size class than similarly aged counterparts would in the wild.

Headstarting is a time intensive yet necessary part of turtle conservation to ensure at-risk turtle species persist in Michigan.



1. Headstarting should only be conducted where habitat is suitable and likely to support target species.

2. Headstarting necessitates a collaborative and thoughtful approach. It also requires agencies to allow for adaptive management and reliance on subject matter expertise.

Although headstarting does not address others threats (e.g., habitat destruction, road mortality, and unsustainable collection), headstarting does improve chances of hatchling survival to maturity, which is essential for maintaining the population while other conservation efforts advance. In fact, there is strong evidence that some northern Michigan Wood Turtle populations have only experienced recruitment through the release of head-started individuals over the last decade (Harding 2013). Additionally, nine-month old headstarted Blanding's Turtle hatchlings may survive at six times the rate of direct-released hatchlings (Green et al. 2024). Wood Turtles exhibit higher survivorship as the length of time they are headstarted increases, before experiencing diminishing returns after about one year. Given limited funds and resources, headstarting turtles for one year may be the most efficient time period (Mullin 2019; Mullin et al. 2023).

Documented Efficacy and Post-Release Ecology

Extensive research demonstrates that headstarting can be highly effective at improving both individual survival and population-level metrics.

•**Survivorship:** This conservation tool has shown incredible results not only for the survival of individual turtles but also for local population viability. Headstarted, turtles demonstrate high survivorship rates of 90–100% compared to <10% survival rate of wild and direct-release hatchlings (Cann et al. 2023; Golba et al. 2022; Richter et al. 2024; Tesche and Hodges 2015). This significantly exceeds the survivorship rate of turtle cohorts that are directly released (as hatchling), which is the practice of immediate release without captive care. Headstarted turtles exhibit dramatically higher post-release survivorship compared to wild hatchlings. Studies report first-year survival rates of 90-100% for headstarted cohorts, which starkly contrasts with the often <10% survival rate of wild hatchlings due to intense predation pressure (Cann et al. 2023; Golba et al. 2022; Richter et al. 2024;). This elevated survival can persist for several years post-release, effectively adding more individuals to the reproductive pipeline.

•**Behavioral Integration:** Once on the landscape, headstarted turtles behave similarly to wild direct release turtles despite possessing a larger body size (Cann et al. 2021; Golba et al. 2022). Concerns that captive rearing turtles may impair their natural behaviors appear to be largely unfounded when proper protocols are followed. Headstarts have comparable home range sizes to wild, similar aged cohorts and have been observed using muskrat dens as well as habitat with more

1. Nest protection can take on very complex to rather simple approaches depending on scope and scale. Simple nest protectors as shown here can be an effective tool to reduce predation pressure and increase turtle nest success. Support for such efforts at a state-wide level is encouraged

2. When releasing headstart turtles, weather and timing are important considerations. Release locations must be screened and reviewed in advance and even shortly prior to release in the event weather conditions change local conditions (too dry or too inundated). The goal is to set the turtles up to succeed in the new habitat. Two main approaches are soft and hard releases, both have value and should be considered and evaluated by a turtle expert.

cattails than open water, willow stands, and lowland forests when equally available (Starking-Szymanski et al. 2018). They are also able to find their own food, establish home ranges, and hibernate upon release (Quinn et al. 2018). Research indicates that headstarted individuals:

- oExhibit similar movement patterns, home range sizes, and habitat selection preferences as their wild counterparts of equivalent age/size (Cann et al. 2021Golba et al. 2022; Starking-Szymanski et al. 2018).

- oSuccessfully forage, establish stable home ranges, utilize natural hibernacula (e.g., muskrat dens), and express appropriate anti-predator behaviors upon release (Tetzlaff 2019; Quinn et al. 2018).

Strategic Applications for Population Recovery

Headstarting is not a standalone solution, but a powerful tool within a comprehensive recovery strategy, addressing specific demographic deficiencies.

•Correcting Age-Structure Skew:

Headstarting is useful because it can augment populations, skewing them younger than what is already present on the landscape (McElroy et al. 2024). Many declining turtle populations are “geriatric,” with a scarcity of juveniles due to chronic nest failure. Headstarting artificially augments the youngest age classes, helping to re-establish a stable population age pyramid necessary for long-term viability (McElroy et al. 2024; Thompson et al. 2020). While older, breeding adults are just as important, when they eventually age out and become less reproductively successful, it is the young turtles that will have to fulfill this important task. A low population of young individuals can result in steady population declines and potential local extirpation. These efforts highlight the importance of maintaining and even increasing the juvenile recruitment of species across the landscape



1. Predated turtle nests are a very common sight from the end of May through June in nesting areas. The greatest threat to turtle recruitment is getting turtles out of the nest.

(Thompson et al. 2020). In general, skewing the sex ratio to favor females will also have a long-term benefit on the establishing adult cohort, improving additional natural recruitment through an increase in the number of females present. While males are an important part of the equation, males can effectively mate with multiple females and females can have multiple paternity, allowing for sufficient genetic diversity with fewer overall males when compared to females.

•Rescuing Relict Populations: This can be used to aid relict populations in maintaining and eventually growing their numbers back on the landscape in historic areas (Quinn et al. 2018). For small, isolated populations on the brink of extirpation, headstarting can provide a rapid influx of juveniles to prevent imminent collapse and buy time for concurrent habitat restoration and threat mitigation efforts (Quinn et al. 2018; Kuo and Janzen 2004).

Integration with Complementary Conservation Measures

Maximum conservation benefit is achieved when headstarting is integrated with other in-situ management actions, creating a synergistic effect.

•Nest Protection: Headstarting coupled with nest protection is extremely effective and can be an incredibly important tool for returning populations back towards sustainable and healthy numbers (Bougie 2020). Protecting wild nests in-situ (via predator exclusion cages or boxes) is the first line of defense. When paired with headstarting a portion of collected eggs/hatchlings, this strategy both safeguards natural recruitment and supplements it, creating a dual pathway for adding juveniles to the population (Bougie 2020; Shortridge et al. 2025). When headstarting is used in combination with nest protection and habitat-restoration practices, the effects of both methods can greatly increase the presence of turtles on the landscape (Bougie 2020). The protection of nests is not only important for increasing turtle survivability, but a crucial part in the influence of gene flow across landscapes and in populations. Long ranged species like Blanding’s Turtles may travel a mile or more for mating, resulting in a gene flow of over 3 miles. The connections made by these nests allow for genetically healthier and resilient populations (McGuire et al. 2013; Rubin et al. 2001).

•Predator Management: In areas with active predator removal, headstarts that are larger at release are found to be less stressed and have a resultant survival rate



1. Efforts conducted in partnership between the USFWS, HRM, Savannah River Ecology Laboratory, and the Detroit Zoo resulted in an a better understanding of nesting threats, telemetry to determine preferred nesting sites, and an effort to recover the Blanding’s Turtle through headstarting efforts in the Shiawasee National Wildlife Refuge.

that is higher when compared to other wild or direct release cohorts (Cann et al. 2021; Golba et al. 2022). In areas with hyper-abundant nest predators (e.g., raccoons, foxes), temporary, targeted predator control can further enhance the success of both protected nests and released headstarts. Headstarts released into landscapes with reduced predator pressure exhibit lower stress levels and higher survival (Cann et al. 2021; Golba et al. 2022; Rutter et al. 2023). A combination of approaches involving the use of headstarting, nest protection, and predator removal may serve as the strongest and most effective method for increasing populations, especially in areas experiencing decline and containing critically imperiled species.

•**Habitat Restoration:** Releasing headstarted turtles into degraded habitat is ineffective. Successful programs must ensure high-quality, threat-mitigated habitat exists to support released individuals throughout their lifecycle. Restoration of nesting areas, basking sites, and overwintering habitat is fundamental (Bougie 2020).

Critical Considerations and Limitations

Headstarting efforts should 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.

•**Risk of Density-Dependent Mortality:** While headstarting can be a very effective tool for boosting turtle populations, it is important to monitor populations at release



1. Partnership and passion are key elements to successful headstarting. Groups like Michigan SeaLife Aquarium have been integral partners in helping headstart juvenile Blanding’s Turtles on multiple projects.

sites. Especially at sites where there are no active predator removal programs, headstarted turtles can fall prey to mass mortality events (Tharusha Wijewardena et al. 2025; Vander Haegen 2010). Releasing large cohorts of naive juveniles can sometimes lead to mass mortality events if release sites harbor concentrated predators or if resources are limited, underscoring the need for post-release monitoring and adaptive management (Tharusha Wijewardena et al. 2025).

•**Genetic Considerations:** Programs must maintain natural genetic diversity by collecting from a representative sample of wild nests and carefully tracking pedigree to avoid inbreeding in captive cohorts and upon release (McGuire 2013).

•**Disease and Biosecurity:** Headstarting can potentially introduce the spread of disease between headstarted turtles and wild populations (Alberts et al. 1998). However, this risk can largely be eliminated by following biological controls with captive animals and assessing disease risk in these individuals prior to releasing them to the wild (Jakob-Hoff et al. 2014; Calle et al. 2018). Captive facilities must implement strict biosecurity to prevent the introduction or spread of pathogens (e.g., ranavirus, herpesvirus) and emerging diseases including Emydomyces between captive and wild populations (Davidson et al. 2025).

•**Long-Term Commitment:** Though headstarting can play an important role in the recovery of a species, these efforts may not effectively bolster turtle populations unless the initial cause for decline is addressed (Smeenk 2010; Burke 2015). The higher adult survivorship is, the more effective headstarting efforts will be (Heppell et al. 1996). As such, headstarting is a management technique that must be employed alongside other methods aimed at addressing other challenges facing turtle populations. Turtle conservation operates on multi-decadal timescales. The ultimate success of a headstarting program is measured by the recruitment of released individuals into the breeding population, which may not be evident for 10-20 years after program initiation, requiring sustained funding and monitoring (Heppell 1998).



Skyline High School Herpetofauna Rescue and Relocation



In 2005, an intensive amphibian and reptile rescue was conducted in Ann Arbor, MI through a partnership between Ann Arbor Public Schools and the 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" to neighbors. Located in an old field adjacent to an oak-hickory forest, this buttonbush (*Cephalanthus occidentalis*) dominated vernal wetland supported a diverse community of herpetofauna, including at least nine amphibian species. A mitigation, 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 the installation of a wildlife barrier fence 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 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 utilized as 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 (fifth year funding was donated to pay for the wildlife barrier fence). 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 Midland Chorus Frogs, previously referred to as 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 historic "frog pond". A decision was made to replace the temporary barrier made of silt fencing 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 planning team with demonstrated expertise.

Update: In 2025, 20 years after the initial work was started at Skyline, opportunistic monitoring was conducted in spring to assess site conditions to determine species presence. All frog species previously known (with the exception of Midland Chorus Frog) were present and breeding in the larger mitigated wetland and the larger natural pond. In addition, Spotted Salamander reproduction was observed through the presence of a few egg masses. The only known population of LJJ did not have any evidence of breeding, and the status of this species is unknown and further, more frequent monitoring is necessary. It is important to also note that the fence was significantly degraded, and a replacement fence was installed. The degraded fence and large gaps allowed salamanders and other herpetofauna access to the roads and may have been a factor for the reduced detection. Long-term funded monitoring and management plans should be developed to prevent the loss of institutional knowledge and prevent management drifts. The site continues to provide opportunities for education about the successes and lessons learned of novel herpetofauna conservation.



7. Management Techniques



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 on 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

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

Chemicals are applied purposefully as well as unintentionally across 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 certain chemicals in the environment, these events can even impact wilderness areas. Conventional management of agricultural lands, golf courses, swimming areas, and manicured landscapes often use chemicals to control pests or weeds and to apply fertilizer (Ingram 1999). Additionally, the introduction of pharmaceutical byproducts into sewage water results in treated wastewater discharge that contains hormones and other chemicals (Garric and Ferrari 2005; Gross 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 2005a). The introduction of chemicals to aquatic and terrestrial ecosystems

7. Management Techniques

can alter water chemistry, which can trigger physiological and morphological responses in organisms present (Hopkins et al. 2005; Brühl 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. Glyphosate based herbicides (e.g., Roundup®, Rodeo®, Accord®) that contain surfactants such as polyethoxylated tallow amine, which are commonly used to treat invasive plants, can severely impact amphibian species and cause population declines (Trumbo 2005; Howe et al. 2009; Relyea and Jones 2009). **For a detailed discussion of chemical related impacts, see Section 3: Threats to Amphibians and Reptiles under Chemical Use.**

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 into aquatic ecosystems, sometimes up to 2.5 miles away (Houlahan and Findlay 2004). Added nutrients, specifically the introduction of phosphorus and nitrogen, can result in eutrophication, or the over-enrichment of water with nutrients that can stimulate excessive plant growth of aquatic systems. This process can facilitate shifts in plant and animal communities and decrease water quality (Smith 2003; Howarth et al. 2011; Chambers 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 can also result in deformities in amphibians (Rouse et al 1999). Increased levels of nitrogen and phosphorus may reduce hatching success, increase deformity rates, and lower survivorship of frogs and salamanders (Blaustein et al. 2003; Daszak et al. 2003; Gendron et al. 2003; De Solla et al. 2002).

To reduce chemical applications, an ecosystem approach to management can be developed, which includes biopesticides, biological agents,

1. Surface water drainage of agricultural areas to nearby wetlands can result in contaminants entering the systems causing harm to herpetofauna. Use of vegetated buffers and swales can reduce these contaminants from entering wetlands.



Figure 10. 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).

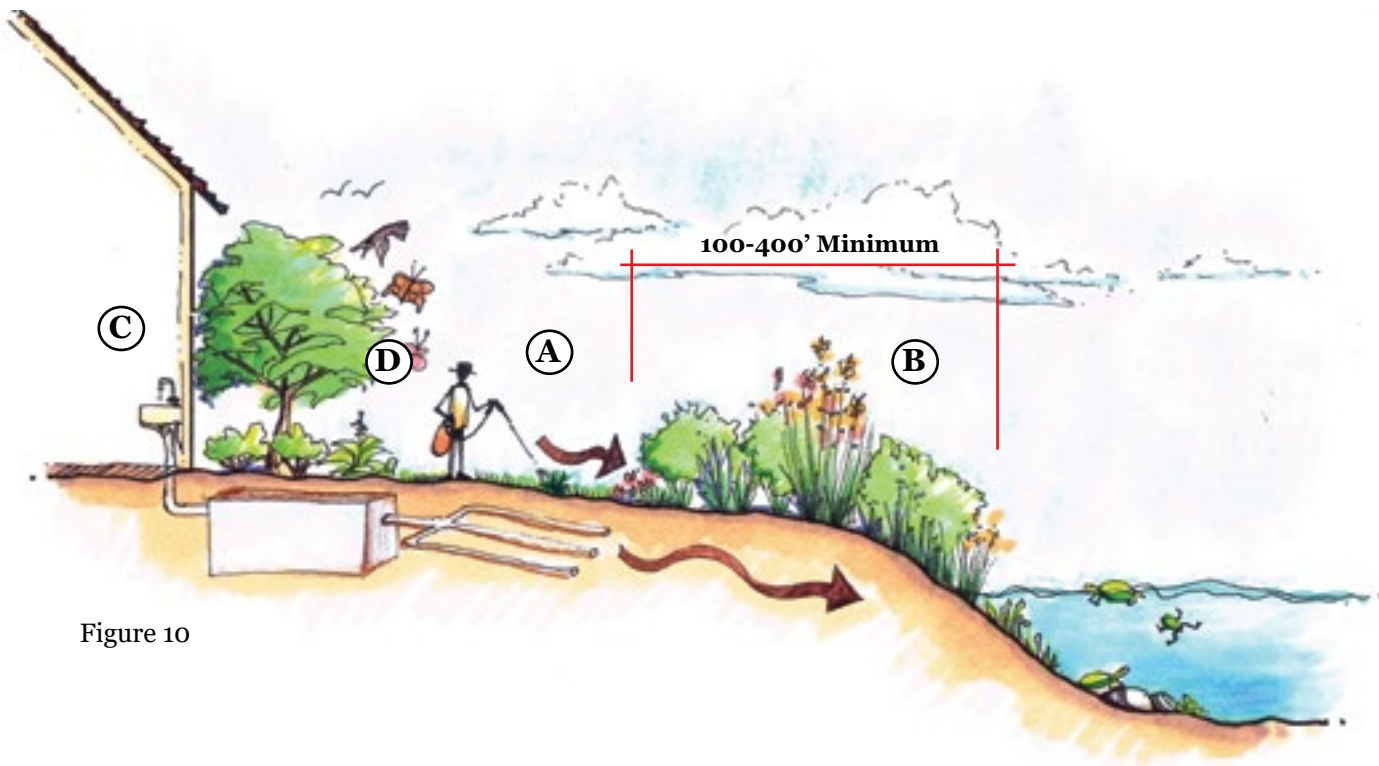


Figure 10

integrated pest management, and site-specific cropping systems that limit pest influence (Lewis 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 applicator before herbicide application. In addition, a permit from EGLE 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.

Chemical Reduction and Natural Landscaping

A method for improving backyard herpetofauna habitat is to reduce or eliminate the use of commonly applied chemicals such as insecticides, fertilizers, and lawn killer. The reduction or elimination of synthetic lawn chemicals is fundamental to creating a safe backyard habitat. Not only can these types of chemicals cause direct harm to herpetofauna, but they also eradicate prey items, contaminate water sources, and destroy native plant communities, all of which can severely degrade herpetofauna habitat (Helping Wildlife U.S. Fish & Wildlife Service 2021).

Direct and Indirect Impacts: Pesticides (insecticides, herbicides, fungicides) can cause direct mortality, sublethal effects (e.g., immunosuppression, developmental abnormalities), and trophic cascades by eliminating invertebrate prey (Relyea 2005; Brühl et al. 2013). Fertilizer runoff contributes to eutrophication of adjacent waterways.



1. Amphibian larvae are highly sensitive to chemicals in their environment. Wood Frogs have been shown to have developmental and mobility issues when exposed to pollutants.

Integrated Pest Management: The presence of robust amphibian, reptile, and avian communities can effectively suppress a wide range of pest species, demonstrating the critical role of healthy ecosystems in effective pest management. Encouraging the establishment of native predators like birds, bats, and herpetofauna can enhance natural pest control. When additional measures are necessary, several natural and more environmentally friendly alternatives are available and should be considered when aiming to create functional backyard habitat. In situations where intervention is needed, the manual removal or targeted use of organic products (e.g., horticultural oils, soap sprays) should be prioritized (Helping Wildlife U.S. Fish & Wildlife Service 2021).

Education about techniques to reduce chemical, fertilizer, and nutrient inputs

- Education about environmental side-effects of

chemical application, non-point sources of chemical contamination (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 un-mowed 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 et al. 2005) can help to reduce the 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

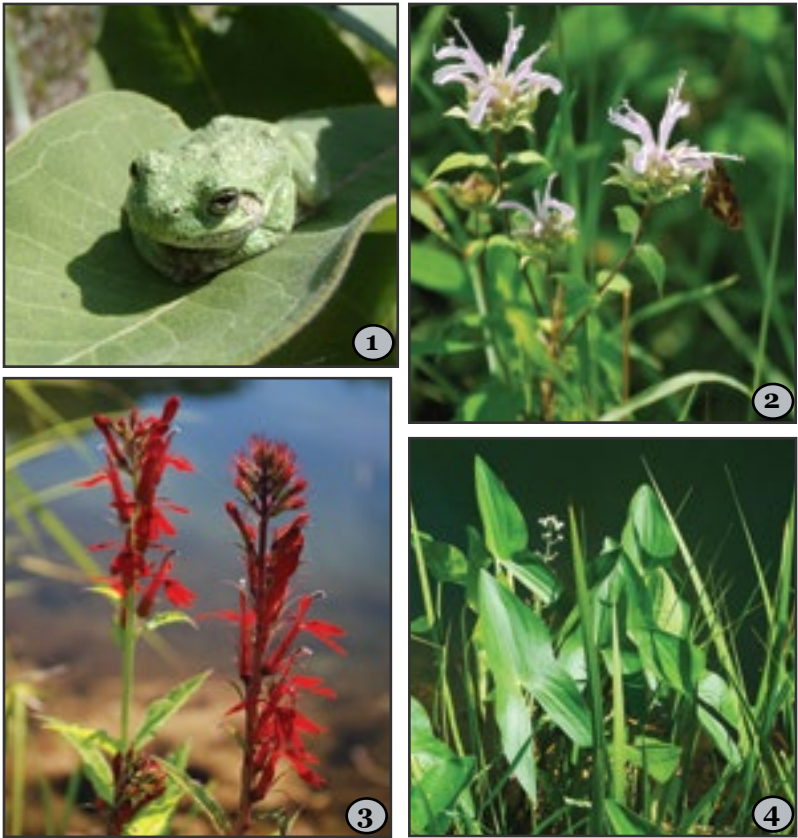
- Prevention of weeds and other pests is the best and most effective strategy for eliminating the need for chemical applications. Changing maintenance practices to support a diversity of native plants and those that provide for beneficial insects and bugs (e.g., ladybugs, bees, dragonflies, predacious wasps, and spiders) can result in a diversity of birds, insects, reptiles, and amphibians to keep “pest” (e.g., aphids, slugs) populations in check. The use of companion planting (the ability of some plants to repel pests) can also 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 habitats 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 into soil particles, intercepted by plant roots, and degraded by soil microbes (Pivet 2001; Nannipieri et al. 2003). Some plant species also sequester chemicals and convert them into inert compounds, making these plants valuable candidates to establish in disturbed areas (Hinchman et al. 1996; Adesodun et al. 2010; Díaz 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, result in healthier herpetofauna 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 and Green Frogs can overwinter and are still present as tadpoles in late



1. The creation of vegetated buffers adjacent to agricultural areas can provide nutrient retention, reduce pollutants from entering wetlands and watercourses, as well as provide critical habitat for pollinators and herpetofauna.



1-4. Common milkweed, 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.

summer and fall (Harding and Mifsud 2017). Applying chemicals in late summer and fall will help to reduce the risk of herpetofauna exposure and associated adverse effects.

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 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) and 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 are estivating or have moved to upland areas, or in late fall when herpetofauna have entered hibernacula (Michigan Natural Features Inventory 2012a). 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 et al. 2012). Some herbicides, such as glyphosate, can persist in the environment for at least 4 months during cool temperatures (Edwards 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 et al. 2009). For chemicals with extended persistence, extreme care and





1-3. Spraying pesticides near wetlands can harm several stages of herpetofauna: (1) Wood Frog eggs, (2) Eastern Gray Treefrog larvae, and (3) Red-eared Slider Turtle.



consideration should be used to determine the necessity of use.

Exclude or relocate rare species during times of greatest risk - If any rare species occur within a treatment area, a wildlife barrier fence to reduce movement into treatment areas during application should be installed. 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, such as essential oils, soaps, low toxicity pesticides, and surfactant-free herbicides, are available that reduce potential ecological degradation and impacts 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, or 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 the mortality of tadpoles and juvenile frogs that is commonly associated with the use of glyphosate-based herbicides that

contain surfactants (Trumbo 2005; Howe 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.

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 et al. 2003) and prevent chemicals and pathogens from entering groundwater. These systems generally consist of a multi-tank arrangement,



Glenn Barrett

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

2. Chemicals applied throughout the landscape have a disproportionately negative impact on sensitive species such as Northern Leopard Frogs.

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).

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 to avoid, as some species of invasive plant may require broadcast application to be effectively eradicated. 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 – Industrial, urban, 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 (Mifsud personal observation 2026). When dealing with long-lived species such as turtles, it is important to address these issues as populations can be negatively





1. Rapid response and recover of impacted animals is essential to maximize the potential for recovery and rehabilitation.

2. It is critical to document long-term species response and survival of animals affected by a spill or other events. This can be done through tagging animals and performing capture-mark-recapture studies.

affected by the loss of relatively few individuals.

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 standards reflective of zoological and animal husbandry settings.

Proper release of herpetofauna - All release sites should possess similar or improved habitat features and quality compared to that of the pre-disaster state of the initial capture site. Preliminary data indicates that turtles captured at a spill site and later released relatively close to 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.

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, tin, zinc, cadmium, and selenium. These metals can inhibit physiological response (Hopkins et al. 2003), leading to deformities in amphibians (Rowe et al. 1996; Rowe 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 et al. 2006). Because of the variety of contaminants and the range of contamination levels at each site, a site-specific decontamination

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 protected nesting sites and basking logs were also placed to maximize site functionality.



plan is necessary in most situations. For more information, visit the EGLE or USEPA website.

Stormwater Management and Soil Erosion Control

Land management and development influences how precipitation 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 et al. 2007). These impacts can decrease amphibian and reptile use through fragmentation and destruction of plant communities and change the distribution of habitat features that support specific

species. **For a detailed discussion of construction-related impacts and mitigation techniques, including erosion control, soil compaction prevention, and habitat protection measures, see Section 8: Development Techniques.**

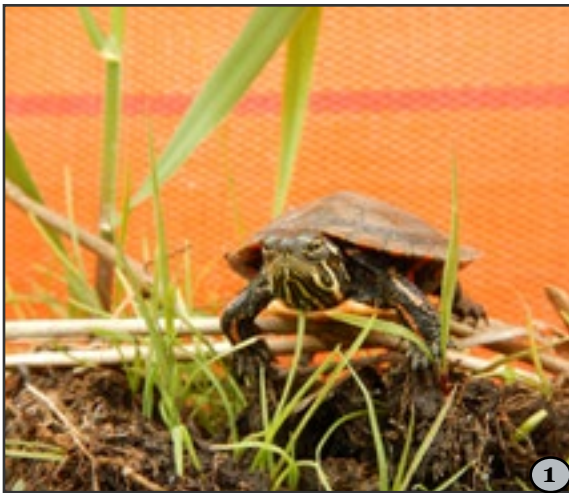
Stormwater management and soil erosion control (SEC) should be an essential part of any construction project and is required by EGLE for activities that disturb one or more acres of land. Visit the EGLE Soil Erosion and Construction Stormwater webpage for more information on these requirements and the MDOT Soil Erosion and Sedimentation Control

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 groundwater 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 EGLE regulations and considers 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



1. Stormwater management can be designed to provide flood retention, water filtration, and habitat value. Sites Like Groesbeck Drain serve these functions.



1. Midland Painted Turtle along the outside of a WBF .

2.WBF installed along linear project corridor to minimize harm to wildlife and protect wetland habitat outside of work space. These measures directly benefit herpetofauna preventing them from entering construction areas.

and risks these measures pose to herpetofauna. Consider techniques that create wildlife habitat and provide long-term stormwater management and erosion control.

Wildlife Barrier Fencing (WBF)

The use of wildlife exclusion fencing for herpetofauna management is becoming an increasingly adopted strategy because it provides a practical and effective way to protect reptiles and amphibians in areas where human activity poses significant risks. By creating a physical barrier that prevents animals from moving into hazardous areas such as roads or construction zones, these fences help to reduce injury and mortality. This is especially critical for herpetofauna since many species exhibit life history traits such as low mobility, seasonal migrations, or delayed sexual maturity that put them at increased risk from anthropogenic disturbances. Beyond simply blocking access, exclusion fencing can also direct individuals towards safe movement corridors or designated capture points, which makes it easier for biologists to conduct monitoring, relocation, or mitigation work with greater accuracy and effectiveness. When exclusion fencing is used in combination with intensive monitoring, it can lead to significant reductions in road-induced mortality (Aresco 2005b).

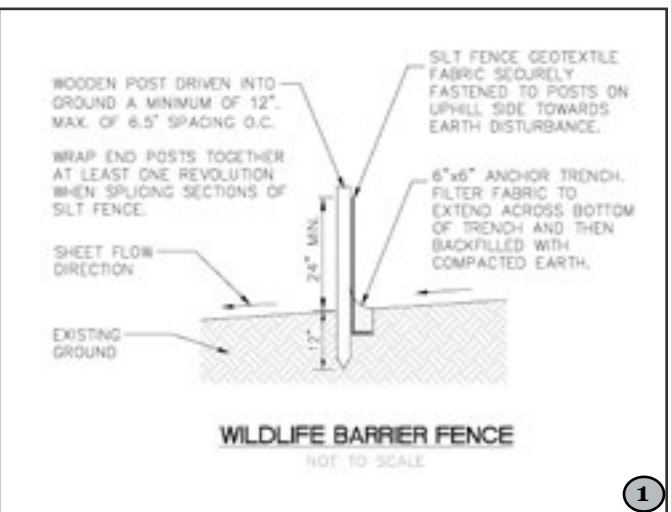
WBF is an effective proactive measure for protecting herpetofauna through reducing the risk for species to be physically injured or killed by excluding animals from active impact areas. WBF typically consists of a three-foot-tall silt fence or net-less soil erosion control fencing with at least twelve inches below the soil surface, with the remaining twenty-four inches exposed aboveground to be effective at excluding wildlife from a construction area. Silt fencing, commonly used for soil erosion control, and WBF can be used interchangeably to serve dual purposes in many cases. WBF should preferably be orange in coloration when installed in locations with the potential for rare species, such as the Eastern Massasauga Rattlesnake, to alert project personnel that protected species may be in the area. When rare species of herpetofauna are not suspected to occur within the area, typical black WBF coloration is preferred. Each terminal end of WBF should have a “J-hook” that forms a curve facing away from the construction site. The radius of J-hook curves is most effective when it is at least three feet in diameter. This design will help deflect animals traveling along the fence away from the project area.

1. Sample diagram of a standard wildlife barrier fence design.

2. Use of J-hooks to encourage wildlife to stay out of construction areas is an effective tool, but more difficult for species Like Blanding’s Turtles who will travel around them.

3. Use of high visibility orange WBF indicate the presence of rare species and helps contractors to stay observant.

WBF should be installed after brush and groundcover have been removed within the proposed delineation, but before any construction activities occur, including the removal of trees and any other remaining woody vegetation within the area. The specific locations for WBF placement are dependent upon the proposed project activities and limits of disturbance. Project personnel should inspect WBF daily to search for holes, tears, and other gaps or damage to prevent herpetofauna from potentially entering the workspace. Any deficiencies should be repaired, and areas for wildlife should be assessed before any vehicles or equipment operate within the workspace. Vehicles and equipment should not travel outside the WBF if within identified habitat areas. WBF should remain in place and be properly maintained until construction activities are complete.



It is recommended that WBF be removed during the final cleanup of a project on the condition that the herpetofauna dormant season has begun (November through March) or activities are closely monitored by qualified biologists. Silt fence and WBF can create an unintended barrier for herpetofauna (Kittredge and Parker 1995; Calhoun et al. 2005; Glista et al. 2009) and can reduce connectivity when it remains on the landscape after a construction project is completed.

Effectiveness for Turtles and Snakes

While strategically placed exclusion fencing provides substantial advantages for reducing overall herpetofauna mortality, its benefits are especially profound for turtles. Human-induced disturbances like drawdowns or land development can force turtles to evacuate and disperse into hazardous areas. Seasonal movement patterns can also compel turtles to travel into high-risk zones, particularly as they transition between essential habitats like nesting sites, foraging areas, and overwintering locations. These long-distance movements put turtles at an elevated risk of encountering roads or human-disturbed landscapes. Exclusion fencing plays a critical role in preventing turtle





1. Hatchling Midland Painted Turtle rescued along WBF.



2. Eastern Snapping Turtle nesting outside of the construction area.

mortality and can be used as a management tool to maintain and even improve the viability of localized populations. It has been found that turtle road mortality was reduced by an average of 78% across study sites when exclusion fencing is configured to meet turtle-specific requirements (Markle et al. 2026). Given that many turtle species exhibit delayed sexual maturation and rely on the long-term survival of adults to maintain population viability, the use of exclusion fencing in preventing adult turtle mortality can yield large-scale conservation benefits.

Snakes represent another group of reptiles for which the installation of wildlife exclusion fencing substantially reduces roadway-related mortality. Favorable thermoregulatory conditions created by warm pavement attract snakes to road surfaces where they are often struck by vehicles due to their limited mobility, low-profile, cryptic coloration, and their tendency to remain motionless in response to perceived threats. Some drivers will also intentionally strike snakes they encounter on roadways. Designated as a Threatened species in Michigan, the Eastern Massasauga Rattlesnake faces an elevated risk of extirpation across much of its historic range due to extensive habitat fragmentation caused by roadways. This fragmentation significantly contributes to their threatened status and persists as a major stressor constraining the longevity of Eastern Massasauga Rattlesnake populations. However, when exclusion fencing was constructed along three roads in Killbear Provincial Park in Ontario, park managers noticed a considerable decrease



3. Following the completion of project restoration, WBF/soil erosion fencing must be removed or it can serve to fragment habitats for limited mobility species.



ERTEC Environmental Systems



ERTEC Environmental Systems

1. ERTEC wildlife fencing with integrated soil erosion material to provide multiple services within the project area.

2. One-directional ERTEC fencing allows wildlife to exit construction areas. In combination with wildlife clearance, this is an effective and cost reducing feature.

in Eastern Massasauga Rattlesnake road-related mortality (Colley et al. 2017). This further demonstrates the effectiveness of exclusion fencing in reducing herpetofauna mortality and as a critical management tool for conserving imperiled species. **For detailed specifications on fencing materials, installation techniques, and species-specific design considerations, see Section 8: Development Techniques under Road Crossing Structures.**

Commercial Exclusion Fencing Products

A variety of wildlife exclusion fencing is commercially available, and many can be tailored to specific project requirements and target species. ERTEC Environmental Systems stands out as a pioneering manufacturer in wildlife exclusion and directional control fencing. While the authors of this BMP are not affiliated with ERTEC, we do consider it important to highlight innovative companies that are developing such products. While conventional erosion control fencing can be effective, ERTEC has engineered a barrier fence designed to address the unique challenges associated with herpetofauna management. By utilizing patented rigid polymer matrix technology as opposed to traditional mono-filament plastic mesh, ERTEC's E-Fence is much more durable and can be reused over many different projects. The E-Fence can also be custom configured for distinct species with designs varying in height, trench depth, and can include accessories like cover boards, pitfall traps, or one-way escape funnels.

It is also available with integrated anti-climb technology, which is very effective at preventing climbing species from entering hazardous areas (Hathaway 2019). The system can also be configured to provide necessary SEC measures, ensuring that state, county, and local government requirements are upheld. ERTEC maintains a comprehensive list of species-specific approved fence configurations that have been developed through applied past projects. Numerous herpetofauna species identified in the Michigan Wildlife Action Plan, like the Blanding's Turtle, Butler's Garter Snake, Eastern Fox Snake, and Eastern Massasauga Rattlesnake, already have existing recommended fence configurations. Additional species include the Eastern Hog-nose Snake, Eastern Musk Turtle, Painted Turtle, and Eastern Snapping Turtle. Beyond its functionality as a wildlife exclusion and directional control fence, it can also be used as a high visibility barrier and sediment control, eliminating the need for separate construction safety barriers and silt fence arrays. It is the role and responsibility of engineers, landscape managers, restoration practitioners, and agencies to evaluate





1. Eastern Garter Snake observed dead in monofilament soil erosion control netting during monitoring. This product was removed to avoid further mortality.

2. These monofilament products are designed to breakdown in the presence of UV. Often vegetation will grow under them creating nets that entangle herpetofauna.

Reports of reptile entrapment in SEC netting often contain descriptions of lacerations on entrapped animals, which appear to suffer high rates of mortality after becoming entangled, often due to dehydration, overheating, stress, and/or physical trauma (Walley et al. 2005; Kapfer and Paloski 2011). The most common reason for reptiles becoming ensnared in SEC netting is likely that apertures in the netting are too small to allow many snakes and lizards to pass through safely (Kapfer and Paloski 2011). At least nine species of native snakes in Michigan have been documented ensnared in SEC netting. These include at least three State-listed species and one Federally-listed species; the Eastern Fox Snake, Black Rat Snake, Butler’s Garter Snake, and Eastern Massasauga Rattlesnake, respectively. Anecdotal evidence of the impacts of SEC netting on some amphibians has also been reported, including the entanglement of Eastern Red-backed Salamanders and metamorph frogs in mesh with fine apertures. Because the mesh tends to break down slowly, it can also impact turtle nesting opportunities and entrap hatchlings that may be under the surface at the time of fabric placement, resulting in increased predation or desiccation.

Alternative options for SEC netting that use biodegradable materials are available. These wildlife-friendly products consist of natural netting materials as opposed to plastic monofilament mesh. These materials should include at least 30% natural

available products and companies to determine the most appropriate fit and effective use for their specific application.

Wildlife-Friendly Soil Erosion Control

SEC materials are a critical component of restoration projects and are typically necessary to ensure the success of a site’s establishment. A significant portion of SEC material used in projects is photodegradable and contains plastic mesh that is intended to degrade after two years. However, once these materials achieve their intended purpose and vegetation is established, UV energy becomes limited or no longer reaches the matting, preventing the complete breakdown of the material. As a result, this plastic monofilament mesh, the same material used for fishing lines, presents major risks to wildlife as it can remain on the landscape for up to a decade or more. Substantial evidence indicates this type of SEC causes direct injury or mortality to wildlife that become entangled (Walley et al. 2005; Kapfer and Paloski 2011; Minnesota Department of Natural Resources 2013; U.S. Fish and Wildlife Service 2022). While a number of animals are known to be vulnerable to SEC materials, herpetofauna, and snakes in particular, are believed to be the most affected, likely due to their limited mobility (Walley et al. 2005).

U. S. Fish and Wildlife Service	Not Wildlife Friendly	Less Risk to Wildlife	Wildlife-Friendly
	• Square plastic netting that is: - Degradable - Photodegradable - UV-degradable - Oxo-degradable - Oxo-biodegradable • Made from: - Polypropylene - Nylon - Polyethylene - Polyester • SEC left longer than required	• Elongated mesh netting - Mesh > 2.54 cm	• Natural fiber netting or no netting • 100% biodegradable • Loose weave, non-welded, movable jointed netting (leno or gauze) • Weed or seed-free • Secure SEC with wooden stakes or live stakes • Bury edges of blankets & mats • Remove SEC when no longer required • Spray on mulch • Seed & plant native vegetation
			1

1. Attributes of SEC materials and their designation as non-wildlife-friendly, wildlife-friendly to a lesser degree, and wildlife-friendly. Wildlife-friendly specifications should be selected as much as possible.



2. Example of wildlife-friendly biodegradable soil erosion material. Several herpetofauna were observed alive within the material.

contents. SEC blankets should also be thoroughly secured to the ground surface to eliminate spaces under the netting and to avoid lifting as vegetation grows. The requirements of a project site and desired longevity of SEC can help determine which design and materials should be used. Natural, biodegradable products have been shown to provide SEC that is equally effective while also helping to retain soil moisture for plant growth. Additionally, the cost of biodegradable products is comparable to that of commonly used plastic materials (Slesar 2009). Recognizing the importance of using such products, some government agencies have updated the standard specifications for work throughout their respective states.

Stabilize slopes with native plants instead of turf grass to reduce long-term erosion - Turf grass is often 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

jute, coir, or other organic fiber with an inner matrix consisting of coconut, straw, aspen, or similar organic fibers. Wildlife-friendly SEC material ideally incorporates leno weave (or equivalent) top and bottom netting, is approximately ¼ inch thick, possesses large apertures at least 1.57in x 1.57in, and contains weed-free



1. Creation and enhancement of stormwater within the ponds reduces impacts from impermeable surfaces and provides some habitat for urban and suburban herpetofauna.

2. Eastern American Toads have frequently been observed using detention ponds to breed. Monitoring of pollutants and maintaining aquatic vegetation that can help sequester heavy metals will improve water quality.

potable water sources (Kjelgren et al. 2000) or drawn from local water tables during the summer when water levels are already 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.

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 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 et al. 2011). Substituting paved

areas with native vegetation can also reduce long-term maintenance costs compared to non-native varieties, since native plants compatible with site conditions require little care beyond establishment.

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 et al. 2007; Baltrenas and Kazlauskienė 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 surface waters will be cooler, cleaner, and provide higher quality amphibian and reptile habitat.



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 increases in salinity can degrade 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.

Vegetated or bio-retention swale – A vegetated, shallow ditch designed to move water and sediment slowly to facilitate increased infiltration. Side slopes should be less than 1:4. Common uses are around parking lots and along roads.

Rain garden or bio-retention cell or infiltration basin – A vegetated depression that temporarily holds standing water and allows 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.

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 the roof.

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.

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. Locate detention and retention features that collect pollution in areas without hydrologic connectivity to 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



1. Discharge to high quality wetlands can reduce ecosystem viability and function, limiting herpetofauna use and species presence.

2. Green Frog egg deposition in a nutrient-rich wetland with abundant algal growth. Frog and toad larva act as important nutrient sinks, exporting nutrients from wetlands as they metamorphose into terrestrial frogs.

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 not only herpetofauna, but also for other wildlife and humans. Many communities are actively moving away from such systems.

Balance withdrawals and discharge from water reservoirs – Water being withdrawn for irrigation, drinking water, industrial use, etc., should be balanced by water inputs and 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).

Habitat Management

Forest Health and Herps

The presence of herpetofauna on a landscape is reflective of a system’s health (Harding and Mifsud 2017). For instance, the health of riverine forests in the Northeast can be determined by Eastern Red-backed Salamander densities and their responses to environmental changes (Campbell et al. 2024; MacNeil and Williams 2014). Often

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. **For a detailed discussion of the impacts of pollution on amphibians and reptiles, see Section 3: Threats to Amphibians and Reptiles under Chemical Use.**

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 et al. 2007) and may need to be removed and replaced if the concentration reaches an unacceptable level or becomes toxic.

Separate storm and sanitary sewer systems – Many urban areas historically supported combined storm and sanitary sewers, which under typical circumstances drain to a water treatment facility. During severe or relatively minor storm events, the



1. Vernal pool habitat is a critical wetland community for several species of herpetofauna. These obligate species necessitate this landscape feature for reproduction.

2. Mature upland forest is essential for many amphibians and reptiles. Species like Wood Turtles can be negatively impacted by incompatible forestry practices.



occurring in greater densities than other highly abundant avian and mammalian species, Eastern Red-backed Salamanders play a significant role in nutrient processing, and their preservation can help maintain adequate forest ecosystem health. Similar findings from work conducted in Michigan have demonstrated the importance of salamander communities to forest nutrient cycling and overall ecosystem function.

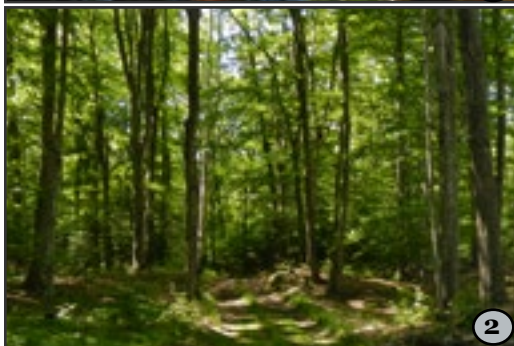
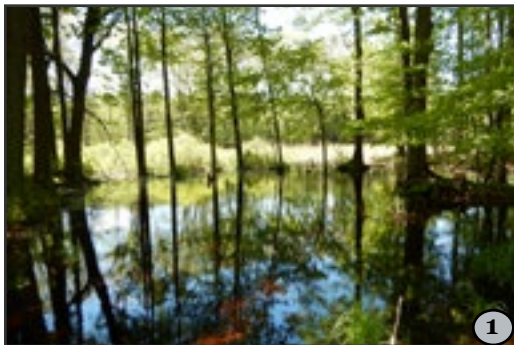
Common forestry management practices can be important in maintaining healthy forest ecosystems; however, they involve activities that can also degrade habitat structure and be detrimental to amphibians and reptiles (Hansen et al. 1991; DeGregorio 2008). Sustainable forest harvest techniques can be beneficial to forest health when applied appropriately; however, there are certain

practices that can negatively impact herpetofauna, resulting in an overall reduction in forest health. 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 the hydroperiod of forested wetlands (Calhoun and Demaynadier 2004). Since forest dwelling amphibians respond to these habitat characteristics (Feder 1983; DeMaynadier and Hunter 1995; Demaynadier and Hunter 1998; DeMaynadier and Hunter 1999; DiMauro and Hunter 2002) their populations can be significantly reduced as a result of these practices.

Wood Turtles, a species of herpetofauna heavily associated with forested riverine and adjacent upland habitat, can be greatly affected by disturbances to forest structure (Harding and Mifsud 2017; Harding and Bloomer 1979). These impacts can often be the result of forest timber practices. Timber production sites can have a variety of harvest schedules, timelines, and cut methods, which can negatively impact Wood Turtle populations within these units. If sustainable forest harvest practices are utilized, it significantly reduces the harmful impacts on this species. By considering the management timelines over the course of a year and in a manner that creates a mosaic of forest age classes, Wood Turtle populations don’t see as large of an impact as opposed to traditional timber harvest methods (Brockman 2024).

Vernal pools, seasonal forest pools, are 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 which, kills off fish. Vernal pools are particularly sensitive to disturbance and are critical to the survival





1. Forestry practices and management should consider the role and critical areas associated with vernal pools that are known or may support habitat dependant species.

2. Use of forestry practices that consider species like Wood Turtle and Eastern Box Turtle can help reduce harm and help recover species locally.

of several amphibian species that do not successfully reproduce or have low species richness in the presence of fish (Figiel and Semlitsch 1990; Hecnar 1997; Snodgrass et al. 2000).

Strategic planning of operations can lessen the impact forestry has on herpetofauna directly and indirectly through the 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 the intent that the following recommendations help to support this aim.

Succession

Succession can occur naturally as part of shifts in community composition over time as well as from the introduction of invasive species. Invasive plants have the potential to quickly alter riparian areas, reducing the ecological and functional value for herpetofauna and other species. Plants like buckthorn,

autumn olive, and Japanese barberry can aggressively overtake understories, creating dense shade that reduces the suitability of surrounding habitat for herpetofauna. Aggressive understory competitors create thick monocultures that limit overstory light penetration, reduce soil temperature variability, and simplify the litter layer, all of which are essential microhabitat characteristics for numerous amphibians and reptiles (Delaney et al. 2021; Maerz et al. 2009). In addition to shading, buckthorn impacts soil hydrology and chemistry; its leaf litter has been found to leach phytochemicals that can negatively affect embryonic development and larval survival in amphibians (Havel and Shurin 2004). Buckthorn also impacts hydrology and as previously discussed, impacts amphibian development and survival of larvae. Aquatic invasives can also be incredibly problematic, including *Phragmites*, non-native cattail, and submergent plants like Eurasian milfoil. Aquatic invasive species can homogenize aquatic habitats, lower oxygen levels, and compromise breeding sites for herpetofauna (Bourgeau-Chavez et al. 2013). Management targeting the protection and restoration of riverine and riparian habitats should be implemented with similar emphasis on land protection, as habitat protection alone does not ensure habitat suitability and function (Markle et al. 2018). Consequently, management strategies should not only focus on land protection but also incorporate active restoration and control of invasive species to maintain habitat suitability and ecological function (Markle et al. 2018).

While some systems can have significant impacts from invasives, some areas that support a lower botanical richness can still provide the necessary ecological utility. This often occurs in urban, suburban, rural, and agricultural landscapes. When assessing landscapes for herpetofauna, it is critical to consider the functional value of present



1. Clear cutting practices that allow for and leave slash can result in improved landscape value to herpetofauna.

2. Forestry practices within vernal pools can be very destructive, impacting short-term and long-term populations of vernal pool associated species. Timing is very important and work should be limited to winter and vernal pools should be delineated in advance and impacts avoided around them and critical areas.

2023). These environments can fulfill critical needs: sites for thermoregulation, substrates for foraging, and shelter from predators. Their adaptive nature and plasticity must be considered and accounted for when considering measures to modify or even destroy habitats that seem undesirable. As a result, habitat evaluations should emphasize functional value rather than subjective aesthetic considerations. Use the Herp HAT when assessing areas for herpetofauna to assist in determining a landscape's functional health herpetologically, and to better guide best management strategies, including cases where no action is warranted to maintain the current functional ecological conditions. **For a comprehensive discussion of the Herp HAT tool, including information on application and development, see Section 4: Conservation Efforts.**

Forest Management and Silviculture

Although relatively undisturbed riverine ecosystems hold high functional value, nearly all Michigan landscapes, including northern forests, bear a history of logging, trapping, and other extractive uses. Since past land management practices typically failed to consider adverse impacts to wildlife, many systems around the state have been ecologically disrupted as a result. Today, however, contemporary silviculture practices, when performed soundly, can benefit both riverine herpetofauna and economic interests. The harvesting of adjacent forested upland habitats to riverine systems can greatly modify pre-existing overstory and ground-cover characteristics.

When an appropriately sized buffer is implemented, impacts to local

vegetation more than merely the botanical richness of the landscape. Herpetofauna often will thrive in less pristine habitats that meet their biological and natural history requirements sites for thermoregulation, substrates for foraging, and shelter from predators regardless of botanical "pristineness." These species were some of the earliest colonizers, often in spartan oligotrophic landscapes. Numerous species demonstrate considerable ecological adaptability, flourishing in habitats that are structurally appropriate yet floristically simplistic, such as urban floodplains, coastal riprap, abandoned fields, and suburban woodlots with vernal pools (Ghoddousi et al. 2021; Halliday et al. 2020; Riley et al. 2005; Sutor et al.





1. Successional reset, that occurs with logging can have value for some species. The increase in pioneer species like blackberries, raspberries, and blueberries, provide food resources to species including Wood Turtles and Eastern Box Turtles. Other species of herpetofauna also benefit from these open landscapes.

2. The Marbled Salamander is a vernal pool dependent species with a limited range in Michigan.



herpetofauna communities, as noted with Wood Turtles, can be relatively unaltered and may even increase due to the creation of temporary standing water in treated stands (Russell et al. 2002). When appropriately sized buffers (e.g., $\geq 30\text{m}$) are maintained, local herpetofauna communities may remain stable or even benefit from temporary pooling in harvest areas (Russell et al. 2002). Care must be taken to maintain critical zones around vernal pools that support vernal pool dependent species. Silviculture techniques that maintain a diversity of tree age, structure, and distribution within the treated area will provide both early and mature successional habitat that will benefit herpetofauna that utilize both types (Mcneil et al. 2013). It is critical that hibernacula and nesting sites of at-risk turtle species, like the Spotted Turtle, be identified and undisturbed for the duration of any

timber harvest operation (Buchanan et al. 2017). Since numerous other riverine-associated herpetofauna also benefit from the maintenance of late successional habitat, land managers should limit disturbances to this type of habitat as well. **For a detailed discussion of vernal pool critical zones, see Section 6: Ecological Restoration, Mitigation, and Habitat Design under Wetland Mitigation and Restoration.**

Historical Context and Modern Practices

Historically, it has been speculated that the logging of northern Michigan and the floating of logs down rivers may have provided significant open riverine landscapes and nesting areas. Historical logging practices in northern Michigan, including clearing and log running (floating logs down the river), may have incidentally created open riparian corridors and nesting areas while also promoting early successional berry-producing herbaceous plants and shrubs. The increased disturbance of substrate from logging and log running activities allowed for greater areas of sand deposition, facilitating an increase in benches and sand banks. The absence of large trees also facilitated the establishment of species like blueberries

(*Vaccinium*), raspberries, blackberries, and other ground berries that provided a food base for Wood Turtles 100 years ago. It is important to remember that these effects lasted long after the log runs were over. This, concurrent with the absence or extreme rarity of predators like raccoons, provided ideal conditions for Wood Turtle establishment and expansion across the Upper Peninsula. During heavy log running at the peak of pine harvest, it is likely that turtles and other

herpetofauna were negatively impacted from physical injury and disturbance from humans. Following this disturbance, coupled with historically low mesopredator densities resulting from historic trapping, may have facilitated the expansion of species like the Wood Turtle in the Upper Peninsula and northern Lower Peninsula (Harding and Bloomer 1979; Harding personal communication 2026).

Recently, greater attention has been placed on balancing logging practices, land management, and imperiled species like Wood Turtles. Modern research reinforces that balanced forest management can create beneficial habitat mosaics for herpetofauna. A study on Wood Turtles demonstrated that a mix of forest age classes, including young forest, mature canopy, and openings, supported robust populations (Brockman 2024). This work has shown how forest management can create beneficial Wood Turtle habitat through a mosaic of mixed age classes and has also developed management recommendations that emphasize the importance of implementing riparian buffers with seasonal adjustments. Seasonal adjustments to these buffers to coincide with nesting season are necessary to accommodate for the movement of female Wood Turtles. Key recommendations include establishing riparian buffers, making seasonal adjustments to buffer zones to support female nesting migrations, and mitigating road mortality by managing haul road use post-harvest. The study also addressed road mortality, identifying the threats of haul roads, analyzing how female Wood Turtles use haul roads post-harvest, and suggesting strategies for how forest managers can reduce turtle mortality from vehicle strikes (Brockman 2024).

Best Management Practices for Silviculture

When implementing forest harvest operations in areas with known or potential herpetofauna habitat, the following modern practices should be considered:

•**Riparian Buffers:** Maintaining appropriately sized vegetated buffers along streams and rivers helps protect critical habitat features and provides travel corridors for species such as Wood Turtles that move between aquatic and upland habitats. When appropriately sized buffers (e.g., $\geq 98\text{ft}$) are maintained, local herpetofauna communities may remain stable or even benefit from temporary pooling in harvest areas (Russell et al. 2002).

•**Seasonal Adjustments:** Harvest activities should be timed to avoid peak movement and nesting periods for sensitive species. Female turtles undertaking nesting migrations are particularly vulnerable to

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





1. Wood Turtle observed in riparian forested habitat.

2. Blanding's Turtle using a vernal pool habitat in early spring.

3. Preservation of high quality forest habitat is necessary to preserve and support health herpetofauna populations in these landscapes.

disturbance and mortality during late spring and early summer. Care must be taken to maintain the critical zones around vernal pools that support vernal pool dependent species. It is imperative that hibernacula and nesting sites of at-risk turtle species, like the Wood Turtle or Spotted Turtle, be identified and undisturbed for the duration of any timber harvest operation (Buchanan et al. 2017).

•**Mosaic of Age Classes:** Creating and maintaining a diversity of forest age classes across the landscape, including young forest, mature forest, and forest openings, provides the variety of habitat conditions needed to support diverse herpetofauna communities throughout their life cycles. Silviculture techniques that maintain a diversity of tree age, structure, and distribution within the treated area will provide both early and mature successional habitat that will benefit herpetofauna that utilize both types (Mcneil et al. 2013). Forest characteristics like snags, amount of coarse woody debris, and a variety of canopy closures contribute to creating a mosaic of early and late-successional habitat components that support a wide range of reptiles and amphibians (Mcneil et al. 2013; Thompson 2018).

•**Haul Road Management:** Roads associated with timber harvest can create significant mortality risk for herpetofauna.

Managers should assess haul road locations relative to known habitat features, implement speed restrictions during sensitive periods, and consider post-harvest road removal or closure to reduce long-term impacts.

•**Preservation of Late-Successional Forests:** Secondary forests and old-growth forests often contain a higher species richness and abundance when compared to human-modified habitats; however, these types of forests are becoming increasingly rare on the landscape, which reinforces the importance of preserving such communities (Thompson 2018; DeGraaf & Rudis, 1986; DeGraaf and Yamasaki 2001).

The historic impact of intensive logging is evident across much of Michigan's forested landscape. While returning to the original "pre-settlement" state of vegetation age and distribution is unfeasible, the value of secondary forests, that being the forests that have regrown since initial logging, is immense. While lower in species richness and abundance than old-growth or primary forests, these secondary forests have a higher species richness and abundance than recently



1. Water gathering in the tire tracks indicates that this access road went through a vernal pool. Pre-harvest surveys should be required on all sites to map wetlands to avoid unnecessary impacts.

2. Eastern Red-backed Salamanders are a top indicator of forest ecosystem health in Michigan. Their presence, abundance, and distribution can be used to evaluate forest condition. Pictured here is the red-backed (left) and led phase (right).

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 the risk of crushing animals and causing soil disturbances (e.g., reduces soil compaction and rutting), which would create unsuitable conditions for herpetofauna like salamanders that depend on the loose soil and litter layer of the forest floor for burrowing.

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) harvest techniques can help maintain various levels of canopy and understory cover. This benefits herpetofauna while also meeting forest management objectives. These techniques may reduce the relative abundance of salamanders, but since these methods 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.

Avoid clearcutting large areas - Strategic clearcuts and seed tree cuts (cutting all trees except a select few to remain to provide seeds for forest

human disturbed landscapes (Thompson and Donnelly 2018). The presence of secondary forests also helps in creating a greater diversity in age classes within an overall forested area. This contributes to the structural complexity of a forest, leading to numerous ecological benefits that positively impact forest health. Yet as forests age, and more land is preserved and conserved through state and national parks, maintaining secondary forests is critical to ensuring a variety of age classes exist within the broader forest landscape. As previously discussed, forest structure and function are the key drivers for herpetofauna success and presence, with less focus on floristic value.





1. Forestry slash can provide critical habitat for herpetofauna and help stabilize banks from erosion.

2. Maintaining brush piles provides habitat for amphibians and reptiles.



regeneration) can be used to create habitat features for some wildlife (i.e., snowshoe hare, Kirtland’s warbler) and can be conducted in accordance with regard for biodiversity (Conroy 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 et al. 2009) and can take decades to rebound (Petranka et al. 1993). Seed tree cuts also reduce 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 the resulting landscape pattern should be considered to minimize negative effects on amphibians and reptiles that rely on the forest (i.e., those that use forest surrounding vernal pools) (Hansen 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) (Mitchell et al. 1997; Harding and Mifsud 2017). Removal of softwoods, such as poplars, 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, ultimately 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 et al. 1991; Ash 1997; Bol 2007). In addition, fallen logs may already provide vital structures for wildlife and should not be disturbed. **For a detailed discussion on these habitat structures, see Section 6: Ecological Restoration, Mitigation, and Habitat Design.**

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



1. Red-spotted newt Efts are a terrestrial subadult form of this newt species. They live in mature upland forest ecosystems, sometimes for several years, before returning to being aquatic.

2. Construction mats help to reduce the compaction of hydric soils and prevent ruts caused by equipment.



cool temperatures needed to support a diversity of herpetofauna (Dupuis et al. 1995; Baldwin et al. 2006; Semlitsch et al. 2009).

Rotate cuts – Rotating cutting to allow for 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 allow 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.

Vehicle Use

Use tracked vehicles – Tracked vehicles distribute the weight of the equipment over the surface of the entire track, which lowers the pressure being 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.

Use construction mats – Large landscape timbers connected together to form 10ft x 10ft 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.

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





1. ATV and other vehicle use in sensitive nesting areas for turtles can harm both the turtles as well as the eggs.

2. Buried turtles and other species are often crushed when equipment runs over them. Pre-construction surveys help identify these threats.



2004). If these ruts do not exist, adults will likely continue searching for 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.

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.

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. Avoidance of high-quality habitat is always 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 that are 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 Turtle 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



1. Vernal pool dependant species require intact vernal pool and forested landscapes to survival. Most Wood Frogs and vernal pool dependant species return to the same pool each season to breed. They are more than a pond, they are a critical part of environmental heritage of that habitat.

2. Eastern Newt eft stage rely on high quality forested habitat to live.

3. Eastern Red-backed salamanders breed and care for young under logs in forests. Here a female guards eggs and newly hatched baby.

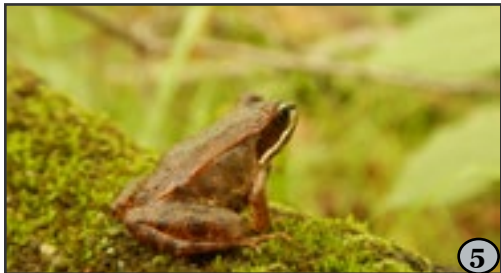
road as a physical barrier to herpetofauna by providing suitable habitat conditions to facilitate their movement across the landscape.

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 isolated, temporarily flooded, depressional wetlands provide amphibian larvae a relatively safe environment to develop, though predation still occurs from non-fish predators, including turtles and snakes (Kenney and Burne 2001; Colburn 2004). These wetlands also act as stepping stones through upland habitat 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 et al. 2007; Holman 2012). Species that rely on vernal pools often experience drastic seasonal shifts in their distribution, clustering around vernal pools when breeding and dispersing throughout adjacent upland

warm, rainy spring nights of the year, and closing roads in key migration areas during these times can reduce amphibian mortality (Timm et al. 2007). This management practice is successfully utilized in the 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





1-5. Northern Spring Peeper (1), Spotted Salamander (2), Blue-spotted Salamander, (3) Blanding's Turtle (4), and Wood Frog (5) are some of the species that rely on vernal pools.

areas throughout the rest of the year (Gibbs and Reed 2007). 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 (contain 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. Vernal pools often support a concentration of biodiversity and population density, particularly for herpetofauna, within forested landscapes (Zedler 2003; Colburn 2004).

Indicator species - Most frog and salamander species utilize vernal pools for breeding, development, foraging, and/or hibernation at some point in their life (DeMaynadier and Houlahan 2007; Semlitsch and Skelly 2008). However, many species are classified as vernal pool indicator species, meaning they depend on vernal pools for all or part of their life cycle (Kenney and Burne 2001; Colburn 2004). In Michigan, indicator species include the Wood Frog and most mole salamanders (*Ambystoma* spp.) such as the Blue-spotted Salamander, Spotted Salamander, Marbled Salamander, Unisexual Salamander, and Small-mouthed Salamander. These species are reliant on vernal pools for breeding, with their eggs and larvae developing in these wetlands before dispersing into upland woods as juveniles (Kenney and Burne 2001; Colburn 2004; Craft et al. preprint). Most mole salamander species are relatively long-lived, a necessity due to the wide variation in reproductive success associated with breeding in seasonal wetlands like vernal pools. The longer lifespans of mole salamanders provide a safeguard against catastrophic reproductive failures but also underscores the importance of ensuring these salamanders and their vernal pool habitats are protected (Taylor et al. 2006).

Facultative Species - Other species that use vernal pools during part of their life cycle but do not require them for survival are known as facultative species (Kenney and Burne 2001; Colburn 2004). Amphibian facultative species include the Eastern Tiger Salamander, Red-spotted Newt, Eastern American Toad, Fowler's Toad, Eastern Gray Treefrog, Cope's Gray Treefrog, Northern Spring Peeper, Midland Chorus Frog, and Green Frog (Colburn 2004; Luymes and Chow-Fraser 2022; Craft et al. preprint). The Eastern Tiger Salamander, though a mole salamander species

1. Fowler's Toad in dune complex.
2. Midland (Western) Chorus Frog during spring breeding.
3. A gravid, female adult Eastern Newt returning to pond

All three species are facultatively associated with vernal or ephemeral wetlands.

that often utilizes vernal pools, can sometimes coexist with predatory fish, and thus is not an obligate vernal pool species. Vernal pools play an important role for Blanding's Turtles as a source of food, hydration, and shelter, particularly during their long, seasonal migrations (Markle and Chow-Fraser 2014). The Blanding's Turtle, as well as the Spotted Turtle and Eastern Snapping Turtle, will spend considerable amounts of time in vernal pools in the spring foraging for amphibian eggs, invertebrates, and other organisms (Kenney and Burne 2001; Harding and Mifsud 2017; Coury 2022). Other reptiles that use vernal habitats in a facultative way include the Northern Water Snake, Northern Ribbon Snake, and Eastern Garter Snake (Kenney and Burne 2001; Colburn 2004).

Threats to vernal pool herpetofauna – Vernal pools, and the herpetofauna they support, are vulnerable to a myriad of threats. Pools themselves and their surrounding habitat are frequently lost to the conversion of habitat for agricultural or development purposes (Windmiller and Calhoun 2008; Baldwin and deMaynadier 2009). Sedimentation, soil erosion and compaction, and runoff can detrimentally alter the water quality and quantity of vernal pools for herpetofauna (Colburn 2004; DeMaynadier and Houlahan 2007). Breeding amphibians are the most negatively affected as their skin is highly permeable, exposing them to any pollutants in the water. Hydrological changes may also increase the mortality of their offspring (Hecnar 2004). Activities that open the canopy around pools can lower humidity levels and degrade the habitat for many



1. Cross section of a vernal pool complex and a timeline of herpetofauna and forest management actions. Consider which species are likely present and their life stages when planning management actions.

amphibian species (Skelly et al. 2002; DeMaynadier and Houlahan 2007). Vernal pool herpetofauna are frequently on the move, traveling between pools and the surrounding landscape. However, these landscapes are increasingly fragmented by the construction of roads and human developments. The isolation of vernal pools can restrict gene flow between populations of herpetofauna, potentially leading to genetic drift and inbreeding (Gibbs and Reed 2007; Gabrielsen et al. 2013; Homola et al. 2019). Fragmented landscapes also jeopardize migrating herpetofauna through increased road mortalities (Windmiller and Calhoun 2008; Craft et al. 2023). Climate uncertainty may impact some vernal pools, causing them to dry out earlier in the year due to increasing droughts and precipitation shifts, disrupting amphibian life-

cycles (Cartwright et al. 2022). Lastly, gaps in the detection and protection of vernal pools further increase the difficulty of conserving pool associated herpetofauna (Baldwin and DeMaynadier 2009).

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

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.



1. A Unisexual Salamander part of a long-term study, migrating to the vernal pool to breed.



2-3. Vernal pools in forested areas are sensitive and important breeding and foraging grounds for many species of amphibians, such as the Wood Frog, which lay communal egg masses.

from none at all to woody species, marsh species, or aquatic species. Vernal pools may be identified with aerial photography, but the confounding potential of small pool size, forest cover, shadows, and wetland connectivity necessitates confirmation with ground surveys (Calhoun and Klemens 2002; DiBello et al. 2016).

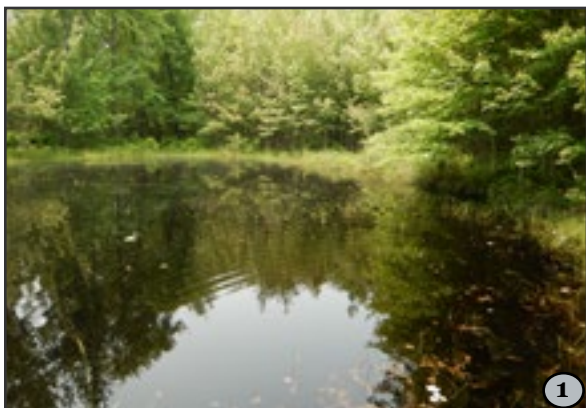
Do not impact the pool

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.

Identify vernal pools – Accurate identification of vernal pools is the first step towards conserving them and the species they support. Vernal pools are seasonal, relatively small bodies of water found in forested depressions throughout Michigan (Colburn 2004). Size is variable, but vernal pools are generally smaller than 2.5 acres and less than 3 feet deep. In the spring, they fill with snowmelt, runoff, and groundwater before reaching a maximum size and then dry through the summer and fall. Filling can also occur in the fall and winter. Periodic drying prevents the establishment of fish populations, which would otherwise predate amphibian eggs and larvae. Water is confined to the pool and does not flow continuously through an inlet or outlet. When dry, the pools reveal hydric soil substrates typically covered in leaf litter. Vegetation in vernal pools vary





1. Vernal pools can be a significant source of amphibian reproduction in forested landscapes.

2. While not a vernal pool specialists, Eastern Red-backed Salamanders are often found along the edge of these systems. Here several recently hatched young emerge from their eggs under a log along the vernal pool edge.

3. Spotted Salamanders are, an obligate vernal pool breeder and can live 30-40 years or more.

depression or core critical area within a minimum of 100 feet – These areas should be protected from any management or development actions. The depression should be defined by the size of the vernal pool during the spring high water mark. When dry, this area can be identified by the presence of leaves that have been darkened and stained by the water/silt, as well as by water marks on nearby trees and rocks. Preserving the pool basin itself is critical as construction alters water quality and quantity, damages buried eggs and larvae, and results in the removal of vegetation used by amphibians for egg-attachment (Calhoun and Klemens 2002). 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; DeMaynadier and Houlahan 2007). The protection of this core buffer area is essential for the maintenance of water quality, availability of shade and leaf litter, and provisioning of moist, upland forest floor conditions (DeMaynadier and Houlahan 2007).

Aim to protect a wider critical zone (600-1,000 feet)

- 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), while Wood Frogs disperse as far as 1,500 feet from vernal pools (Berven and Grudzien 1990). Protecting the terrestrial critical zone of 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 et al. 2005). The importance of this terrestrial buffer zone surrounding vernal pools is often underestimated. However, this area is essential habitat for the entire juvenile and adult herpetofauna populations for feeding, growth, maturation, and maintenance (Semlitsch 1998).

Simply preserving the 100-foot core area without this critical life zone does not adequately protect vernal pool associated herpetofauna (Semlitsch 1998; DeMaynadier and Houlahan 2007). Management or development actions within this buffer should not impact greater than 25% of the area to reduce the risk of local population declines (Calhoun and Klemens



1. Protection of vernal pool edges are critical to preserving population viability and community composition.



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

addition to critical zones, 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). When possible, excluding roads from the pool's buffer, particularly roads with moderate to high projected traffic volume, can help maintain habitat corridors (Fahrig et al. 1995; Colino-Rabanal and Lizana 2012). As vernal pools are an inherently vulnerable habitat, corridors are necessary to counteract the extinction of local populations through the colonization of new sites (Gill 1978). These corridors will help ensure the long-term viability for salamander and frog populations. Consult a professional herpetologist or wildlife biologist for recommendations specific to the wildlife communities present at a site.

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.

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. Additionally, canopies provide an input of leaf litter, which serves as the base of vernal pool food webs (Calhoun et al. 2014). Forest canopy cover in and near vernal pools influences the presence and abundance of salamander and frog species (Skelly et al. 1999; Skelly 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. Though clearcutting is not compatible with the preservation of vernal pools, selective harvesting can coexist with effective herpetofauna habitat management (DeMaynadier and Houlahan 2007; Calhoun et al. 2014). Suitable forest habitat surrounding vernal pools must maintain a minimum of 50% canopy cover (Patrick et al. 2006; DeMaynadier and Houlahan 2007).

Maintain habitat corridors - In

1. Planning and site evaluations are necessary to effectively highlight project impacts and minimize threats to species identified through baseline surveys.

2. Preservation of critical shoreline habitat for Wood Turtles is necessary to provide nesting areas for them and other riverine turtle species.

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 that address hydrologic processes, provision of woody materials for egg attachment, establishing native vegetation, and presence of herpetofauna, should be established at the onset of pool planning to improve the 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 individuals to ensure successful pool restoration and creation that is responsive to specified criteria. The creation of man-made vernal pools, when done correctly, can sustain similar ecological function and herpetofauna diversity as natural vernal pools (Korfel et al. 2009). Restored and created pools can provide important ecosystem services; however, the 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).

Streamside/Riparian Zone Harvest

Avoid disturbing riparian zones and adjacent terrestrial areas – Harvesting trees along riparian areas can reduce channel stability, tree canopy, and amount of large woody debris (Murphy et al. 1986), which reduce herpetofauna habitat suitability. Streamside harvest can also reduce tadpole density and tadpole habitat quality for



1-2. Forest harvest practices should consider the holistic impacts and incorporate BMP measures to improve the quality of these sites for herpetofauna.

Some companies have adopted best forestry practices that include reducing harm to herpetofauna.

the bank, prevent severe erosion, and reduce the colonization of 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 and savanna ecosystems in the Midwest, making fire a useful tool for managing the vegetation structure of native and invasive plants. Fire has influenced the ecosystems of the Great Lakes for thousands of years, occurring both through natural ignition and intentional human manipulation. This resulted in the vegetation community assemblage observed on the landscape during European settlement and even in areas today. Records of fire scars in the Red Pine Barrens of Michigan's northwestern Lower Peninsula date back over 500 years, revealing a history characterized by somewhat

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 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 et al. 1984; Lee et al. 2004). Eliminating disturbance in these areas can maintain 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 stabilize

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 and essential BMP to minimize the impact of fire on refugia.



frequent, low-intensity fires (Stambaugh et al. 2024). In contrast, peatlands in the Upper Peninsula have undergone less frequent but more severe fires, with low intensity fire years ranging from 7-31 years, to much longer stretches of nearly 500 years between intense burns (Sutheimer et al. 2021; Uhelski et al. 2023). Fire frequency within the southern Lower Peninsula was much higher, given the large swaths of prairies and savannahs that extended across the region. More intensive human colonization of this area also contributed to an increased frequency of fire events, since early settlers often administered burns to manage for agriculture, hunting, and travel (Stambaugh et al. 2024). It's important to understand that these management strategies were conducted at a time when massive, contiguous landscapes occurred across Michigan. Presently, much of

southern Michigan contains fragmented and isolated landscapes, where use of fire as a management tool is still common but requires novel critical considerations.

Prescribed fire can be used to restore native plant communities and can be valuable for improving habitat suitability (e.g., maintain open areas, which can facilitate basking) for some Michigan herpetofauna (Mushinsky 1985; Semlitsch and Bodie 2003; Setser and Cavitt 2003; Harner and Geluso 2011). Modern prescribed burning is commonly used by land managers to set back succession and maintain disturbance-adapted communities, but its application in today's fragmented landscape requires greater caution. While fire can be an effective management tool, it can also ignite contrasting philosophical opinions regarding how landscapes should be managed. This can include a difference in perspectives on natural succession, the timeframe for a landscape's restoration, and suitable management methods that are in the best interest of not only the vegetative community, but also the wildlife species that occupy it.

Fire can be useful in reducing the density of a mid-story canopy, such as that created by thickets of



2. An Eastern Garter Snake emerging from a recently burned habitat with some minor burns on scales.



1-2. Burning during dry, late fall or winter days when amphibians and reptiles are inactive and many underground, reduces their exposure to fire and harm. Active season burns, especially in June have the greatest potential ecological impact species like turtles.

strategy that can increase herpetofauna abundance and diversity from the creation of more thermoregulatory opportunities stemming from a reduction in ground cover (Moseley et al. 2003).

When conducting a prescribed burn, there are many important factors to consider. These include restricting the frequency of burns, conducting burns during windows of inactivity of rare and imperiled species (especially those that are long-lived and slow to mature), creating refuge areas, establishing burn breaks around critical herpetofauna habitat features, burning small areas infrequently, and determining appropriate burn intensity based on a site's present environmental factors. Actions such as pre- and post-burn inventory surveys and monitoring can be beneficial in formulating a prescribed burn plan that limits herpetofauna mortality. If a controlled burn is to be conducted as part of restoration or land management, the following points can

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 et al. 2007; Melvin and Roloff 2018), most Michigan herpetofauna **are not** adapted to frequent and intense burns. Although fire as a management tool has been shown to directly and indirectly impact rare and common herpetofauna, the full impact of fire on herpetofauna is yet unknown (Pilliod et al. 2003). Populations of vulnerable, rare, or threatened species can be negatively impacted by burns (Cross 2009; Gibson 2009; Woodley and Kingsbury 2011; Cross et al. 2015; Hileman et al. 2018; Harris et al. 2020a); however, loss of herpetofauna diversity in small, burned areas may be offset by greater diversity on a larger scale (McCleod and Gates 1998). When administered properly, prescribed burning can be an effective management tool as part of an overall holistic management and conservation



help reduce the associated negative effects to herpetofauna and other wildlife.

Planning Considerations

•**Landscape Level Analysis:** Landscape level analysis on fire regime history and management areas in need of burning should be considered, which can include utilizing GIS analytical tools that highlight these disturbance-adapted ecosystems (Cohen et al. 2021). Allowing a prescribed burn to skip over areas where the fire naturally extinguishes and limiting work in areas of refugia can help protect habitat features herpetofauna may use.

•**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 2012b). These species require several burns, or a fire with the heat needed to kill the stems and roots, which may result in the death of buried or burrowed herpetofauna. Some sites should avoid the 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 fire 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 when planning to reduce the negative impacts of fire. 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. **For a detailed discussion of prescribed fire related impacts, see Section 3: Prescribed Fire.** Some species, such as Northern Ring-necked Snakes, 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

1-2. Burning in early spring when species like the Eastern Massasauga Rattlesnake and Eastern Box Turtles are emerging from hibernation can have a catastrophic impact on populations of vulnerable species.

These species are slow to move and even conducting walkdowns to look for animals would have limited success due to difficulty in detection. Use of dogs to aid in finding turtles prior to a burn would be a request for burning in early spring once animals are active.

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 HRM Species Overview webpage (<https://www.herprman.com/species/>).

•**Account for undetected rare species** – Rare herpetofauna populations can be difficult to detect and are particularly sensitive to burns, as they are not likely to recover quickly and generally do not have adaptations that help them withstand fire. The loss of individuals can be particularly devastating for species with delayed sexual maturity. The loss of only a few adults within select species can dramatically affect population viability. Eastern Box Turtles are an example of one such species. At present, it is often assumed that post-fire surveys are an effective means of assessing the burn-induced mortality of Eastern Box Turtles; however, the average detection probability 48 hours after a burn event is “low and highly variable among observers”, even for turtles outfitted with radio transmitters (Melvin and Roloff 2018). In response to the presence of fire, Eastern Box Turtles are known to actively negotiate the flame front and bury themselves (Melvin 2017). These behaviors expose turtles to the harms of the fire. Buried turtles remain underground for up to 12 hours and attempt to relocate to unburned areas after resurfacing, while still suffering from burn-induced wounds, oftentimes resulting in subsequent mortality (Melvin and Roloff 2018). It may be necessary to assume prescribed burn techniques are more harmful to turtle populations than surveys might indicate. Incorporating these considerations of rare species into plans can reduce losses. Prior to burning (or the use of other





1. Salamanders are impacted when spring burns are conducted and the leaf litter is eliminated. This is more problematic when they have already emerged for the spring and are within the leaf litter.

2. Though rather quick, Blue Racers are not immune to burns and fire can enclose an area which can be extra problematic even for highly mobile species.

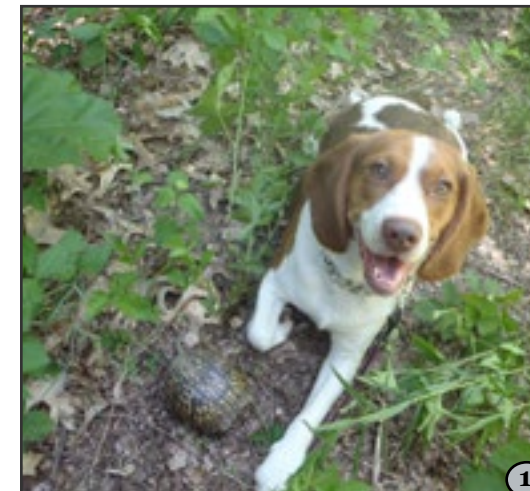


high-impact management methods such as mowing) in known rare or sensitive herpetofauna habitats, managers should carefully consider whether the result will benefit population viability and whether the actions can be modified or timed to reduce or eliminate mortality. Any management plan that threatens the local or large-scale destruction of vulnerable native animal populations should be reassessed.

•Conduct burns during seasons when herpetofauna are less at 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, the elements, and 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 2009a; Harris et al. 2020a). 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 2009a). Spring soil temperatures lower than 46°F at a depth of approximately 4 inches indicate a high probability that Eastern Massasauga Rattlesnakes are still underground (Hileman et al. 2018). 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 for maintaining population viability. In June of their second active season, neonate Eastern Box Turtles remain very close to their natal openings in open canopy habitat (Laarman et al. 2018). However, by July, the neonates often disperse into nearby forests and wetlands. This suggests that burns of open canopy habitat should occur after July.

•Wildlife Clearance and Relocation: Rescue and relocation of herpetofauna to suitable sites outside of a designated burn area should be conducted if burns are to occur during the active season where rare and protected



1-2. WDD with an Eastern Box Turtle helping to document species occurrence and distribution.

3. Avoid burning near wetlands especially vernal pools. The loss of leaf litter in vernal pools and reduction in water quality negatively impact egg development.

herpetofauna occur. This practice should be integrated into all burn plans and should emphasize species that are long-lived, slow to mature, and have limited mobility. Incorporating professional wildlife detector dogs (WDDs) to detect species should be strongly considered.

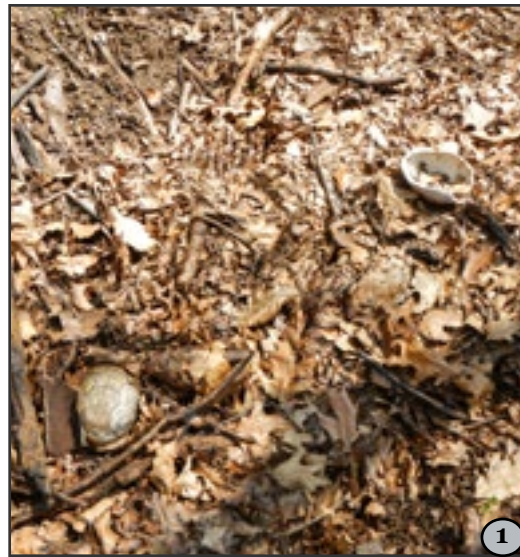
•Monitor herpetofauna and wildlife communities pre- and post-burn – Incorporate wildlife monitoring as a metric for measuring restoration success. This will provide a more comprehensive approach to understanding the benefits and timing of prescribed burns and minimize future impacts to amphibians, reptiles, and other sensitive wildlife. Land managers should consider that traditional post-burn survey methods may not accurately reflect the mortality of herpetofauna such as the Eastern Box Turtle (Melvin and Roloff 2018).

•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 rely on the presence of adequate cover. The loss of leaf litter in vernal pools and reduction in water quality negatively impact egg development and species selection of already imperiled sites (McDonald et al. 2018). Burning can create unsuitable habitat conditions for these species and exposes them to the risk of direct mortality. If wetland or adjacent upland communities are adapted to disturbance 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).

•If burning prairie fens is necessary- Pre-and post-burn rescue and relocation efforts, along with species inventory surveys, are critical since Michigan prairie fens support numerous rare species such as the Eastern Massasauga Rattlesnake, Blanchard's Cricket Frog, Spotted Turtle, and Blanding's





Turtle. Use of WDD should also be considered if feasible. Burns should be administered in late fall or early spring when groundwater discharge is high, the peat surface is fully saturated, there is no drought stress, and soil moisture is high to prevent smoldering, peat ignition, and hydrologic disturbances. Use low-intensity, slow-moving fires, and avoid head fires. Focus burning on the fen margin rather than the fen interior and leave unburned patches to serve as refugia. Avoid burning known hibernacula or overwintering sites. Do not burn during mid-to late summer or during dry periods when water tables are low and the peat surface is dry.

•**Create refuge areas** – Creating brush piles, snags, or other small areas with vegetative cover that 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, select frogs, snakes, and Eastern Box Turtles hide under cover objects and within the duff on the forest floor. By not burning these essential habitat components, these animals are given some protection from fire. There are both natural and mechanical methods for establishing breaks, though natural breaks are encouraged as these do not result in greater landscape disturbance. Maintain unburned refugia and establish firebreaks around critical habitat features like rocky outcrops, downed logs, wetlands, and known hibernacula.

•**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 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 in 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



1. Burns in the early season or in areas of thick duff that support turtles can have a high rate of mortality. Creating burn breaks around a valley can reduce harmful impacts.

2. Avoid burning brush piles as they are important burn refugia for herpetofauna and can become a sink if allowed to burn.

1. Burn breaks protected refugia and can avoid mortality events of Eastern Box Turtles. This singular burn resulted in seven adult female turtles succumbing to death from burn injuries.

a diverse native plant community (Schurbon and Fauth 2003). Since most wildlife species respond differently to burned areas and to the time elapsed since the last burn, a burn schedule should aim to create a matrix of burned areas varying in age (Fuhlendorf and Engle 2004; Wilgers and Horne 2006). Burn small parcels infrequently and adjust the intensity based on fuel loads and weather to avoid severe soil heating.

•**In areas with herpetofauna that may be able to escape the site, create slow-moving fires** – Although most herpetofauna are not fast moving, some species, such as frogs, have been known to flee from the sound of fire (Grafe 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 is 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 structures can protect herpetofauna that are not able to quickly flee an area; however, fire can be especially detrimental to the Eastern Box Turtle. These turtles, even if partially buried, are often exposed directly to fire during a burn, resulting in life threatening injuries if not direct mortality. Alternatives to fire should be considered in areas where the Eastern Box Turtle is present or are likely present (MWPARC 2009a).

•**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 are not fast-moving, fires should be executed to burn at cooler temperatures (MWPARC 2009a; Harris et al. 2020a). 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



2. Pickerel Frogs are sensitive to chemicals and negatively impacted from fire retardant.





1. When impacts from prescribed burn to rare species occur and are avoidable, mitigative measures should be required regardless of the practitioner.

2. Consider the ecological need of the burn. If the botanical composition provides the functions and values needed consider other management.



even in dilute concentrations (Pilliod et al. 2003). Instead, use leaf blowers or rakes to create fire breaks (MWPARC 2009a).

•**Documentation of findings** – It is imperative that data on dead and living amphibians and reptiles be recorded as part of any burn management activities. Historically, most groups have not documented the responses of wildlife to prescribed fires. However, groups like the 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.

Mitigate for Mortality – If “take” occurs during a private or public burn when it could have been avoided, the involved individuals, organizations, and agencies should be held accountable. In situations where long-lived species are killed and populations are negatively impacted (often anything above 4% annual mortality), mitigation should be required to offset the loss of critical landscape species and ecosystem function. Efforts like headstarting and repatriation efforts should be funded in part through a mortality mitigation fund where death attributed to management techniques, like burns, are offset through reintroduction efforts. This concept could also be applied to the infrastructure sector as well, where mortality is not addressed and impacts known or avoidable.

Avoid burning herpetofauna nesting sites- Burning of areas that are occupied by rare turtle species should be thoughtfully considered since severe fires can affect the thermal and moisture regimes of soil. This can be detrimental to the development of eggs since altered soil dynamics can negatively impact the suitability of nesting sites. A study focusing on the eastern shoreline of Georgian Bay, Lake Huron, determined that hatch success was nearly 20% lower in burned rock-barren habitat as compared to unburned rock-barren habitat (Markle et al. 2024). Mitigate this by creating burn breaks around areas known to contain nesting habitat.

Mowing

Mowing is a tool for maintaining early successional habitat that requires careful timing to minimize impacts. When mowing, it is most important to mow infrequently and to avoid mowing during turtle nesting season as well as during the peak foraging or migration season of other herpetofauna. Implement mowing operations to align with the phenology of local herpetofauna to ensure that mowing is conducted during times of peak inactivity.



1. Brush mowers can be an effective tool for restoration, but if used when herpetofauna are active or emerging from overwintering, can harm and kill species.

2. Avoid mowing during peak active period and consult with herpetological experts to minimize threats.



Best Practices:

- Avoid mowing during peak turtle nesting (late May–July), amphibian breeding migrations (spring/fall), and foraging seasons.
- Use a high-cut setting (10–12 inches minimum) to allow herpetofauna to escape and find refuge. A minimum mower deck of 10–12 inches from the ground should be used.
- Mow from the center of a field outward, or in alternating strips, to provide escape routes and avoid trapping wildlife. Mowing should start in the center of the target area, gradually moving outwards while ensuring to avoid cover objects or moving up and down an area to avoid trapping. **For a more comprehensive discussion on mowing, including detailed information**

regarding proper mowing techniques and practices, see Section 8: Development Techniques

Managing with Animals

Wildlife and livestock can be utilized in a non-invasive manner to manage the landscape and set back succession to create favorably habitat conditions for herpetofauna. Fens, wet meadows, and other high quality habitat for herpetofauna can be maintained and restored by the grazing of large herbivores (Middleton et al. 2006; Reshetiloff 2009; Cornelissen 2017). Many large herbivores have been eradicated from the landscape, including the American Bison (*Bison bison*), which used to inhabit southern Michigan and played a key role in facilitating the spread of woody vegetation into important habitats (Hornaday 1889). The reintroduction or management of this large, keystone mammal on certain landscapes can support herpetofauna populations, as they are ecosystem engineers that help sustain diverse plant and arthropod populations in prairies through their grazing and wallowing habits (Collins et al. 1998; Nickell et al. 2018). The creation of wallows compact the soil and fill with water following rain events. The bison then either expands or abandons these flooded wallows (Barkley and Smith 1933). Abandoned, inundated wallows have been used by frogs and toads for breeding habitat in Kansas (Gerlanc and Kaufman 2003), while dry wallows are thought to have provided suitable sites for Eastern Box Turtle nests.

Rewilding

The Illinois Rewilding Act (Public Act 104-0062;





1. Historically, Woodland bison grazed and set back succession in the prairie landscapes of Michigan.

2. Surrogate species for bison such as domestic sheep are effective means of setting back succession and to help control these nuisance plant species.

originally House Bill 2726) establishes a state-level framework authorizing the Illinois Department of Natural Resources (IDNR) to incorporate rewilding as a conservation and land management strategy. The Act was signed into law in August 2025 and became effective on January 1, 2026.

For the purposes of this Act, rewilding is defined as a management approach intended to restore ecosystems to a more natural, self-sustaining condition. This approach emphasizes active restoration of ecological structure and function, moving beyond passive conservation measures.

Implementation of rewilding under this framework includes restoration of lands to conditions that approximate historical ecological states, based on best available science. This may include re-establishment of native vegetation communities, hydrologic regimes, and habitat connectivity.

The Act supports the reintroduction and recovery of native species, with emphasis on keystone species and apex predators due to their ecological importance in maintaining system function. Species that contribute to ecosystem engineering and trophic regulation are specifically recognized.

Rewilding efforts are also intended to restore natural ecological processes, including disturbance regimes and species interactions such as flooding and predation, using appropriate historical baselines where applicable. The Act does not establish new regulatory requirements but provides a policy framework to guide future program development, planning efforts, and potential legislation related to habitat restoration and natural resource management.

Managed Grazing

The use of livestock to setback successional advances through grazing provides a critical and natural alternative to more anthropogenic management methods. The implementation and planning of this practice vary based upon the landscapes present, management goals, and site conditions; however, livestock grazing has proven to be an effective and natural tool for managing succession.

•Implementation: Goats and sheep are most commonly used, with goats being particularly effective on brushy vegetation due to their broad dietary range. Goats and sheep are most traditionally used and work best in loose soils (Dressing 2003) . Goats will also consume a range of food. When implementing livestock to manage for succession, goals can be made to target specific growth stages and vegetation types, as well as to either slow or accelerate succession based upon the land manager's desires.

•Planning: Grazing plans should be tailored to specific vegetation objectives, livestock species, stocking density, and timing to achieve desired structural outcomes without causing soil compaction or excessive disturbance to ground-dwelling herpetofauna



Tom Beauvais

1. Fires that occur before Eastern Smooth Green Snakes emerge from hibernation in the spring can lessen the impacts of burns 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 are underground reduces their exposure to fire.

(Agostini and Bilenca 2023; Dressing 2003; Larson 2014; Schmutzer et al. 2008).

Domestic goats, a much more accessible and feasible herbivore alternative to the American Bison in most situations, are woody plant specialists (Glasser et al. 2013). Goats are adept at converting shrub-infested landscapes into grassy prairies and meadows more suitable for herpetofauna. Goats will consume brush and weeds before converting them into nutrients that cycle through the ecosystem (Hart 2001). Clearing out shrubs allows forbs and grasses to emerge as they are no longer shaded and out-competed by woody plants. Goats are resistant to several plant toxins and anti-nutritive factors, allowing them to consume a wide variety of plants that cows are unable to eat, including tree bark (Hart 2001). These abilities allow goats to successfully restore and maintain wetlands and other habitats for the benefit of herpetofauna (Reshetiloff 2009). The grazing of other livestock, such as cattle, can potentially benefit herpetofauna as well, particularly those occurring in open-canopy habitats (Howell et al. 2019). However, grazing intensity, particularly by cattle, must be monitored since overgrazing can lead to permanent reductions in biodiversity (Middleton et al. 2006; Smalling et al. 2021).

Small mammals can also positively influence herpetofauna richness and density. Often, herpetofauna will use the burrows created by small mammals as shelter from unfavorable climatic conditions or as a refugia from predators (Gálvez Bravo et al. 2009; Buyandelger et al. 2022). Burrowing small mammals in Michigan, such as

the Groundhog (*Marmota monax*), are ecosystem engineers that provide important habitat features. The protection of a steady population of burrowing mammals on a landscape is beneficial for herpetofauna.

Animals can aid herpetofauna not only in the manipulation of the landscape, but also in active conservation and management practices using WDDs. These dogs can be used in a herpetofauna inventory capacity but can also be used to locate herpetofauna for clearance purposes (Powers 2018). Their heightened olfaction sense allows WDDs to detect herpetofauna more efficiently than humans can on their own (Heaton et al. 2008; Nussear et al. 2008; Kapfer et al. 2012). The use of WDDs is growing, particularly to locate at-risk turtle species like the Eastern Box Turtle, for academic research purposes (Kapfer et al. 2012; Harris et al. 2020b). However, WDDs can also provide immense benefit for herpetofauna through the applied usage of surveying and clearing species, such as the Eastern Box Turtle, that are vulnerable to management techniques like mowing and prescribed burns (Harris et al. 2020a).



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

2. Where possible, use alternative controls including beetles, where invasive species are limited.

Lakes, Ponds, and Rivers

Lakes and ponds are often managed for multiple reasons including, for 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 the timing and technique of maintenance activities can benefit herpetofauna.

Aquatic Weed Control

Aquatic weeds can be native plants, which are an important part of aquatic ecosystems and 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 aquatic weed control are detailed below.

Control nutrient inputs - The most effective and sustainable aquatic weed control is through the management of nutrient inputs, usually nitrogen and phosphorous (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 the growth of aquatic weeds.

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

Avoid mechanical aquatic weed harvesting - Removal of aquatic vegetation eliminates essential habitat for larval amphibians and hatchling turtles and reduces available prey items for multiple species. Mechanical aquatic weed harvesting and cutting also displace, and often kill, turtles and amphibians (Booms 1999). Turtle



1. Blanchard's Cricket Frogs are very sensitive to chemicals and no testing has been conducted to determine the LD50 on most amphibians.

2. Eastern Newts are aquatic for a majority of their lives. This makes them more susceptible to chemicals used for the treatment of aquatic plants.

fragments have been observed in the chopped plant material (Mifsud personal observation 2022). 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 and individuals under the surface of the water which are difficult to see.

Avoid chemical control – Herbicides can harm amphibians and reptiles as well as other non-target plant and animal species (Getsinger et al. 2008). Herpetofauna are 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 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 et al. 1999; Hayes et al. 2002b; Hayes et al. 2003; Coady et al. 2004; Howe et al. 2009; Relyea and Jones 2009). Unfortunately, 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.

If avoidance is not possible, carefully time aquatic weed control – If suitable management of nutrient inputs is not possible, carefully timed herbicide application or mechanical aquatic 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, consume large amounts of aquatic plants. Creating suitable habitat conditions for these species may help to control aquatic weed growth. Encouraging native wildlife and maintaining healthy, diverse ecosystems is an effective strategy for reducing and preventing nuisance aquatic weeds.

1. Timing of drawdowns can have a significant impact on community composition. Conducting drawdowns during winter when most species are inactive can result in high rates of mortality.

2. Wood Turtle mortality associated with a drawdown event that occurred in late winter.



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 et al. 2004) to:

- 1) Assume every water body is contaminated.
- 2) Clean and dry boats and equipment between trips.
- 3) Decontaminate equipment following each use which can reduce the likelihood of introduction of invasive vegetation to other water bodies.

Lake and River Level Alteration

Wetland and lake levels are altered via drawdowns and inundations to manage for aquatic vegetation, reduce structural damage to marinas, boat docks, and launches, and increase habitat for waterfowl and other wildlife, (Ducks Unlimited 2005). However, depending on the timing of these management techniques, herpetofauna numbers can be significantly reduced. 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). **Dams and impoundments represent a more permanent form of lake and river level alteration, creating upstream reservoirs that fundamentally change water levels, flow patterns, and habitat conditions for herpetofauna.** The following management recommendations can provide information about when and how to alter water levels with minimal impacts to amphibians and reptiles. **For a detailed discussion of Dam related impacts and threats, see Section 3: Dam Maintenance, Drawdowns, and Refill Operations.**

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 et al. 1997; Standing 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



1-2. Drawdowns, even for restoration, must be timed to reduce threat and harm to wildlife. This winter drawdown resulted in 23 Midland Painted Turtles dying.

3. When drawdowns are scheduled to occur while species are active, wildlife clearance should be conducted.

mortality (Kaltenecker 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 late-summer through early-fall – Drawdowns at any time of year can present risks to wetland herpetofauna; however, cooler temperatures and moist conditions in late summer through early fall (late-September to early -October based on region and local temperature conditions) can reduce stress on amphibians and reptiles. Most animals have metamorphosed by late summer (aside from a few species of amphibians which have multiyear larval development) and will have an opportunity to relocate to a suitable area for hibernation before a fall drawdown (Hoffman-Sailor West 2003); however, drawdowns between March and July (overwintering emergence and peak active season) 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. Although drawdowns conducted in early fall are generally less impactful, any management action that substantially alters the landscape poses inherent risks to wildlife, regardless of when it is implemented.

Do not conduct mid-autumn and winter drawdowns – Mid-autumn and winter drawdowns (October through early April)

risk displacing amphibians and reptiles that are searching for environmentally-stable overwintering sites and expose hibernating individuals to conditions and temperatures that cause them to freeze or desiccate and die (Bodie and Semlitsch 2000a; Bodie and Semlitsch 2000b). These drawdowns also kill littoral zone vegetation, which provide habitat for herpetofauna, by exposing their roots to freezing conditions. Late summer and early fall drawdowns pose less of a risk to herpetofauna but can still be impactful to many organisms that depend on the littoral zone. Water level drawdowns conducted during late fall and winter can be particularly detrimental to herpetofauna hibernating within the sediment of lake and riverbeds, causing hypoxia and direct exposure to freezing temperatures. If structurally necessary, an expert herpetologist must be involved to assist with wildlife clearance and mitigative measures accounted for due to likelihood of mortality

Drain water towards small pools, which will remain – When planning for a drawdown, identify 'low' areas within the area to be drained,



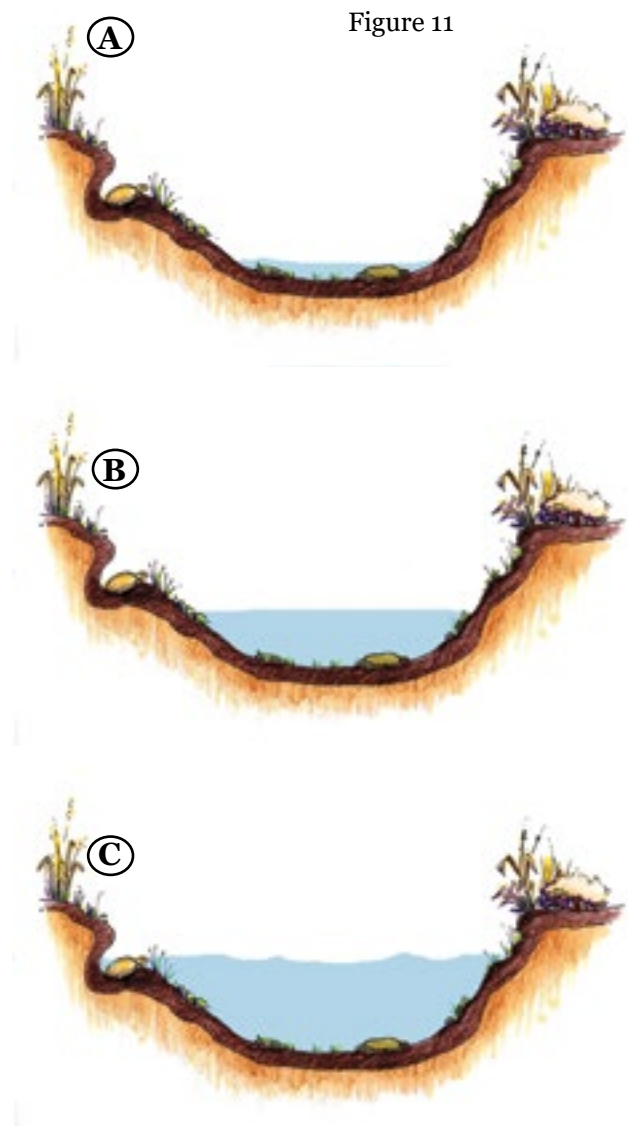


Figure 11

Figure 11. 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).

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 locations 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. Reduced surface water levels caused by drawdowns can also lower the surrounding groundwater tables, putting species that rely on stable subsurface moisture, such as snakes using crayfish burrows for overwintering, at an elevated risk of desiccation or freezing (Harvey and Weatherhead 2006; Markle et al. 2020).

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 professional herpetologist or wildlife biologist with demonstrated experience trapping and sampling for herpetofauna prior to the drawdown, when

herpetofauna are still active and foraging. State and/or Federal permits may be necessary to conduct amphibian and reptile recovery and translocation.

Maintain water in newly inundated areas – Drawdowns can dry ephemeral pools and other shallow ponds utilized by amphibians as breeding habitats, resulting in mass larval mortality and disrupting important life cycle processes (Swan et al. 2015). It is critical that water is maintained for herpetofauna that require water for the duration of egg and larval development. 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**

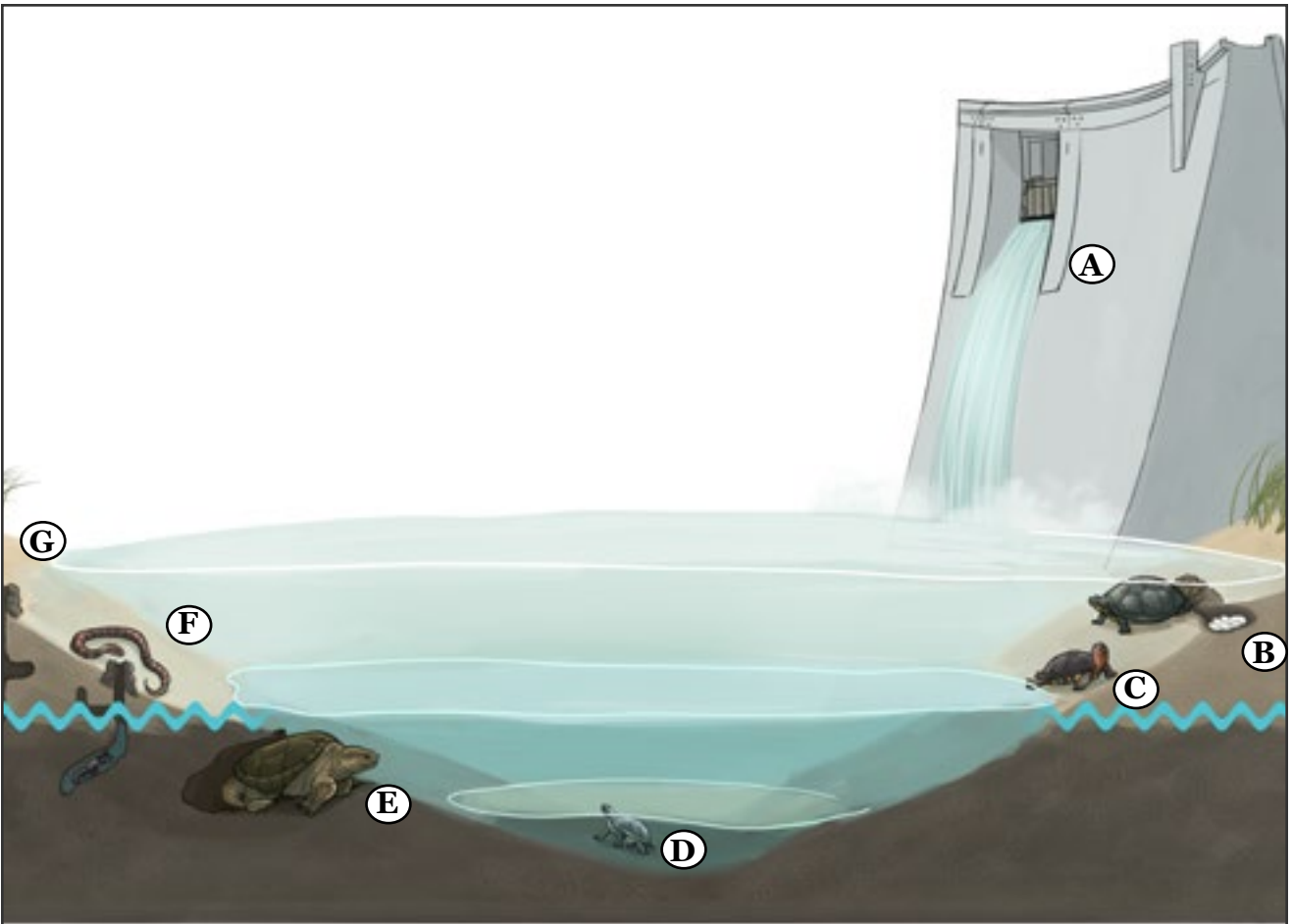


Figure 12.

- A. Dam withdrawal or refill has a significant impact on the surrounding landscape and species that rely on these habitats.
- B. Refill of impoundments when turtles have nested or during the nesting season can impact available nesting sites and potentially drown developing turtles.
- C. Wildlife can adapt to the established base level hydroperiod as shown with blue wavy line.
- D. An almost complete lack of water will cause what little water is left to freeze solid. 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.
- E. Late fall and winter draw downs can expose hibernate species in the underwater banks of the wetland.
- F. Snakes and other herpetofauna rely on crayfish chimneys as overwintering sites and if water levels are increased these species can drown in chimneys.
- G. Significant inundation times outside of active season for herpetofauna can result in high rates of mortality.



1. Blanding's Turtles often hibernate in shallow water. They can sometimes remain partly active under the waters surface. Drawdowns during winter can expose them freezing temperatures and death.

to provide for the life cycle of these species (Paton and Crouch III 2002).

Lake Refill

Inversely, the refilling of impoundments can also negatively impact herpetofauna, largely tied to timing, refill rate, depth, and water quality. If a refill is conducted while herpetofauna are hibernating along the shore of an aquatic system that is not inundated, the increase in water levels can drown these animals. If water levels are refilled too quickly, even if species have begun to become active, they may not be able to seek terrestrial shelter in time. If water bodies are refilled too high, overwintering species such as Eastern Massasauga Rattlesnakes, garter snakes, salamanders, and frogs that utilize crayfish chimneys can

become flooded and drowned. Additionally, the introduction of warmer water, such as stormwater runoff or rapid influxes during filling, can significantly reduce dissolved oxygen levels, potentially resulting in acute stress or mass mortality events for aquatic and semi-aquatic species.

This can be avoided by incorporating seasonally appropriate consideration for aquatic and nearshore wildlife. Avoid refilling these systems until April or when temperatures are above 40°F. Refill at a slow enough rate to account for slower moving wildlife. Consider natural melt rates and thaw recharge when setting refill rates. When refilling, also consider adjacent upland and riparian habitat. Do not refill too late in the season, where turtles may have nested, which can occur as early as mid-May. It's important to note that recommended best management practices in this manual are designed specifically for herpetofauna and may not align with the phenological timelines of other wildlife species.

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



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

of exotic species can degrade local ecosystems (Patel 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 unintentionally be harmful to aquatic amphibians and reptiles. Northern Mudpuppies are particularly vulnerable to bycatch mortalities and have been found as bycatch in the Detroit River, resulting from a variety of fishing equipment, including setlines, minnow traps, fyke nets, eggmats, and cement anchors (Craig et al. 2015; Lennox et al. 2018; Neuderfer et al. 2024). Significant efforts have been made by fisheries biologist to reduce bycatch.

Hook and line fishing

Snakes, Northern Mudpuppies, and turtles are commonly impaled on hooks intended for catching fish or other game species. Removing the hook from these animals may not always be possible, in which hooks are sometimes left in the flesh indefinitely, affecting the survival of the individual. Herpetofauna, particularly Northern Mudpuppies, often ingest bait hooks, which can cause mortality (Lennox et al. 2018). For some species of turtles, females and larger individuals are more likely to ingest fishing hooks than males and smaller individuals (Steen et al. 2014). Fishing tackle should always be removed from the environment when finished, and tackle containing lead should always be avoided. To reduce the risk of causing additional harm to non-target amphibians or reptiles, hooks should not be forcibly removed when it is difficult to do so. Barbless hooks are preferred to barbed hooks when fishing, as they are easier to remove from hooked turtles. Circle hooks are more difficult to remove from turtles' mouths than J-hooks, and simply cutting the line is more likely to result in the turtle's survival than attempting to remove the hook (Parga 2012). The greatest risk longline fishing poses to turtles occurs when fishermen pull the line on board the boat without using a net, causing the hook to embed deeper into the turtle (Parga 2012). Instead, a net should be used, or the turtle should be lifted out of the water by its shell. Pliers should then be used to gently grab and twist the hook's shank, but if not possible, then the line should be cut as close to the hook as possible. Similarly, deep set hooks in Northern Mudpuppies are dangerous to remove, and the line should be cut as close

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 recruitment could be lost.



to the hook as possible in hopes that they can pass or shed the hook (Lennox et al. 2018). For shallower set hooks in Northern Mudpuppies, using pliers to gently grab the shank of a hook and twisting is the best way to try and free the individual.

Northern Mudpuppies are killed when caught by anglers due to the assumption that they are predators of some game fish species; this is a misconception, and the unnecessary killing of these animals should be discouraged. The use of salamanders and frogs as bait is also strongly discouraged. Commonly used species such as the Eastern Tiger Salamander, Spotted Salamander, Northern Leopard Frog, Pickerel Frog, and





1



2

1. Northern Leopard Frogs are very susceptible to chemicals in their environment.
2. During lampricide treatment USFWS incorporates a rapid response and triage for Northern Mudpuppies to reduce stress and mortality. Location data is also recorded.

Mink Frog are commonly used as bait despite experiencing population declines. Suitable artificial baits are available that provide a similar function without the need to harm herpetofauna.

Electroshocking/electrofishing

Although electrofishing has been documented as a safe way to sample aquatic salamander communities (Williams et al. 1981), this technique causes temporary paralysis in herpetofauna, much the same as it does in fish. One species frequently reported in bycatch during electroshocking is Northern Mudpuppies. When catching and releasing these and other herpetofauna, surveyors should be aware that shocked and stunned herpetofauna are subject to potential predation. 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. Short and long-term effects of electroshocking on herpetofauna remain largely unknown, with existing studies limited primarily to amphibians (Allen 2012; Carrera Suárez and Catchpole 2021; Morrison 2019).

Chemical Fish Control and Sampling

Chemical control, mainly through the use of rotenone, is used to remove diseased fish populations or non-native and native fish experiencing irregular population structure (Ball 1948; Turner 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 a useful tool for sampling fish in small areas (Turner 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 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 et al. 2007). Despite the potential negative impacts of rotenone on amphibians, the use of rotenone to remove fish from ponds can improve amphibian reproductive success (Walston and Mullin 2007). The following recommendations can help reduce the impacts of rotenone applications on amphibians and reptiles.

Apply rotenone or other chemicals to control fish late in the year– Applying



United States Geological Survey

1

1. Northern Mudpuppy eggs located on a concrete form used as part of aquatic monitoring. Mudpuppies are opportunistic nesters even using submerged doors and car hoods as nesting sites.

rotenone in the fall or winter after larval amphibians have lost their gills and move between aquatic and terrestrial habitats, will reduce the potential contact amphibians have with rotenone (Turner et al. 2007). However, Northern Mudpuppies, Western Lesser 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 the effects of rotenone on overwintering turtles, as this might be an issue during cold weather applications.

Do not apply rotenone in areas with rare herpetofauna –There is a high likelihood that any amphibians and reptiles which encounter 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 main control method for sea lamprey, an aquatic invasive species in the Great Lakes, which significantly affects native fisheries, such as lake trout. Rotenone 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 et al. 2003; Dawson 2003; Hubert 2003; McDonald and Kolar 2007; Neuderfer et al. 2024). **As detailed in Section 3: Chemical Use, Piscicides, the application of lampricides such as TFM and Bayluscide poses a significant and well-documented threat to non-target aquatic organisms, particularly amphibians** (Christie et al. 2003; Jubar et al., 2021; McDonald & Kolar, 2007). More recently, alternative treatments, including the use of pheromones, sterilization, trapping, and the use of barriers, have successfully reduced local sea lamprey populations (Lavis et al. 2003; Johnson et al. 2005; Bergstedt and Twohey 2007; Johnson 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 Northern Mudpuppies (Gilderhus and Johnson 1980; Boogaard et al. 2003; State of Vermont 2011). As a fully aquatic salamander, the Northern Mudpuppy, is exceptionally vulnerable to lampricide treatments that routinely cause large-scale, acute mortality events. Mortality rates of Northern Mudpuppies in lampricide treated streams can exceed 90%, which could take affected populations decades to recover due to their longevity and low reproductive rate (Matson 1998; Boogaard et al. 2003; Neuderfer et al. 2024). Also, long-term accumulation of lampricides in Northern Mudpuppies may





1. In general, fish hatchery ponds can make good amphibian and reptile habitat with little to no impact on fish. Species like Eastern Tiger Salamanders use these ponds for breeding. Because they can take 2-3 years to metamorphose they are often killed when maintenance is preformed.

Use alternatives, such as pheromones, trapping, and sterile male release – Alternative lamprey management includes use of pheromones to attract and trap lampreys (Wagner et al. 2006), injury-released chemical alarm cues which are chemosensory repellents (Imre et al. 2010), and sterile male release (Bergstedt and Twohey 2007). **Reducing reliance on lampricides requires scaling up these alternative control methods, including physical barriers (permanent and seasonal low-head barriers to block lamprey spawning migrations), enhanced trapping of adult lampreys, and sterile-male release techniques** (Hansen et al. 2016; Twohey et al. 2003). 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 Northern Mudpuppy habitat, and applied during a time that avoids the presence of amphibian larvae. **Managers should refine treatment protocols to minimize non-target impacts by: using the minimum effective dose based on precise water chemistry calculations; avoiding treatment of stream reaches with known, significant Northern Mudpuppy populations when possible; and conducting thorough pre-treatment surveys to identify and document herpetofauna presence** (Borowiec et al. 2021). This compound has been shown to have high lethality to Northern Mudpuppies, and in some cases, hundreds have historically died in a single application along single sections of streams in Michigan. Though significant 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

result in shortened lifespans and decrease reproductive ability (Parren and Hart 2012). Reports of hundreds of Northern Mudpuppies dying after treatment are not uncommon (Michigan Herp Atlas 2022). 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 the State Endangered Salamander Mussel, is likely highly unsustainable. **Sublethal exposure can impair growth, development, and immune function in surviving individuals and other amphibian species. The removal of a top benthic predator like the Northern Mudpuppy can trigger trophic cascades, altering invertebrate community structure and overall stream ecosystem function** (Browne and Paszkowski 2010; Borowiec et al. 2021).



1. 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.

and can potentially increase the 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. **Robust, long-term monitoring of Northern Mudpuppy and other amphibian populations in treated watersheds is essential for understanding population recovery trajectories, assessing the cumulative impact of repeated treatments, and informing adaptive management strategies that strive to protect both fishery and herpetofauna resources** (Browne and Paszkowski 2010).

Fish Hatchery Rearing Ponds

Most fish hatchery and rearing ponds are earthen dikes that 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 is used to cull a group of diseased fish or to “clean” the water between fish harvest and the introduction of a new cohort of fish. Rotenone treatments will not only kill unwanted pathogens, but 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 exclusion fencing (i.e., soil erosion control fence or other similar barrier) to prevent herpetofauna from entering rearing ponds and becoming subject to rotenone poisoning.

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 for 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 et al. 2004; Dorcas 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 et al. 2011). Hoop-nets result in the bycatch and death of several species of Michigan turtles, including the Midland Painted Turtle, Eastern Snapping Turtle, Northern Map Turtle, and Eastern Musk Turtle (Larocque 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 et al. 2011). Incorporating devices such as turtle excluders or turtle chimneys can prevent turtle mortality from drowning (Epperly 2002; Fratto et al. 2008). Turtle chimneys allow turtles to rise to the surface to breathe while preventing fish from escaping, and turtle excluders allow turtles to escape nets. The use of floats within fyke nets can reduce the frequency and intensity of anoxia in trapped turtles, though they are not always entirely effective in preventing mortality (Larocque et al. 2012). These different features can be incorporated into net construction to reduce turtle mortality (Larocque et al. 2012).

Do not set traps in warm water – Set traps in water ranging 40 – 50°F (Ultsch et al. 1984; Herbert and Jackson 1985). Turtles are more likely to be found dead in nets/traps that are set in warmer, deeper water than in cooler, shallower water (Barko et al. 2004). 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 amount of dissolved oxygen in the water, making the intake of oxygen increasingly difficult. Because turtles have extrapulmonary gas exchange (breathe in part through their skin), lower dissolved oxygen levels can decrease turtle survival when trapped under water (Ultsch 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 – Sampling efforts typically focus on open-water fish



Jeanette McGuire



Jeanette McGuire

1-2. In New Zealand to reduce spread of disease and invasive species, boot cleaning stations have been constructed to protect landscapes from harm.

1. Disinfection station with concrete basing to contain products and items for cleaning
2. Thoroughly scrub items with dish detergent soap to remove all organic debris
3. Rinse boots in basing and prepare for next step.
4. Thoroughly and generously decontaminate items with a 10% freshly made bleach solution or other identified broad spectrum cleaning agent.

Following the bleach treatment set to dry in full sun for additional UV treatment.

communities, with nets deployed in the limnetic zone of lakes. However, sometimes nets are set randomly or within a variety of habitats, including marshes. Sampling in these habitats often yields 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 bycatch, observations should be submitted to the Michigan Herp Atlas website.

Decontamination of Clothing and Equipment

The unintentional introduction of invasive species and pathogens is a primary driver of herpetofauna decline and ecosystem degradation. To mitigate this threat, a rigorous decontamination protocol for all clothing, equipment, vehicles, and pets that have been in the field is essential. These procedures are critical for halting the spread of detrimental organisms such as amphibian chytrid fungus (*Batrachochytrium dendrobatidis*), ranaviruses, snake fungal disease, invasive invertebrates (e.g., New Zealand mudsnail), and invasive plant seeds and propagules (Fisher and Garner 2020; MWPARC 2012). Effective biosecurity protects naïve populations and preserves the integrity of conservation and research efforts.

Decontamination of Boots and Non-Porous Field Equipment

All non-porous field equipment (e.g., rubber boots, chest waders, dip nets, funnel traps, PVC pipes for cover boards, calipers, data loggers) must be decontaminated between sites, with heightened vigilance when moving between watersheds or from areas with known pathogens or invasives to uninfected sites.

Primary Method: Thorough Drying – Allow all equipment to dry completely for a minimum of three (3) full days in direct sunlight, if possible. Desiccation is lethal



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4





1. Heavy equipment should be cleaned of organic material between jobs.

to many aquatic pathogens and invertebrate invaders (Johnson et al. 2003; Murray 2011)

Chemical Disinfection: Sodium Hypochlorite (Bleach) Solution – When equipment is required for use at another site within the 3-day drying window, chemical disinfection is mandatory. A minimum 10% v/v bleach solution is required, made by mixing 1 part standard household bleach with 9 parts clean water. The solution must be mixed fresh daily, as diluted bleach degrades rapidly, losing up to 50% of its effectiveness within 24 hours (Ono 2006; Environmental Health and Safety 2025).

Critical Pre-Treatment Step: All visible debris, mud, soil, leaves, and organic matter must be physically scrubbed and rinsed off with clean water before applying the bleach solution. Organic material rapidly neutralizes bleach, creating a false sense of security (Michigan Department of Environment, Great Lakes, and Energy, Michigan Department of Natural Resources, & Michigan Department of Agriculture and Rural Development 2025; MWPARC 2012).

Contact Time: Submerge or thoroughly soak all equipment surfaces for a full 30-minute contact time to ensure efficacy against resilient pathogens like ranavirus.

Post-Treatment Rinse and Neutralization: After 30 minutes, rinse all equipment thoroughly with clean water to remove residual bleach, which is toxic to wildlife and corrosive to gear. For sensitive optical or metal equipment, a final rinse with a 70% isopropyl alcohol (IPA) solution will neutralize any remaining sodium hypochlorite and promote rapid drying.

Alternative Physical Methods: Heat and Freezing – As alternatives to bleach, equipment can be rinsed with water heated to >110°F for at least 20 minutes, or cleaned equipment can be frozen at 0°F for a minimum of 24 hours (Michigan Department of Environment, Great Lakes, and Energy, Michigan Department of Natural Resources, & Michigan Department of Agriculture and Rural Development 2025).

Decontamination of Field Clothing and Gear

Porous materials like clothing, waders, gaiters, gloves, hats, and backpacks require specific protocols.



2. Construction mats should be used on job sites and thoroughly cleaned between job sites or disposed of.

1. All field equipment, especially when conducting wildlife clearance, **MUST** be decontaminated to avoid risk and spread of diseases.

Laundering:

Wash in a hot water cycle $\geq 140^{\circ}\text{F}$ with standard laundry detergent. The combination of heat, detergent, and agitation is effective against many pathogens and removes seeds.

Heat Drying: If hot water washing is not available, drying clothing on the highest heat setting in a mechanical dryer for a full cycle is an acceptable alternative.

For Delicate or Non-Washable Gear: Isolate and dry thoroughly for a minimum of five (5) days before use in a new location.

Decontamination of Aquatic Vessels and Gear

Larger aquatic equipment, including canoes, kayaks, jon boats, motors, trailers, and fishing gear, is a major vector for invasive aquatic species. All water must be drained, and all debris (mud, plants, animals, invertebrates) must be removed following the Clean, Drain, Dry protocol:

CLEAN: Inspect and remove all visible aquatic plants, animals, and mud from the vessel, trailer, motor, and all gear (anchors, ropes, life jackets).

DRAIN: Drain all water from bilges, live wells, bait buckets, and coolers away from the waterbody.

DRY: Allow the vessel and all associated gear to dry completely for a minimum of five (5) days before launching in a different water body. Drying times may need to be extended in humid or cool conditions (Rothlisberger et al. 2010; The Green Marina Education and Outreach Project 2012).



2. Turtle traps must be cleaned of all aquatic vegetation, organic material and thoroughly decontaminated prior to use and additional locations.





Decontamination of Terrestrial Vehicles and Heavy Equipment

Passenger vehicles, ATVs, and equipment used for construction, agriculture, forestry, and land management are significant vectors for invasive plant seeds, soil pathogens, and small terrestrial animals.

Inspection: Inspections must be conducted both before entering a new management area (to prevent introducing contaminants) and after exiting an area (to prevent spreading contaminants elsewhere). Focus inspection on high-risk areas: the undercarriage, wheel wells, tire treads, bumpers, radiator grille, and cargo beds where mud, soil, and plant material readily accumulate (Halloran 2013; Michigan Department of Environment, Great Lakes, and Energy, Michigan Department of Natural Resources, &

Michigan Department of Agriculture and Rural Development 2025; Pickering and Mount 2010). Any vehicle that has operated in muddy conditions requires meticulous inspection, as invasive plant seeds easily embed in soil.

Cleaning:

Physical Removal: At a minimum, use a brush or scraper to remove all caked mud and visible plant debris from the vehicle.

Washing: Wash the vehicle’s exterior, focusing on the undercarriage and wheel wells, at a commercial car wash or in a designated wash area. **Critical:** The wash area must be at least 100 feet from any storm drain, wetland, stream, or other waterbody to prevent contaminated runoff. Collected wastewater should be disposed of in a sanitary sewer system, not on vegetated ground.

Interior Cleaning: Vacuum the vehicle interior (floor mats, cargo areas) to remove seeds (Halloran 2013; Michigan Department of Environment, Great Lakes, and Energy, Michigan Department of Natural Resources, & Michigan Department of Agriculture and Rural Development 2025).

Heavy Equipment: Requires meticulous high-pressure washing of tracks, blades, and buckets between job sites, following the same runoff precautions.

Summary of Core Principles

Assume Contamination: Act as if all gear, clothing, and vehicles are contaminated after field use.



1. All construction equipment must be cleaned to avoid harm to habitat and herpetofauna.

2. All field equipment must be decontaminated between locations and projects. A final end of season cleaning is necessary prior to use the following season.



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

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

Remove Debris First: Physical cleaning is always the first, essential step before any disinfection.

Fresh Solutions Only: Never use “leftover” diluted disinfectants.

Respect Drying Times: Adhere to minimum drying durations; extend them in humid conditions.

Protect Water Quality: Manage runoff from cleaning and disinfecting activities responsibly.

Document Protocols: Include standardized decontamination steps in all field work plans, permits, and contractor specifications.

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. 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. **For a comprehensive discussion of these threats, see Section 3: Threats to Amphibians and Reptiles under Invasive Species/ Nuisance**

Decontaminate clothes and equipment – Since many invasive species are unknowingly introduced, the strict decontamination of clothing, equipment, vehicles, and pets that have been in the field is vital in stopping 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 (Hayer and Murphy N.D.; Michigan Department of Environment, Great Lakes, and Energy, Michigan Department of Natural Resources, & Michigan Department of Agriculture and Rural Development 2025; Murray 2011; MWPARC 2012). Alternatively, equipment can be rinsed with hot water >110°F or frozen at 0°F for at least 24 hours (Michigan Department of Environment, Great Lakes, and Energy, Michigan Department of Natural Resources, & Michigan Department of Agriculture and Rural Development 2025). Larger aquatic equipment – such as boats



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

- 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 plants and animals (Halloran 2013; Michigan Department of Environment, Great Lakes, and Energy, Michigan Department of Natural Resources, & Michigan Department of Agriculture and Rural Development 2025). Inspections should be conducted before entering a new area, especially one that may not have invasive species established, as well as when exiting an area where invasive species may have been present. Any vehicle or equipment that has been 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 to.



2. The Northern Map Turtle is sexually dimorphic, with males and females selecting for different prey as adults. Adult female turtles specialize on mollusks and actively consume zebra mussels and Asian mystery snail. They are a critical predator on these invasive species.

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; Michigan Department of Environment, Great Lakes, and Energy, Michigan Department of Natural Resources, & Michigan Department of Agriculture and Rural Development 2025).

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



1. Northern Mudpuppies are recognized predators on several invasive species. They will eat round gobies, rusty crayfish, and zebra mussels.

until native species are established and involving community or conservation groups in long-term monitoring and removal of any invasive individuals.

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. However, herpetofauna can also serve as a valuable component of integrated pest management by shifting foraging.

Importance of Herps for Invasive Species Management

Herpetofauna can aid in the management of certain invasive species, most often by shifting their diets to include those invaders, sometimes to an extreme degree. This dietary plasticity can help suppress populations of certain invasive species and modulate their ecological impact, though it also carries risks for the predator.

Turtles as Molluscivores: In the Great Lakes region, several turtle species have incorporated invasive dreissenid mussels into their diets.

Northern Map Turtles: Studies in dam impoundments have documented a significant dietary shift in Northern Map Turtle prey preference, with zebra mussels constituting a major portion of their intake (Bulté and Blouin-Demers



2. Invasives such as Autumn Olive can overrun grassland habitat. Habitats dominated by this species provide little habitat for herpetofauna. In areas where this plant is more sparsely dispersed several species of reptiles and amphibian can persist.



1. Invasive landscapes make movement difficult for low mobility species, especially their young. Even if an adult female Eastern Snapping Turtle can navigate through *phragmites*, their young will be challenged to get to the waters edge in highly impacted areas.

2010; Richards-Dimitrie et al. 2013). While this may benefit native mussel communities by reducing zebra mussel pressure, the long-term nutritional and health impacts (e.g., shell ingestion, potential toxin bioaccumulation) on these long-lived turtles remain a concern (Gacheny et al. 2021).

Eastern Musk Turtles: This benthic forager also preys on invasive mussels, demonstrating the broader potential for native turtle assemblages to exert top-down pressure on these invasive species (Patterson and Lindeman 2009).



Amphibians and Snakes as Predators: The role extends beyond turtles.

Northern Mudpuppies: These large, fully aquatic salamanders are generalist predators known to consume invasive Rusty Crayfish, Round Gobies, and dreissenid mussels, highlighting their potential role in controlling multiple aquatic invaders (Beattie et al. 2017).

Lake Erie Water Snake (*Nerodia sipedon insularum*): This subspecies of the Northern Water Snake provides a prominent case study of a predator capitalizing on an invasive prey base. Following the invasion of the Round Goby, the Lake Erie Water Snake's diet shifted overwhelmingly, with gobies now constituting >92% of prey items. This shift is credited with supporting the snake's population recovery and subsequent delisting from the Endangered Species Act (King et al. 2006).



Plant Invaders

There are several invasive plant species that are common throughout Michigan's

2. *Phragmites* dominated landscapes provide limited ecological value. Controls including biological that have the potential to significantly set back this species must be considered. Even if they also impact native phragmites. Seedbanks can be stored and reintroduction of native form once the non-native is better managed.

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, controlling 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 to upland overwintering sites (Hokanson n.d. ; 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 n.d. ; 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 have emerged. Areas should remain flooded (≥6" of water) for at least one year. Drawdowns 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. Place cover crops to stabilize soils and reduce colonization of invasives. Only use native seed for restoration sites.

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 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 regions 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 dissipate from 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 consistently performed. 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 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 colonization. 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. For more information about mowing, burning, and chemical application techniques, refer to prior information presented in this section.

Cover or treat freshly graded soil – Earthwork creates disturbed conditions, allowing invasive plants to become established. Cover bare soil with mulch or non-invasive cover crops or native plants to prevent invasive plants 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 EGLE, 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 5). 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 californiensis*) 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 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.

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

1. Brown lipped snails (*Cepaea nemoralis*) are native to Europe and were introduced into the United States. They can be locally abundant and compete with native species. In large numbers they can also modify local environments. Several species of snake, frog, salamander and turtle actively consume this species.





1. Species like Eastern Box Turtles specialize on invasive slugs and earthworms, making them an important predator of these invasives.

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.



goby, Eurasian ruffe, and spiny and fishhook waterfleas) have negative impacts on ecosystem function and on herpetofauna. **For a comprehensive discussion of these threats, see Section 3: Threats to Amphibians and Reptiles under Invasive Species/ Nuisance**

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 the 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 transmission emerald ash borer).

Do not release pets - The release of pets and non-natives can introduce disease to which native species are susceptible, and increases 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 adapted to recognize some invasive species as a food source (e.g., Northern Mudpuppies and Northern Water Snakes eat round gobies and Northern Map Turtles will eat zebra and quagga 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



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

2. Turtle nests are frequently predated by raccoons, resulting in almost 100% nest mortality at many sites. This is unsustainable and will likely result in impacts to population viability, if allowed to continue.

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

Consider Fertility Control – Methods of fertility control are dependent on the target species 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 with the MDNR 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 oiling 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, these techniques are not effective solutions for large scale invasive

opportunities for native species. By restoring vegetation and other structural and functional components (e.g., branches, logs, 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 ensure the success of any control program.

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 Northern Mudpuppies (Gilderhus and Johnson 1980; Kane et al. 1993; Waller et al. 1993; Boogaard et al. 2003; Dawson 2003; McDonald and Kolar 2007; Billman et al. 2011). If applied, target sea lamprey populations and avoid locations and times of year when larval amphibians and Northern Mudpuppies are present. Applications should be conducted near the beginning of the winter (i.e., December-January) to prevent residual rotenone affecting amphibians as they come out of hibernation.





1-3. Avoid fresh mulch for nesting areas as it creates too hot conditions from decomposition. Waiting a season will make this a better option. Protecting turtle nests from predation by an artificial cover will increase the chances of egg and hatchling survival.

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

eradication. Use of pheromones to attract sea lamprey can help to increase the 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 et al. 2009) Urbanization also leads to a creation of roads, sidewalks, open lawn and park areas, that fragment herpetofauna habitat. These are easily navigated by raccoons and other urban-adapted wildlife, which can disperse widely across the landscape. These conditions have helped to facilitate dense populations of raccoons in urban and suburban landscapes (Prange et al. 2003) Unfortunately, raccoons and other mesopredators are savvy predators of turtle nests (Standing et al. 1999; Burke et al. 2005) often eliminating all annual turtle reproduction in an area, as well as predating on adult and juvenile turtles (Seigel 1980; Seabrook 1989; Browne and Hecnar 2007; MWPARC 2009b; Herpetological Resource and Management 2011; Harding and Mifsud 2017). Although turtles have relatively good defenses (ability to hide in their shells, swiftly swim away, or deliver a ‘snapping’ bite), raccoons are highly intelligent and well-adapted hands this allow them to dig up turtle nests and catch



4. Monitoring and controlling subsidized predator populations or implementing nest protection devices are essential in ensuring turtle population stability and growth.



1. Raccoon predation of turtle nests can be significant resulting in 100% loss of nesting success in several parts of Michigan. Where populations are artificially high such as urban, suburban and country landscapes, Raccoon and other subsidized mesopredators can have a ecologically significant impact on recruitment and population viability of turtles and several other species of herpetofauna.

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). Efforts to return the natural population densities of subsidized mesopredators include direct 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.

Discourage feeding of raccoons and other mesopredators

– Further increases in populations of problematic mesopredators populations can 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 et al. 2006; Suzuki and Ikeda 2020). 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 2009b). Raccoons can be caught in live traps with marshmallows as bait, cotton balls dipped in vanilla extract or in foothold traps baited with sardines; both trap and bait combinations reduce capture of non-target mammals including pets (Curtis and Sullivan 2001). Free-ranging cat spay/neuter and lethal control programs can be implemented to reduce the negative impact of cats on wildlife. Within small geographic areas, these control methods can be implemented by trapping cats, allowing for the avoidance of harming pet cats (Cecchetti et al. 2020). Lethal control and spay/neuter programs are most effectively implemented on farms with livestock, as they are more likely to support several free-ranging cats than other residences (Coleman and Temple 1993). Warfarin, the active ingredient in the only feral hog bait approved by the United States EPA, effectively kills feral hogs and, when used in the correct concentration, poses a reduced risk to non-target wildlife species (Poche et al. 2019). Raccoon, cat, feral swine, and other predator control methods should always be conducted humanely and comply with state regulations.

Protect turtle nests and other sensitive herpetofauna habitat – 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 et al. 1997; Smith et al. 2012), especially in areas where lethal control is not a viable option. The installation of a two-wire electric fence with wires five and ten inches aboveground is an effective method of excluding raccoons from an area (Curtis and Sullivan 2001; Quinn et al. 2015). Various designs of physical nest protective structures have proven effective in excluding raccoons, including a square wire design (Bougie et al. 2020)



1-2. Eastern Box Turtles, like many other turtle species, carefully excavate a nest underground using their back legs and subsequently cover up the hole, never laying eyes upon the eggs themselves (1). Within an incubation period of approximately 2 months, hatchlings will emerge from the nest. Annual mortality of turtle nests approach 100% in many parts of Michigan due to subsidized predators.

2. Cats that live indoors are shown to have longer lives and fewer health issues. Devices and enclosures are designed to allow for cats to enjoy outside spaces in a controlled and safe framework.

and lightweight, conical, wooden dowel design (Buzuleciu et al. 2015) of exclusion cages. It should be noted that these techniques are labor and time intensive and do not remove predation pressure on adult turtles by mesopredators. In addition to the physical protection of turtle nests themselves, the active removal of raccoons has increased the survivorship of Blanding's Turtle nests (Urbanek et al. 2016). In areas where feral swine are an issue, hog exclusion fences can be effective tools to protect sensitive herpetofauna habitat (Brown et al. 2015).

Educate the public – 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, feral or outdoor cats, and other mesopredators. 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. Vet clinics and pet stores can also educate pet owners on the dangers posed by cat and dog predation to wildlife (Twardek et al. 2017).

Do not allow outdoor cats and dogs – 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 et al. 2003; Baker et al. 2005; Beckerman 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 et al. 2013). Keeping pets indoors prevents herpetofauna and other wildlife from being harmed in addition to increasing the lifespan of the pets themselves (Lloyd et al. 2013). Though highly discouraged, if cats must be let outside, certain products can reduce their negative impact on herpetofauna. Birds-Be-Safe cat collar covers (Hall et al. 2015) and CatBibs (Calver et al. 2007) are both harmless to cats and may reduce herpetofauna mortality rates. Providing refuge habitat of dense vegetation on a site can also increase the safety of herpetofauna and decrease predation by cats (Edgar et al. 2010).



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8. Development Techniques

This section describes approaches that should be taken during development activities within 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 intent is to minimize impacts to natural resources while still addressing the development goals and objectives.

Horizontal Directional Drilling and Boring

Horizontal directional drilling (HDD) is a trenchless construction technique that avoids open-cut trench excavation by routing natural gas pipelines, fiberoptic cables, and transmission line segments through a drilled tunnel underneath the right-of-way (ROW). The underground tunnel travels in an arc line from the entry point, underneath the specified obstruction, and to the surface of the opposite side. Advanced technology and trained technicians guide the drill head and resulting path electronically to maintain a precise angle, depth, and exit point to adhere to environmental and engineering protocols. During the drilling process, a bentonite clay mixture (natural, non-toxic substance) is utilized to lubricate the tunnel and remove drill cuttings. Once the underground tunnel is complete, the pipeline segment can be pulled through the arched tunnel to the opposing side to be welded or connected to the rest of the system. Boring is a similar installation technique to HDD but does not require a deep arc path and is typically utilized for smaller diameter segments such as cable or optic lines.

1. HDD equipment can reduce impacts to habitats by working underground. There are limitations and concerns that must be considered with any construction technique.

Additional precautions should be taken when conducting HDD or boring to avoid an inadvertent mud release (IMR) of the bentonite clay mixture used for drilling, particularly when used under sensitive habitats, waterways, and areas of concern.





1. In high quality habitats including fens that support suitable habitat for the Eastern Massasauga Rattlesnake, use of HDD can minimize surface threats and impacts

The use of this non-toxic substance has little to no direct impact when contained within the drill path; however, if unintentionally released into wetlands or waterways due to fractures in sub-surface geology, wildlife, including benthic invertebrates, aquatic plants, fish and their eggs, mussels, and all life stages of herpetofauna species can be smothered by the fine particles. An environmental contingency plan that includes protocols for monitoring and preventing IMR, as well as an organized, timely, and “minimum impact” response in the unlikely event of a release during HDD or boring activities, should be implemented to minimize the risk to sensitive ecological areas. A good contingency plan will include instructions for

minimizing the release through use of straw bales or sandbags. Small releases should be removed by hand tools to avoid heavy equipment that may cause more harm than the release itself. Larger releases will often utilize suction dredges and other heavy machinery, but this should be avoided unless it is determined that the site is easily accessible and will not cause additional harm to the habitat.

Despite the potential for an IMR, the HDD and boring processes have a significantly reduced impact on the landscape as they minimize impacts on the area above the drill. When bore entry and exit pits are placed in an appropriate location, typically there are no direct or indirect impacts to herpetofauna along the path of the ROW as no existing habitat, vegetation, or hibernacula is temporarily impacted, and no herpetofauna are likely to be injured or killed. HDD and boring are the preferred burial methods for pipelines or cable segments as opposed to open-cut trenching, which results in the temporary removal of habitat and potential impact to herpetofauna.

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 analysis may help to determine the appropriate trajectory for restoration efforts.

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 to support a greater variety of amphibians and reptiles and their prey items. These gentle slopes are easily traversed by herpetofauna, 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

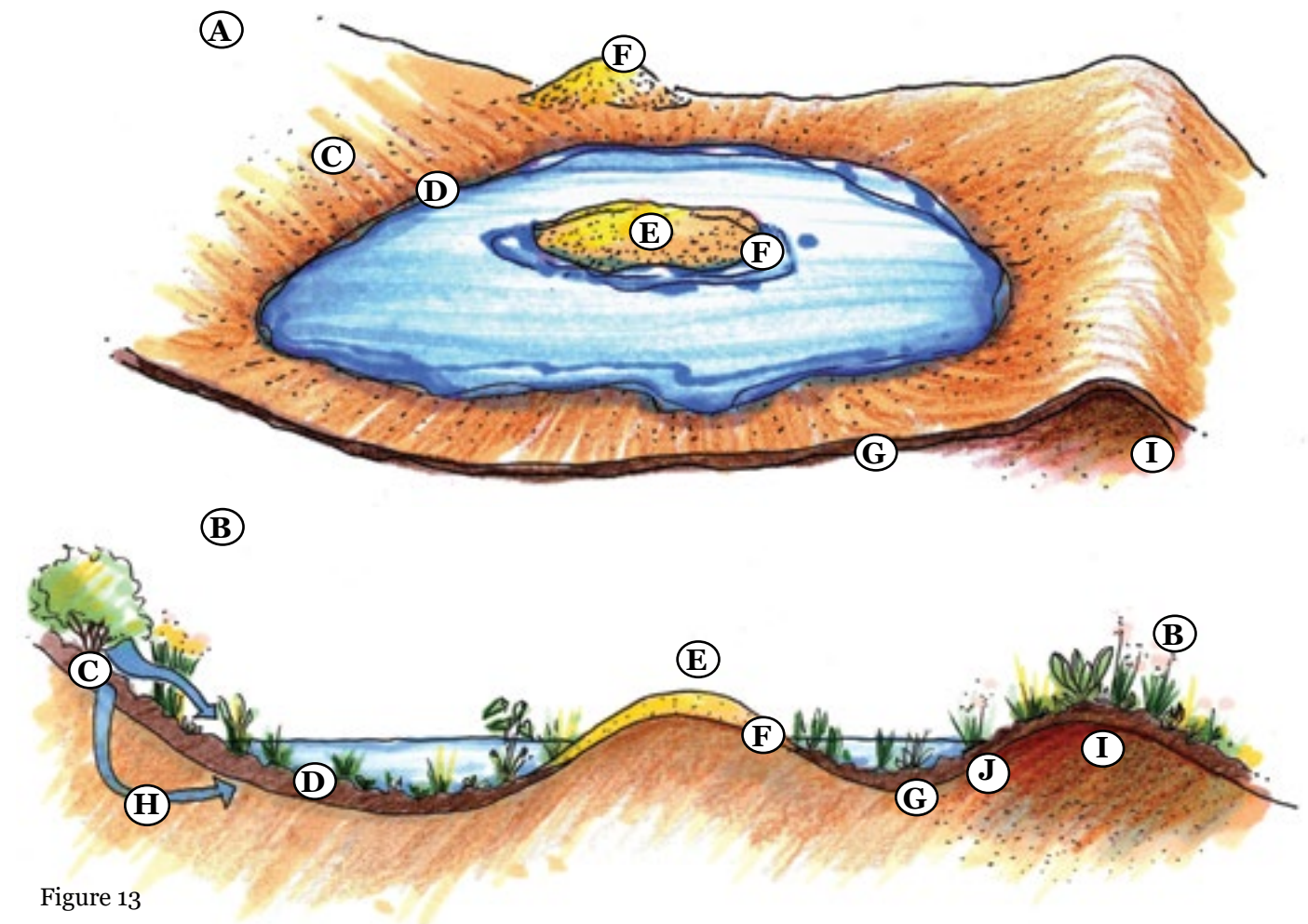


Figure 13

Figure 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).

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) (WI NRCS 2010).

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 – Different soil types vary in texture and permeability and can be used

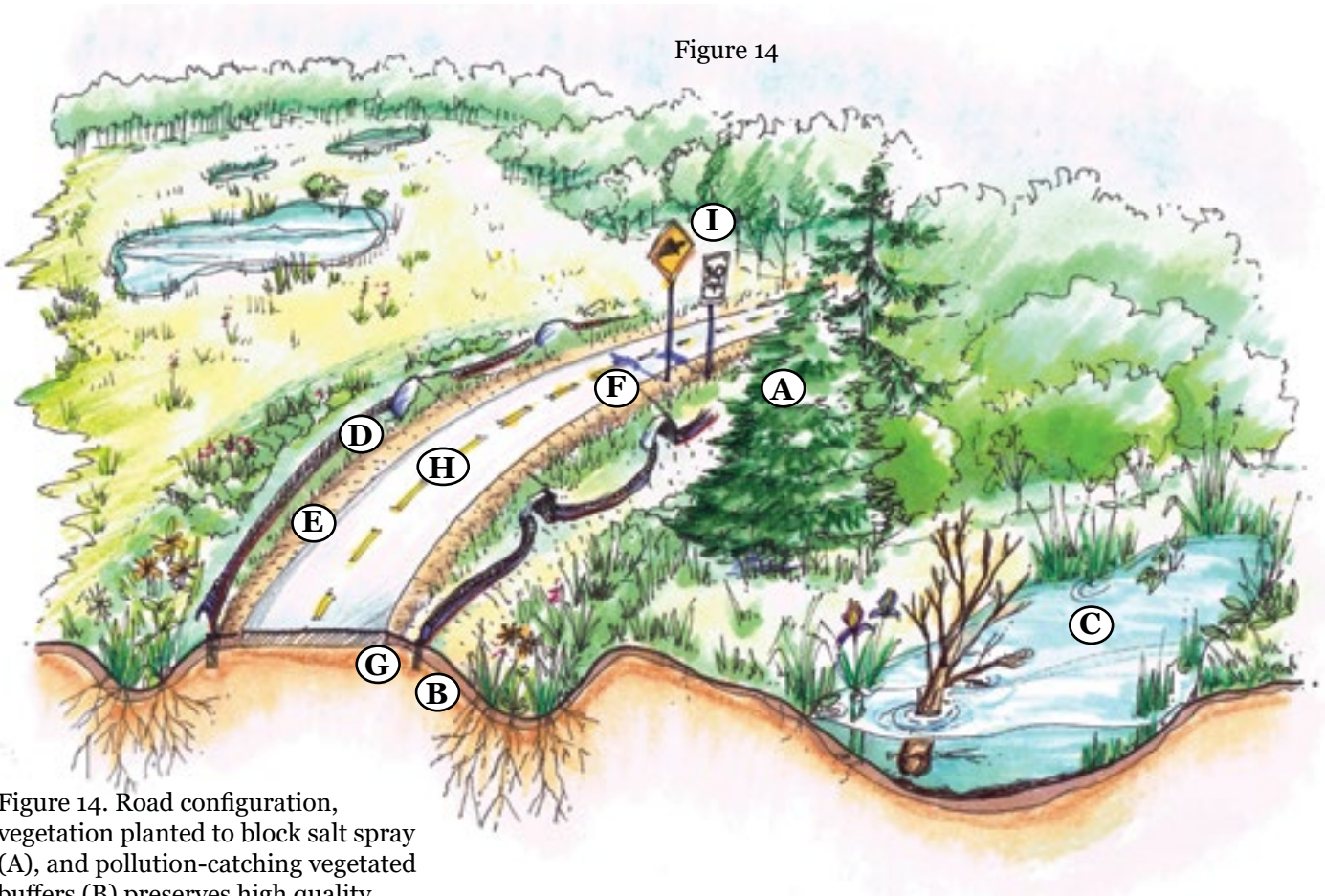


Figure 14. Road configuration, vegetation planted to block salt spray (A), and pollution-catching vegetated buffers (B) preserves high quality wetlands (C).

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).

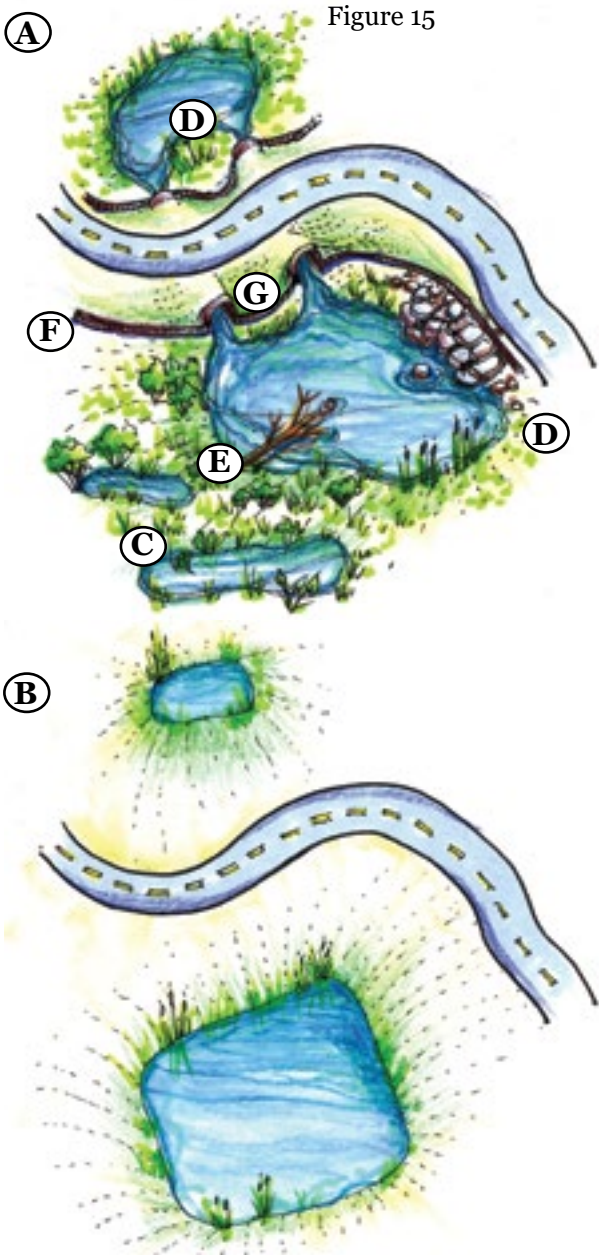


Figure 15. Landscapes which maintain hydrology, a variety of wetland types, and animal movements (A) provide habitat for a greater variety of amphibians and reptiles than do simplified landscapes with disconnected hydrology (B).

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.

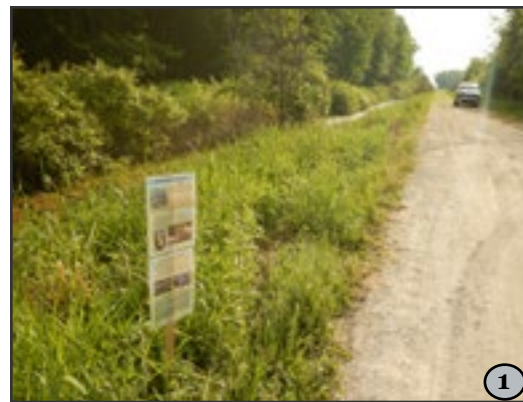
to create a variety of wetland features and structures. Sand can be used to create well-drained areas, such as turtle nesting sites; clay can be used to create berms or slopes on the lower side of wetlands; and organic soils and topsoil can be used to topdress terrestrial areas for plant establishment (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.

Transportation

Roads and 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, nesting, and travel corridors (Trombulak and Frissell 2000; Steen and Gibbs 2004; Andrews and Gibbons 2005b; Rowe et al. 2005; Bartoszek and Greenwald 2009; Patrick et al. 2011; Iosif 2012; Clauzel et al. 2013; Hartzell 2015; Dornas et al. 2019) . Boating traffic also poses several threats to herpetofauna, including direct mortality and injury, shoreline habitat degradation and erosion, and reduced water clarity (Bulté et al. 2010; Fonseca and Malhotra 2012; Lester et al. 2013; Hollender et al. 2018; Bilkovic et al. 2019; Schafft et al. 2021). Despite the many threats to herpetofauna associated with transportation, placement, construction techniques, and maintenance, public education can be used to lessen the impact of roads, railways, and boats on herpetofauna. **For a detailed discussion of transportation impacts, see Section 3: Roads and Other Transportation**

Road 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 the 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



1. When roads bisect nesting areas in construction areas, install temporary signage to alert contractors and worker of the potential for an interaction.

maintenance and vehicle use will impact water quality and the herpetofauna in those habitats. Preventing pollutants from entering wetlands via roadways is the best option.

Avoid herpetofauna habitat – Locating roadways away from essential herpetofauna habitats can minimize the impact on herpetofauna. Plan roads to circumvent all identified areas of critical habitat when possible; however, if this is not feasible, essential 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 an essential habitat feature (e.g., a vernal pool), a landscape

buffer should be used to mitigate impact to that feature and the herpetofauna using it (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 (non-point) pollution, and degrade pollutants before discharging water into herpetofauna habitat. Finally, if a wetland area cannot be avoided entirely, the road should be placed so that the wetland is only on one side of the road to reduce the mortality of amphibians and reptiles crossing between the wetlands (Langen 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 et al. 2005; Jenkins et al. 2006); however, most movements across the landscape are driven by an animal’s life history and long-term ecological conditions (Russell 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 et al. 2001; Jenkins et al. 2006). Weather conditions, such as temperature and precipitation, can trigger migrations between upland and wetland areas for mating, egg laying, post emergence dispersal, and hibernation (Sexton et al. 1990; Russell 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 herpetofauna mortality (Bassel 2002; Dodd et al. 2004; Pelletier et al. 2005; Rees et al. 2009; Colley et al. 2017). It has been highly documented that numerous turtle, snake, frog, salamander, and lizard species have been observed crossing through under-road passages, making them a critical



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

1. Amphibians and reptiles, like this Eastern Snapping Turtle, may cross roads during migrations or bask along the roadside in sandy areas. Reptiles such as this Blanding’s Turtle (2) and Eastern Fox Snake (3) are a common sight in these habitats. This behavior is most frequently observed during spring emergence, turtle nesting season, and fall migration.

and necessary measure to mitigate mortality for herpetofauna (Jackson and Tynning 1989; Yanes et al. 1995; Jackson 1996; Allaback and Laabs 2002; Schrag 2003; Taylor and Goldingay 2003; Laidig and Golden 2004; Gartshore et al. 2005; Kaye et al. 2005; Painter and Ingraldi 2007; Patrick et al. 2010; Caverhill et al. 2011; Pagnucco et al. 2012; Parren 2013; Bain 2014; Jackson et al. 2015; Sievert and Yorks 2015; Colley et al. 2017). Passages that are placed near high traffic locations can help to significantly reduce road mortality. In Vermont, wildlife underpasses have reduced overall amphibian mortality by 80%, with non-arboreal amphibian mortality declining by 94% (Marcelino et al. 2025). A professional designer or engineer should be consulted on the design of these structures to ensure public safety.

Document “kill zones” – Determining where amphibians and reptiles cross roads to identify areas of greatest risk can 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”. It has been suggested that “kill zone” analysis does not account for high-traffic roads where previous roadkill mortality has already reduced population size to the point of decreasing rates of roadkill (Fahrig et al. 1995). To compensate for this, models of animal movement behavior and habitat distribution should be considered when identifying road-crossing sites (Lesbarrères and Fahrig 2012). A herpetologist or professional wildlife biologist who has demonstrated experience with herpetofauna can provide assistance in conducting these surveys. It is important that observations of all amphibian and reptile data (dead or alive), be contributed to the Michigan Herp Atlas to help document these areas and help managers mitigate the negative impacts.

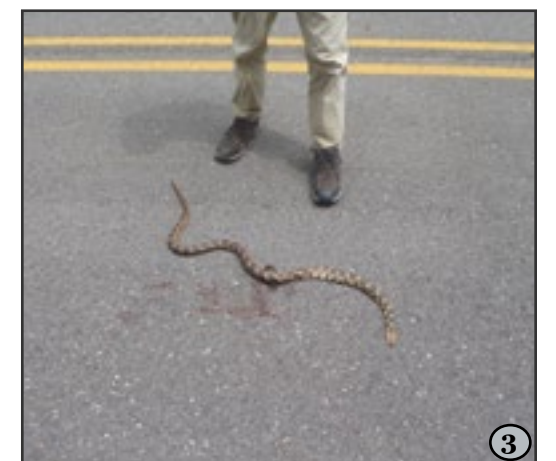


Figure 16. Culverts historically have been undersized (left). This can create an impoundment upstream (A) and incise the channel downstream (B). This restricts hydrology and natural stream meanders as well as wildlife crossing in the culvert. Oversized culverts and overflow culverts (right) accommodate 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.

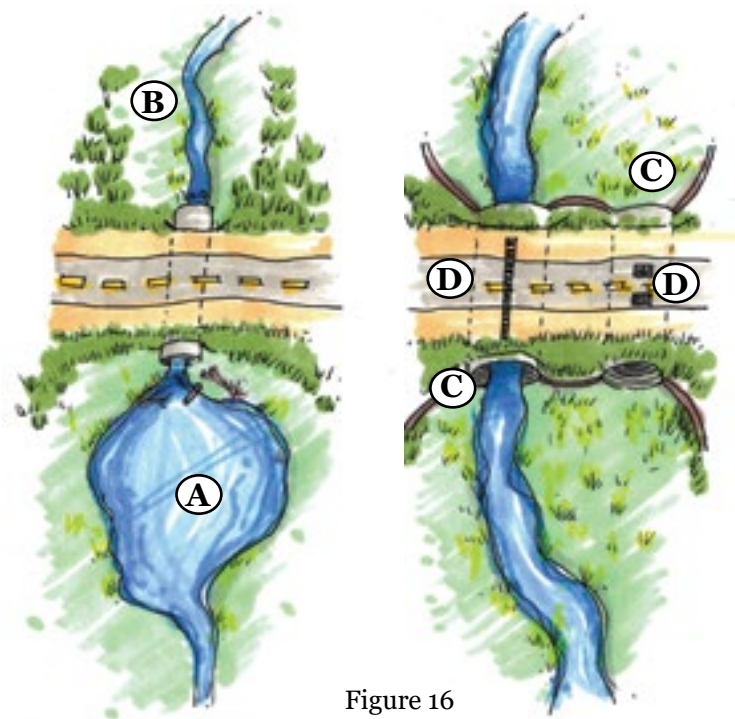


Figure 16

Install crossing structures and barriers at “kill zones” – Implementation of crossing structures at identified “kill zones” reduces herpetofauna mortality (Bassel 2002; Dodd et al. 2004; Pelletier et al. 2005; Rees et al. 2009; Colley et al. 2017). Fencing and/or barrier walls, when used in conjunction with wildlife culverts, can further decrease road mortality (Aresco 2005b; Glista et al. 2009). The mobility and natural history of species occurring within the impacted area should be considered when designing wildlife passages. Such factors influencing the configuration of passages include species with low mobility, moderate mobility, or high mobility. Herpetofauna are typically categorized within the low and moderate mobility categories (Berdweg et al. 2019; Flego et al 2025; Younquist and Boone 2014).

•**Amphibians (Frogs, Toads, Salamanders, Newts)** – prefer dark, moist, and enclosed spaces. Best suited crossing structures are designed to be small in diameter, low openness, low light, high humidity, and contain a natural substrate of soil or leaf-litter. This species will benefit from a substrate that provides moist conditions to prevent desiccation.

•**Small Terrestrial Snakes (Garter Snakes, Northern Brown Snake, etc.)** – prefer sheltered, enclosed spaces, and thermal stability. Best suited crossing structures are designed to be small to medium in diameter, low openness, low light, moderate humidity, and contain a substrate of fine gravel or soil. These species will also benefit from the addition of native plants near the entrances to serve as cover.

•**Large Snakes (Eastern Massasauga Rattlesnake, Eastern Fox Snake, etc.)** – prefer moderate openness, large spaces, and thermal heterogeneity. Best suited crossing structures are designed to be medium to large in diameter, moderate openness, moderate light, moderate to low humidity, and contain a natural substrate of soil. These species will also benefit from the addition of native plants near the entrances to serve as cover.

•**Aquatic and Semi-aquatic Turtles**



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

Figure 17.

A. Wildlife barrier fence to reduce movement across road and reduce mortality.

B. Culvert to mitigate road mortality of herpetofauna.

C. View from within the culvert with grating to allow natural light in.

D. Spotted Salamander moving through culvert.

E. Blanding’s Turtle nesting in created nesting site to prevent migration attempts.

F. Eastern American Toad along the fence being directed to culvert to the crossing.

G. Marbled Salamanders moving toward breeding pool.

H. Eastern Box Turtle using grassland habitat safe from road mortality.

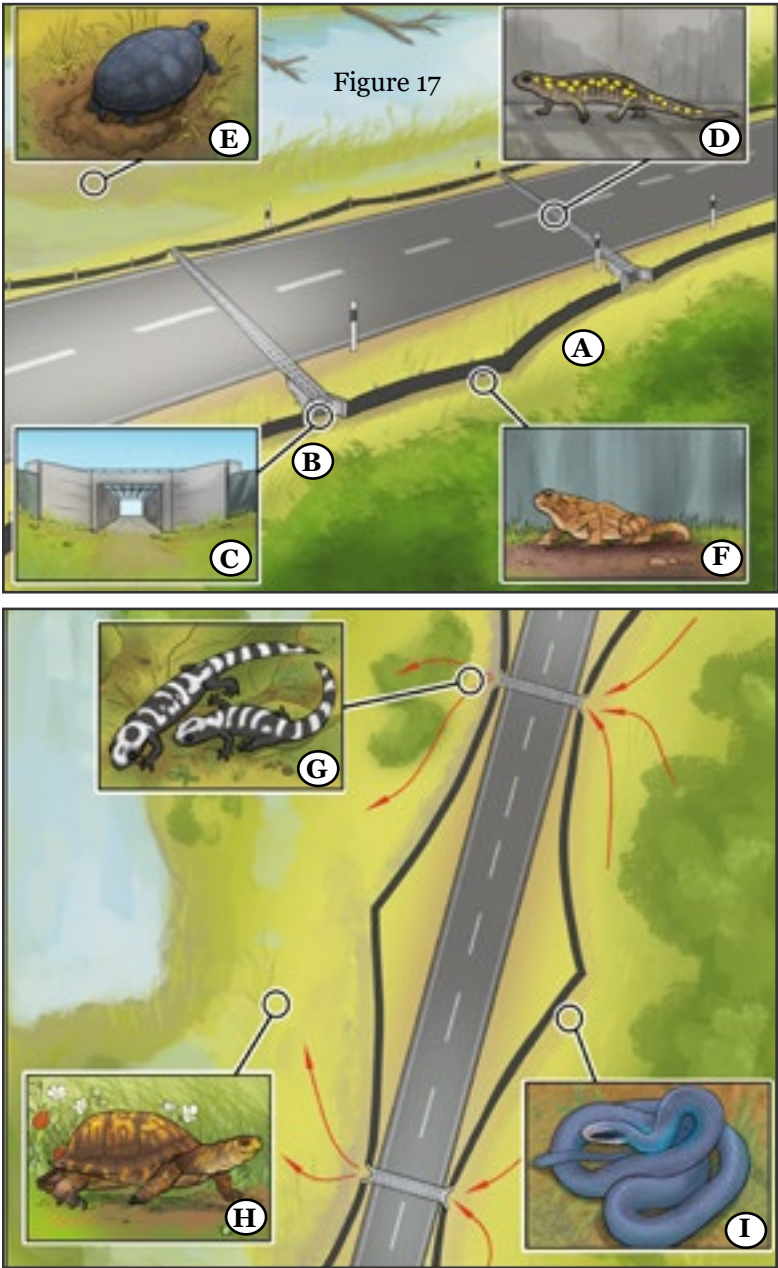
I. Blue Racer along fence thermoregulating.

(**Blanding’s Turtle, Spotted Turtle, Wood Turtle, etc.**) – prefer bright, open, and unobstructed spaces. Best suited crossing structures are designed to be large and wide in diameter, high openness, high light, and are open bottomed to allow for natural substrate and hydrologic connectivity. These species will also benefit from the installation of dry shelves to allow movement during high water levels.

•**Terrestrial Turtles (Eastern Box Turtle)** – prefer bright, dry, open spaces. Best suited crossing structures are designed to be large and wide in diameter, high openness, high light, dry, low humidity, and contain a natural substrate of leaf-litter or soil. These species will also benefit from the installation of barrier fencing to direct their movements to safe crossing structures.

•**Lizards (Five-lined Skink, Six-lined Racerunner)** – prefer bright, open, and warm spaces. Best suited crossing structures are designed to be medium in diameter, medium openness, high light, low humidity, and contain a natural substrate of rock or coarse material. This species will also benefit from sun-exposed entrances.

Crossing structures should also account for species habitat preference since they can be engineered to accommodate high openness herpetofauna or low openness species. Each group has specific best management techniques for both use and design, which





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

2. 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.



differ in recommended substrate, passage dimensions, lighting conditions, and appropriate spacing intervals. Designs such as open bottom bridges, culverts, shelves, and associated fencing serve different wildlife guilds and vary in size and placement. These structures are most effective when implemented in combination to function synergistically and offer broader species utility.

Wildlife Barrier Fencing – Fencing and barrier walls are essential components of development construction designed to keep animals off roads and project sites by guiding them toward safe crossing structures. In situations where habitat connectivity is not an issue, fencing may be used as a standalone mitigation measure to reduce road mortalities (Jackson et al. 2015).

Key design considerations for wildlife barrier fencing include:

•**Barrier Depth and Height:** Barriers should be embedded at least 6 inches into the ground to prevent “burrowers” (e.g., Mole Salamanders) 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 design has been demonstrated to reduce road mortality for herpetofauna and other wildlife (Bassel 2002; FHWA 2003; Dodd et al. 2004). Some modern fence designs even incorporate anti-climbing technology, which can be highly effective at preventing climbing species from entering hazardous areas (Hathaway 2019).

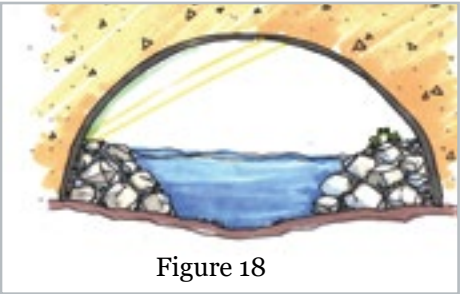
•**Placement and Orientation:** Barriers should be placed to funnel herpetofauna directly into the entrances of existing culverts or bridges, or toward new crossing structures designed specifically to provide passage for wildlife. Angling barriers toward crossing structures rather than positioning them parallel to the road may encourage greater tunnel use (Pagnucco et al. 2012).

•**Integration with Crossing Structures:** Fencing should be integrated with wildlife underpasses, culverts, and other crossing structures to create a complete passage system that directs animals away from hazardous areas and safely beneath roadways. **For comprehensive information on fencing applications, installation timing, maintenance requirements, and species-specific effectiveness, see Section 7: Management Techniques under Wildlife Barrier Fencing.**

Temporary fencing solutions, such as silt fence or drift fence, can be used as a temporary, low-cost solution to help move reptiles and amphibians safely across roads (Glista et al. 2009). However, several manufacturers produce plastic, metal, and concrete wildlife barrier products that are more aesthetically pleasing and durable. A variety of wildlife exclusion fencing products are commercially available, including durable polymer options that can be customized for target species with configurations varying in height and trench depth. **For detailed information on product specifications, species-specific configurations, and manufacturer**



1-2. Wildlife crossing structures are becoming increasingly used throughout the U.S., Canada, and Europe. Figure 18. Section of a culvert with dry ledges to accommodate amphibian and reptile passage even when water levels are high.



recommendations, see Section 7: Management Techniques under Commercial Exclusion Fencing Products.

Maintain barriers and road crossings to ensure animal use – Overhanging vegetation can provide a path for herpetofauna over barriers and onto the road, particularly for excellent climbers like Cope’s Gray Treefrogs and Eastern Gray Treefrogs (Dodd 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 along impacted areas 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 utilizing road crossing structures placed over 90 feet apart (Jackson 1996).

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 et al. 2008). If a wildlife crossing structure contains a stream or river, the design recommendations discussed later in this section should be consulted.

Carefully select culvert materials – Investigate potential impacts from the culvert material. Galvanized metals and some types of plastics may leach chemicals while concrete can retain 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 with low-impact manufacturing

1-4 Old and outdated culverts and recently restored culverts providing bank width flow allowing for better hydrological conveyance as well as movement for wildlife. These systems were inventories prior to construction and restoration and then monitoring to assess changes in community composition.

5. Eastern Snapping Turtle safely nesting on outside of construction area.

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 more closely mimic natural conditions typically encountered by wildlife are more suitable for herpetofauna to cross (Dexel 1989; Jackson 1996; Sievert and Yorks 2015). This can be accomplished by creating larger tunnels or installing grates or slotted tops on culverts. Culverts with an open or lined 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; Lesbarrères et al. 2004). 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 riprap or other stone placement near culverts. If rocks must be used, use as few as possible. Rock should be placed with gaps to allow for the intermittent planting of native herbaceous vegetation to provide better access and cover for amphibians and reptiles (Yanes 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 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 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, create features, such as turtle nesting sites or suitable breeding pools, away from the road surface. When possible, placement of newly created habitat features on both sides of roads may reduce or avoid the need for herpetofauna to cross.

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 (Piegras et al. 1998; Harding and Mifsud 2017; Mifsud personal observation 2026).

Recommendations to avoid this unnecessary road mortality are described below.

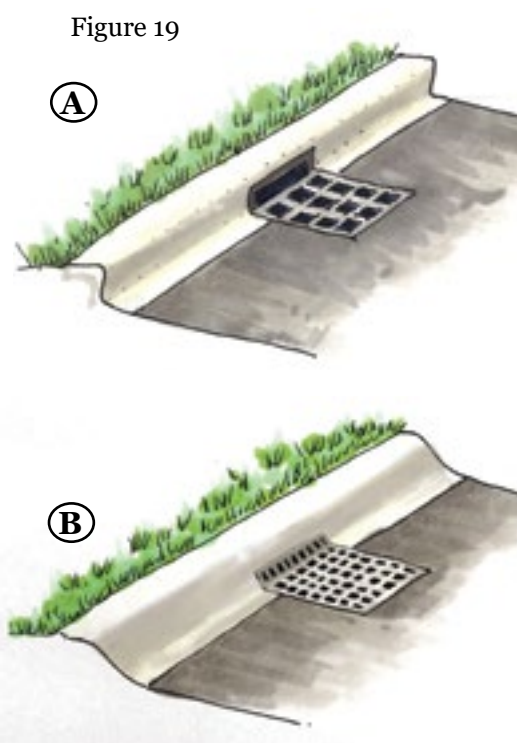
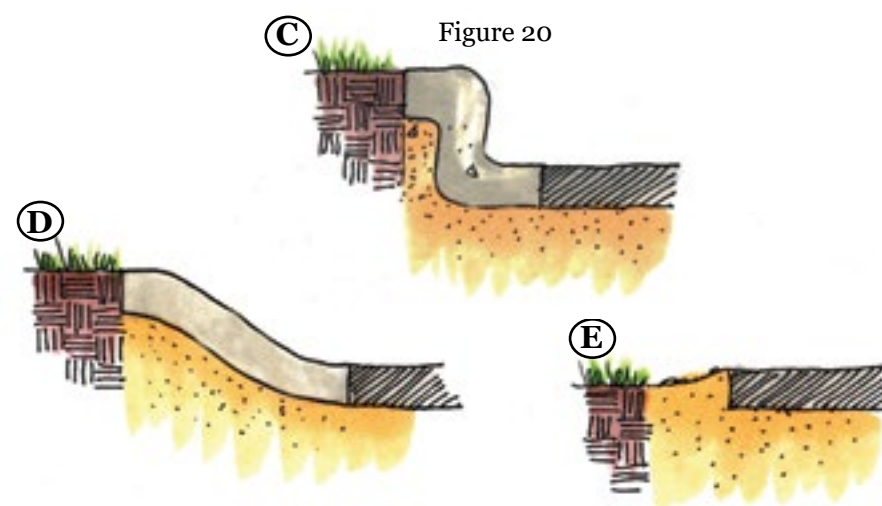


Figure 19. Typical drain grate (A) and wildlife friendly (a.k.a., bicycle safe) grates (B). Grates with smaller openings and grating along the curb prevent amphibians and reptiles from falling through.



Figures 20. 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.

Avoid placing or remove standard 6” vertical curb and gutter – A vertical 6” standard curb can trap small amphibians and reptiles on the road. By not placing or by removing a standard 6” curb and gutter, herpetofauna can cross roads more quickly, thereby lessening the amount of time spent in a ‘danger zone’. The absence of a curb and gutter allows runoff to drain as sheet flow along roadway edges, reducing the need for drainage structures that endanger herpetofauna. Gutters also 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 (Piegras 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.

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 the water quality of nearby wetlands, further reduce fragmentation, and prevent road mortality to help maintain populations of herpetofauna. As discussed in detail in the Road Crossing Structures section, the installation of wildlife passages such as under-road crossings and culverts can significantly reduce road mortality when properly designed and placed (Marcelino et al. 2025). Discussed below are management techniques that can be implemented to help reduce road mortality in 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[KS1.1] amphibians such as Spotted Salamanders, Wood Frogs, Northern Spring Peepers, and Green Frogs (Karraker 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 Kazlauskienė 2009).

Educate the public and motorists – Given the overwhelming evidence that the

1. Vegetated buffers along roads can reduce nutrient and contaminant inputs into wetlands. Use of sickle bar mowers is encouraged when mowing is necessary to reduce mortality .



1-2. Wildlife crossing signs are an inexpensive and valuable educational tool to alert drivers of the presence of species and to be mindful. Seasonal signage has been shown to be more effective compared to permanent signage to engage the public.

Time maintenance to avoid herpetofauna – Curb and shoulder maintenance activities can be scheduled to avoid 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 et al. 2007). These road closures have been successful in Europe, Canada, and parts of the U.S. (Seigel 1986; Jochimsen et al. 2004).

Engage the public to move animals – The manual 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.



Massimo Gulino



1. Seasonal migration in spring across roads can be a source of significant mortality for herpetofauna.

2. Amphibians and reptiles, such as this Eastern Snapping Turtle, often become trapped between railroad rails and either desiccate or are crushed. Placement of crushed stone ballast every 300-500 feet within the rails provides ramps for herpetofauna to exit safely.

may be an option in residential or rural areas (Walston 2010).

Railroad Mitigation Measures

The placement and crossing structure guidelines outlined for roads are generally applicable for railroads as well. However, some railroad mitigation measures are unique, given the design of railroads. Due to the steep angle between the rails and the interior of the track, turtles that find their way onto the railroad often become unable to escape (Vincent et al. 2025; Vincent 2022). While trapped, these turtles can easily overheat and desiccate (Kornilev et al. 2006). Various engineering solutions can be implemented to provide an escape route for trapped herpetofauna. Asphalt can be placed between the rails in such a way that it gradually thins and slopes downward, similar to a common crossing structure for vehicles (Malloy et al. 2014). This ramped solution could allow turtles to exit the railroad. Another option is the implementation of an interlocking plastic crossing apparatus between the rails. Designed for vehicle crossings, these structures could also allow trapped turtles to escape a railroad with the addition of ramps on either side of the plastic (Turtle Plastics 2019). Similar to road culverts, open-air crossings beneath the metal rails can be utilized to



The main road leading to Presque Isle Park in Marquette, Michigan, bisects an essential salamander migration route. In an effort to protect the spring migration of vernal pool dependent amphibians, the road is closed annually as a collaborative effort between Northern Michigan University (led by Dr. Jill Leonard), the City of Marquette, and numerous other partners and volunteers. Between March 17 through May 15, the Marquette Police Department closes the road to traffic between 8 pm and 8 am. Efforts like this, a first for Michigan, are critical to move toward a community understanding of the role amphibians play and the impacts roads can have on seasonal species movement.

Slow traffic – Reduced speed limits and speed bumps can reduce traffic speeds, which also reduces road mortality. This

Hailey Brown

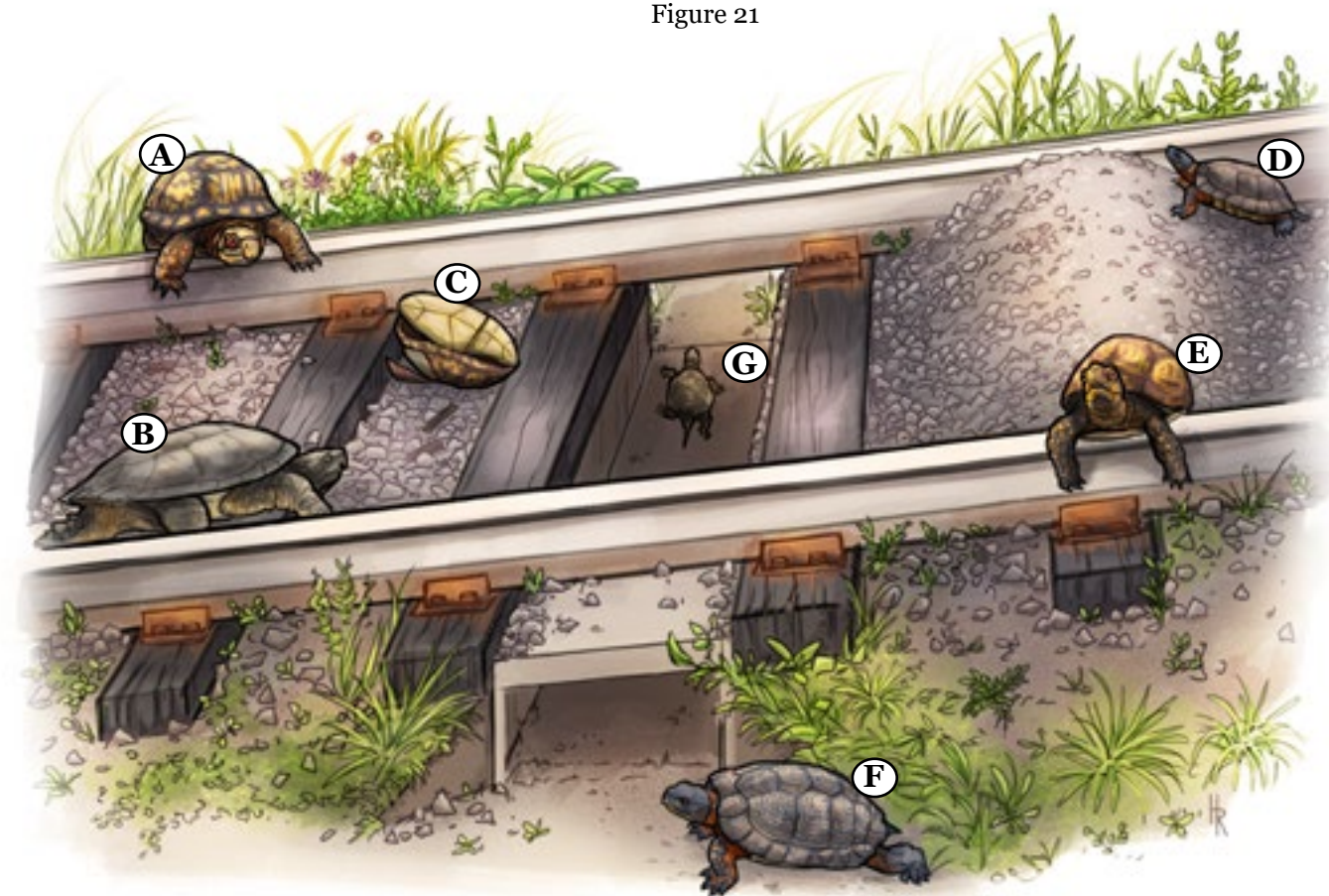


Figure 21

Figure 21. This figure depicts railroad-associated turtle mortality and methods that can be put in place to mitigate it.

Turtles, and other herpetofauna commonly disperse across large areas to seek out additional habitats, mates, and nesting areas. As a result, these animals often encounter railroads that bisect their natural habitats. These animals then climb over in an attempt to reach their destination (A). The ground between the rails is

oftentimes lower in elevation than the ground along the outside of the railroad. This results in turtles and other animals that were able to initially traverse the rail to become entrapped between the rails on the inside of the tracks. Even large turtle species, such as the Eastern Snapping Turtle, are commonly trapped (B).

Trapped turtles are oftentimes crushed by a passing train or die of exposure and desiccation (C). Implementing mounds of crushed

rock sloping to or near the top of the rails allows trapped turtles and other herpetofauna to escape (D-E).

The usage of wildlife culverts positioned underneath railroad tracks, especially when utilized at railroads that bisect high quality habitats, allows turtles and other wildlife that frequently attempt to cross safe passage to the opposite side (F-G).



1. Spotted Turtles have successfully used culverts.

2. Use of culverts and ramp systems will benefit a wide range of herpetofauna.



Tom Beauvais

facilitate safer travel across a railroad. Spotted Turtles have been documented utilizing this type of crossing structure (Pelletier et al. 2005). A simple and cost effective measure includes the use of crushed stone ballast (usually granite or similar hard rock), which is already on site or used as part of maintenance. Every 300-500 feet (depending on species and need), place mounds that reach the top of the rails to allow trapped turtles and other herpetofauna to escape. Similarly to road intersections with rail lines, this can be an incredibly effective and simple solution.

Boating Mitigation Measures

On water bodies with large populations of aquatic turtles, such as Northern Map Turtles and Eastern Spiny Softshell Turtles, the use of high-powered motorized boats is discouraged because of 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 a loss of habitat for herpetofauna and other aquatic organisms. Speed limits can provide turtles more time to evade oncoming boats and lessen the wave action produced by the boat that may damage the shoreline (Sorensen 1973; Hazel et al. 2007; Bulté et al. 2010; Hollender et al. 2018; Bilkovic et al. 2019). Closing certain areas with high densities of turtles during their active season can protect turtles from direct collision mortalities as well as prevent the wake-induced erosion of crucial shoreline that provide nesting opportunities for turtles and habitat for many other herpetofauna (Schwimmer 2001; Bulté et al. 2010; Fonseca and Malhotra 2012; Lester et al. 2013). Other areas to consider for boat closures include prime basking sites, communal hibernation sites, and nesting areas (Bulté et al. 2010; Heinrich et al. 2012).

Improperly maintained and older engines can also introduce contaminants, 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 et al. 2006; Slabbekoorn et al. 2010), and may also disrupt herpetofauna. Although these impacts are likely comparatively small to other threats impacting 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



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

(e.g., row-boat, canoe, kayak) or electric-powered watercraft can also avoid chemical and noise contamination (Heinrich et al. 2012). Boater education courses that teach boat operators the effects boats can have on wildlife and how to avoid these detrimental impacts can aid in the long-term protection of aquatic herpetofauna (Heinrich et al. 2012; Lester et al. 2013).

Maintained Landscapes and Park Open Space

Simple steps in landscape maintenance can improve habitat quality, and connectivity, while conserving 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

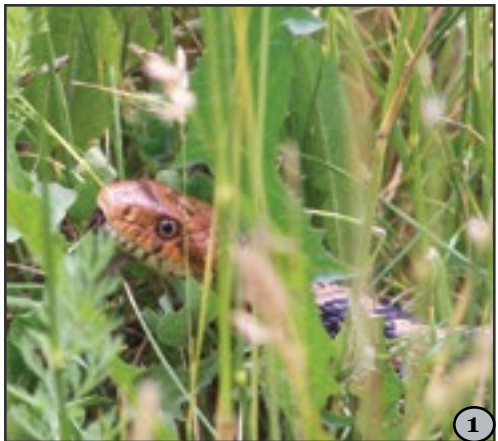
Although mowing can also be an effective management tool for reducing woody plant growth, it can cause direct mortality (Mitchell 1988; Durbian 2006; Meshaka Jr et al. 2008; Humbert et al. 2009) and severely injure amphibians and reptiles. It can also discourage the use of sites by herpetofauna, resulting in significant negative impacts (Saumure et al. 2007). **Mowing is another common management technique used to maintain early successional habitat and can be achieved with significantly less consideration when compared to prescribed burning.** When utilizing mowing as a management tool, it is important to consider how its application will also affect habitat structure, temperature, humidity, and exposure of herpetofauna to predation and desiccation.

Mow infrequently and during the hottest times of the year – Less frequent mowing results in fewer mower-related mortalities of herpetofauna and other wildlife.



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





1. Grass maintained at <2" in height will deter amphibians and reptiles from inhabiting lawns, and subsequently reducing mortality during mowing events.

Figure 22. Alternately letting grass grow to >6" will provide cover and prey for amphibians and reptiles.

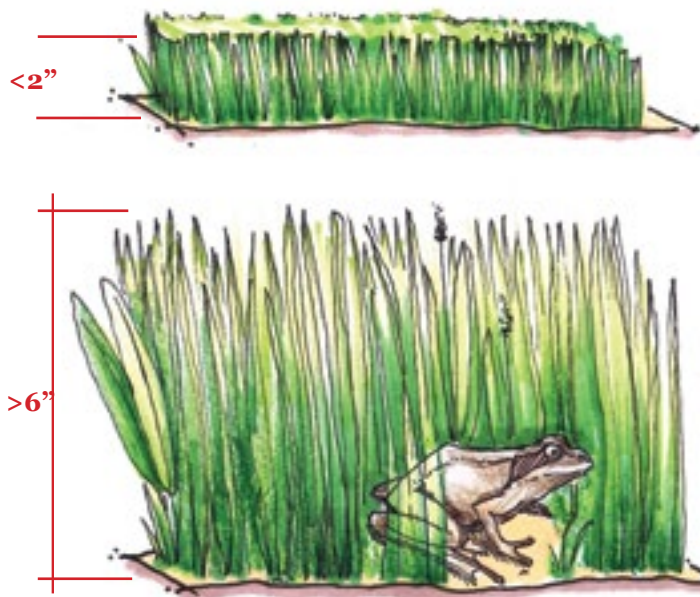


Figure 22

Also, mowing less frequently costs less and reduces carbon emissions. When mowing, it is most important to mow infrequently and to avoid mowing during turtle nesting season as well as during the peak foraging or migration season of other herpetofauna. The best time to mow is during the hottest time of year, which in Michigan is generally July, when animals can flee. Alternatively, mowing in late fall to early winter when animals are inactive. Best practices include avoiding mowing during peak turtle nesting (late May – July), amphibian breeding migrations (spring/fall), and foraging seasons. Turtles use edges of lakes and ponds and even the 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 herpetofauna.

Set mower decks high (>6in) or low (<2in) – Setting mower blades 6in or more from the ground can help to avoid ground-dwelling wildlife. A minimum mower deck of 10 – 12 inches from the ground is recommended to allow escape and refuge. Use a high-cut setting (10 – 12 inches minimum) to allow escape and refuge. Additionally, by beginning in the center of the area to be mowed, herpetofauna may escape in all directions (Iowa NRCS 2005). Mowing should start in the center of the target area, gradually moving outwards while ensuring to avoid cover objects or moving up and down an area to avoid trapping. Alternatively, if the presence of herpetofauna is not compatible with a landscape (e.g., discouraging Eastern Massasauga Rattlesnakes in public areas), mowing grass short (<2in) 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.

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



1. Mowing activities during peak turtle activity can result in higher rates of mortality. Here an Eastern Box Turtle was killed during habitat mowing in June.

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

the 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.

Controlling Access

Contact with nature can provide health benefits for people and enhance their appreciation and subsequent protection of the environment (Maller et al. 2008). Unfortunately, human access to natural areas can result in degraded wildlife habitats (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, and increase incidental collection (Garber and Burger 1995; Simberloff and Cox 1987; Simberloff et al. 1992; Hess



thermoregulate (Sievert and Hutchison 1991), food availability, distribution, and movement between landscape features, as well as egg and breeding ground suitability (Halverson 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 to the 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





1



2

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

2. For projects that involve direct habitat alteration, such as dredging or a drawdown, animals should be collected as part of a wildlife clearance effort and relocated.

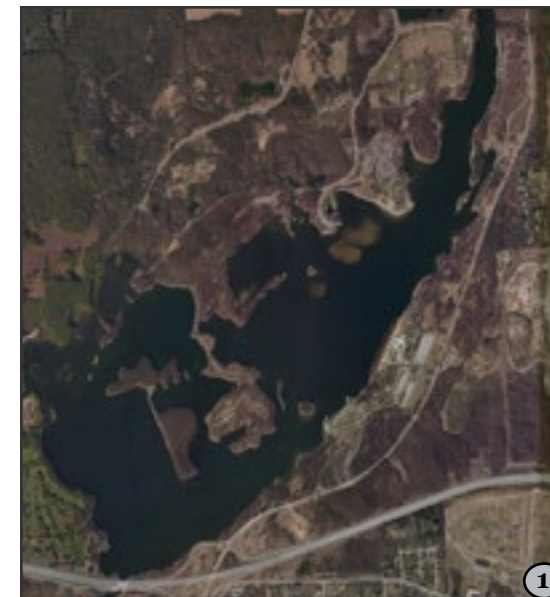
1994). They also fragment landscapes and increase the potential for negative human interaction and persecution.

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 lakebed composition that are suitable for their habitat requirements (Kupferberg 1996). Shoreline development, 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 et al. 2000; Bodie 2001; Paton and Crouch III 2002; Lenhart 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 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 et al. 2011). Dams represent one of the most severe and pervasive threats to riverine herpetofauna, inducing impacts through physical fragmentation, hydrological alteration, and geomorphic change (Fagan 2002; Bárcenas-García et al. 2022). 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 increases the likelihood of colonization by invasive plants and animals (Galatowitsch et al. 1999; Zedler and Kercher 2004). Dams not only fragment the landscape by creating physical barriers, but they can also alter the timing and intensity of natural flooding events (Magilligan and Nislow 2005). These changes can be detrimental to species that depend on seasonally inundated floodplains, ultimately contributing to reproductive loss and decreased gene flow. Dams also disrupt lateral connectivity between the channel and its floodplain. Changes to the timing, duration, and intensity of natural flood pulses caused by dams can degrade or eliminate seasonally inundated wetland habitats that are essential for amphibian breeding, turtle foraging, and nutrient cycling (Magilligan and Nislow 2005; Tockner and Stanford 2002). Species like the state-endangered Blanchard's



1

1. While creating impoundments should be avoided, those that have existed for 50+ years or more, can develop a suite of wildlife associated with that community.

connection. This elimination of standing water can result in mass larval mortality and disrupt important life cycle processes (Swan et al. 2015). 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 for wildlife movements at a site. Culverts are now more typically sized for bank full or 100 year events. Undersized culverts can result in insufficient hydrologic equalization and impoundment of water upstream of a culvert, causing 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 at bankfull elevation or higher 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.

Decrease impermeable surface area – Urbanization and increased impermeable surfaces within a watershed can alter hydrologic processes, degrade water bodies, and reduce wildlife diversity (Booth and Jackson 1997; Roy 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.



1. Undersized culverts can result in impounding of water.

2. 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.



Avoid impounding aquatic systems – Impeding the flow of water can convert a wetland into a lake with reduced value for herpetofauna on the upstream side of the impediment while virtually eliminating the wetland on the downstream side, further reducing available herpetofauna habitat. The creation of an impoundment induces a fundamental shift in aquatic conditions, transforming a flowing river (lotic system) into a still or slow-moving water body (lentic or semi-lentic system). This extreme shift in physical habitat structure destabilizes the ecological community that had adapted to historic riverine conditions. This abrupt, forced transition of flora and fauna from one community type to another is often accompanied by

widespread mortality (Alho 2011). The shorelines created by reservoirs typically fail to replicate the riparian habitat conditions that previously existed along undammed rivers. The creation of reservoirs also disturbs or eliminates vital habitat features used by aquatic turtles along adjacent upland edges and riverbanks. Reservoirs impede animal movement, dispersion, and migration within river systems and the surrounding upland habitat (Alho 2011). If creation of impoundments is necessary, relocate animals prior to construction and associated drawdowns, and time construction and drawdowns for when herpetofauna are most mobile and able to respond to the change.

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 the channel and floodplain to remain intact and to reduce impacts on stream stability and habitat.

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 an essential 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

1. Dredging materials in littoral zones should only be conducted with integrating a wildlife clearance component.

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 it is 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 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. **For a detailed discussion on these habitat structures, see Section 6: Ecological Restoration, Mitigation, and Habitat Design.**

2. Use of on-site materials like logs and rocks can be used to create hibernacula and basking logs. Here a hibernacula was constructed along a coastal marsh habitat associated with Lake St. Clair.



Install or maintain vegetated buffers and natural rock as an alternative to seawalls and hardened channels – Structures intended to reduce shoreline erosion and washouts, as well as prevent amphibians and reptiles from accessing upland habitat for basking, nesting, and foraging (Engel and Pederson 1998; Mosier and Witherington 2002; Witherington et al. 2011). Shoreline hardening





1. Northern Brown Snakes can be associated with riprap along rivers and large lakes.

2. Seawalls serve as a form of fragmentation for several species especially turtles.

3. Shoreline restoration should include VFR and natural channels to facilitate movement and connectivity for the greatest number of herpetofauna.

replaces natural shorelines for constructed features to minimize wave action against shorelines and to prevent erosion. Common artificial shoreline features include seawalls, bulkheads, riprap, and revetments. Natural shorelines differ from hardened shorelines in terms of habitat structure and functionality. Hardened shorelines tend to be steeper and drier, and have slower rates of organic matter decomposition. Natural shorelines have more gentle, undulating shorelines and slopes with greater organic material that support a larger invertebrate community composition (Wensink and Tiegs 2016). Limiting the availability of natural shoreline significantly reduces suitable nesting sites for riverine turtles. Armored shorelines can also act as a barrier to dispersal, preventing aquatic herpetofauna species from accessing terrestrial habitat. 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 et al. 2005). Natural rock provides crevices and irregular surfaces which diffuse water velocity and give herpetofauna places to hide.

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 can provide places for snakes to take shelter and hibernate. A way to mitigate movement barriers caused by riprap revetments is by creating small pockets of natural shoreline within the riprap to allow for increased connectivity between aquatic and terrestrial



1. In high wave action and erosion areas a combination of rock and emergent vegetation is recommended to provide the greatest function and habitat value.

2. Eastern Fox Snake using recently restored shoreline habitat.

habitats. Where seawalls are present, install a gently sloped ramp containing a textured surface for grip to facilitate dispersal. It is important to conserve natural shorelines and streambanks by offering natural solutions to maintain these critical nesting spaces. A rough surface with several horizontal structures can provide places where a turtle or snake can climb out of the water to bask. Despite riprap presenting a large challenge to turtles, many species of snake, particularly the Eastern Fox Snake, Northern Brown Snake, Butler's Garter Snake, and Northern Water Snake, avidly utilize riprap as essential habitat features (Harding and Mifsud 2017). Riprap likely provides a type of surrogate habitat that resembles aspects of the natural historic shoreline, which once included fractured limestone shelves that served as critical refugia and sites for egg deposition. Careful consideration should be given to any landscape modification project that would eliminate such critical features in areas where this and other species may occur.

Void-Filled Rip Rap (VFR) is a practice where conventional riprap is filled with smaller, well-graded materials like gravel or soil to eliminate the small gaps that turtles would otherwise be unable to climb over or get stuck in. Planting native vegetation within these crevices to further enhance habitat suitability and support a wider range of herpetofauna species. This process can be implemented in small, spaced-out segments that establish a path from the water to upland habitat, with suitable nesting sites created at the top of the pathway with southern or southwestern exposure. **For a detailed discussion on these habitat structures, see Section 6: Ecological Restoration, Mitigation, and Habitat Design under Stream and River Restoration and Mitigation.**



Herpetofauna-Friendly Shoreline Development Designs

Bruce Kerr & EGLE



Low-Energy Design - Natural shoreline vegetation and substrate provides low to moderate wave energy absorption while maximizing nesting opportunities and habitat for herpetofauna, macroinvertebrates, fish, and wildlife.

Bruce Kerr & EGLE



High-Energy Design - Natural shoreline vegetation and rip-rap provides moderate to high wave energy absorption while still providing both terrestrial and aquatic habitat for herpetofauna and other wildlife.

Bruce Kerr & EGLE



Seawall Design - Sloped, fortified rip-rap seawall provides maximum wave energy absorption while still offering herpetofauna and other wildlife land-water access and habitat.

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.

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 Southern 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.

Dam Bypasses and Fish Ladders

Dam bypasses, or fish ladders, can range from natural landscape designs to more complex and heavily engineered structures to address specific species and objectives. Fish ladders are a common type of wildlife passage typically used in riverine systems associated with dams or barriers preventing fish from accessing upstream or downstream habitat. These ladders allow fish to traverse through a series of connected step-pools that form an upstream passage over a dam. While fish ladders are commonly used to reconnect upstream

and downstream sections of dammed rivers, comparable ladder systems designed specifically for herpetofauna currently do not exist in North America. However, this does not mean that amphibians and reptiles are incapable of using ladder-like structures; in some cases, they have been observed utilizing designs intended for other species. For example, a Northern Water Snake has been documented ascending an eel ladder to circumvent a dam (Welsh and Loughman 2015). Eel ladders consist of sloped ramps outfitted with closely spaced protrusions that provide traction points for eels, allowing them to brace, coil, and propel themselves upstream. Such observations highlight the potential for adapting or expanding these designs to develop more inclusive herpetofauna passage structures that mitigate habitat fragmentation in dammed river systems (Welsh and Loughman 2015). These eel structures may be ecologically beneficial to species like the Northern Mudpuppy and, to a lesser degree, the Western Lesser Siren. Modeling and testing should be conducted to determine the needs of Northern Mudpuppies and design to reconnect these species on the landscape.



2. Northern Mudpuppies are slow moving bottom dwellers swimming minimally. In a dam failure these species would be washed down river and in most cases die.

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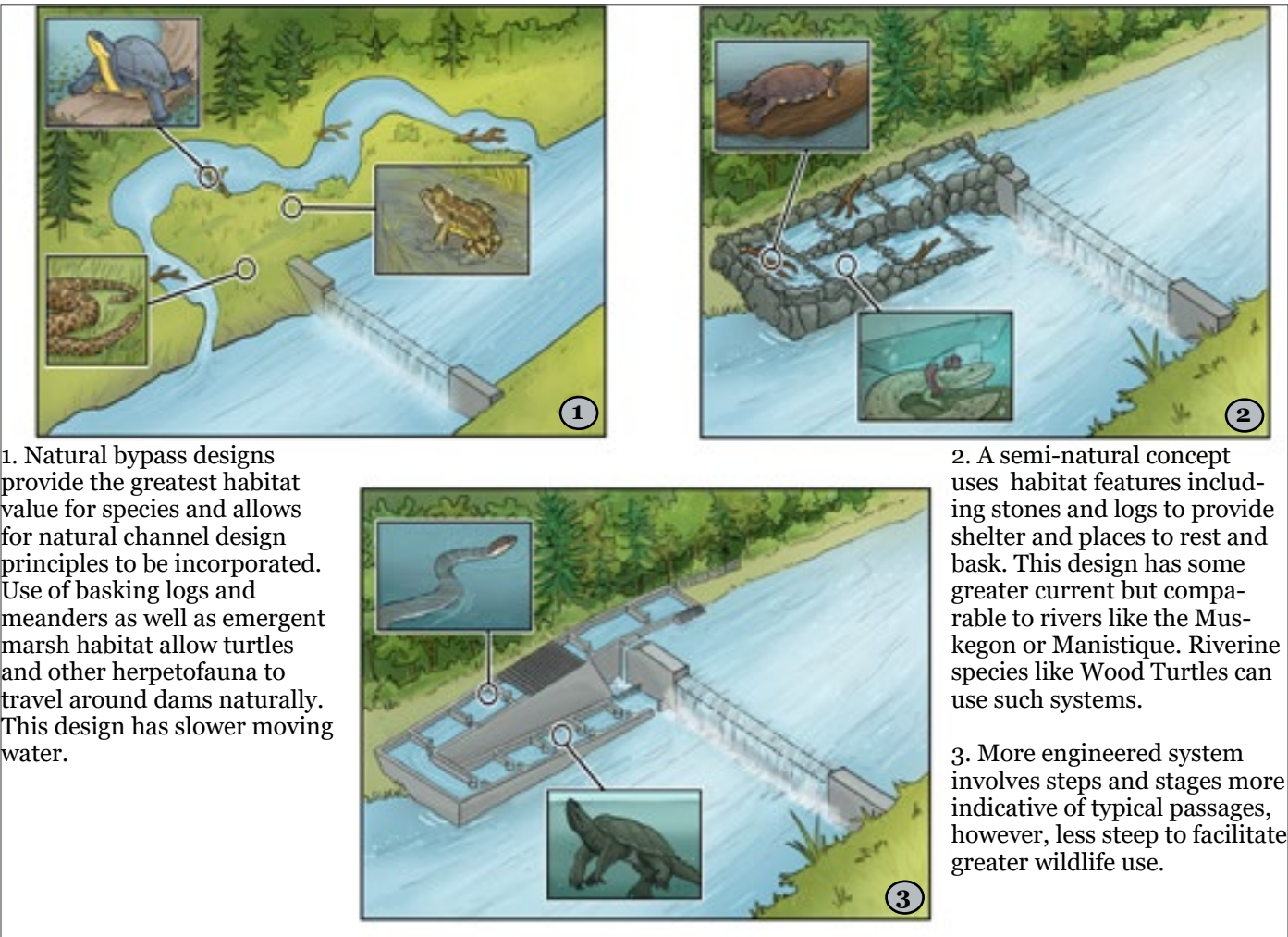
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1. Natural bypass designs provide the greatest habitat value for species and allows for natural channel design principles to be incorporated. Use of basking logs and meanders as well as emergent marsh habitat allow turtles and other herpetofauna to travel around dams naturally. This design has slower moving water.

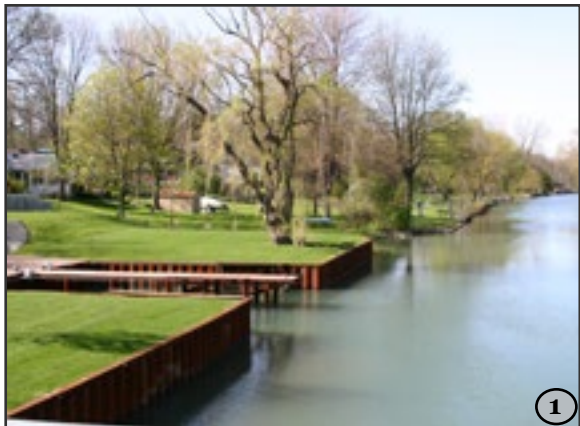
2. A semi-natural concept uses habitat features including stones and logs to provide shelter and places to rest and bask. This design has some greater current but comparable to rivers like the Muskegon or Manistique. Riverine species like Wood Turtles can use such systems.

3. More engineered system involves steps and stages more indicative of typical passages, however, less steep to facilitate greater wildlife use.

Turtle-Specific Passages

A pioneering wildlife passage system designed specifically for riverine turtles has been installed in the Fitzroy River in Queensland, Australia. This structure was engineered to provide upstream and downstream passage for endangered species like the Fitzroy River Turtle and White-throated Snapping Turtle, both of which have experienced movement barriers created by the Rookwood Weir (Pratt 2025). The bypass incorporates textured concrete ramps that provide sufficient traction for turtles to ascend the weir, along with strategically placed resting pools and shaded areas. These features assist in reducing thermal stress and allow individuals to recover during the passage. The ramp design is based on research showing that, rather than swimming through strong currents, many freshwater turtles select to walk along the riverbed. Although this turtle bypass may require slope and spatial adjustments to accommodate riverine turtle species in Michigan, the documented use and function of such structures warrant review and consideration to facilitate the movement of imperiled species.





Shoreline Access Ramps

Shoreline habitat access and the steepness of some shorelines can limit the available habitat for some turtle species. Painted Turtles, Musk Turtles, and Map Turtles, among others, need access to shorelines for nesting, and if shorelines are too steep or inaccessible, it can limit their reproductive success. Mitigation for this can be the installation of ramps from the water up onto shoreline areas. These ramps should not exceed 40 degrees in tilt and should be textured to provide adequate grip for climbing (Scott et al. 2023).



Dam Removal and Restoration

Michigan contains more than 2,500 dams (Michigan Department of Natural Resources and Michigan Department of Environmental Quality 2004). As these structures continue to age, they require maintenance or removal to address safety concerns. Because repairs can be prohibitively expensive, removing dams that are obsolete or pose environmental risks is often a more cost-effective solution. Dams can act as barriers to movement for amphibians and reptiles and significantly modify hydrologic patterns and thermal regimes, influencing key life history activities such

1. Vertical sea-walls with no land-water access and absent native vegetation provide extremely limited habitat for herpetofauna and other wildlife.

2. Dock ramps allow turtles and other wildlife to access terrestrial habitat to bask.

as breeding, nesting, basking, and overwintering (Ligon et al. 1995; Lind et al. 1996; Bettaso 2013). By fragmenting once contiguous aquatic landscapes, dams can disrupt flood-dependent wetland connectivity. This fragmentation bisects populations as well, resulting in a cascade of ecological impacts for herpetofauna, restricting essential movements such as breeding dispersal, foraging, and seasonal migration, which can lead to population isolation, reduced genetic diversity, and increased risk of local extirpation (Bárcenas-García et al. 2022; Fagan 2002). Removing dams that disrupt natural flow regimes can restore ecological function, increase habitat connectivity, and improve the diversity and viability of wildlife populations within river systems. However, impoundments created by these structures often form ponded habitats that may support species not typically associated with free-flowing systems. Wetlands and exposed substrates within impoundments can also provide important nesting areas for turtles. The process of dam removal, including drawdown and dewatering of riparian wetlands, can displace wildlife and alter chemical, physical, and biological conditions, thereby affecting herpetofauna habitat (Hart 2002). While dam removal is a critical restoration tool, the process itself presents significant short-term risks that must be managed to avoid undermining long-term conservation goals. It is important to prepare for and address these potential problems to minimize impacts to the larger ecosystem.



Pre-Construction Planning and Baseline Data

A comprehensive herpetological assessment is a non-negotiable prerequisite. This work must establish baseline data on species presence, relative abundance, age structure, and spatial ecology, including critical features like nesting areas, hibernacula, and movement corridors relative to the structure (Sousa et al. 2021). Context can be gained through a historical review of data prior to the dam’s construction, indicating which species may have been historically present. Examining adjacent landscapes with more typical, undisturbed conditions will further inform restoration targets and the steps required to meet them.

Dewatering and Wildlife Considerations

1. Inventories are needed to assess and plan wildlife clearance work to reduce the threat and harm to herpetofauna. In situations where time and resources are limited, priority should be given to long-lives, slow to mature species with low reproductive output compared to species that mature fast and produce large numbers of off spring. Those species can recover quicker.

2. Oxbows and sloughs provide critical habitat for several riverine species.

Dam removal or repair initiates a dewatering phase that can have severe ecological consequences. A primary concern is the rapid mobilization of trapped sediment; increased loads can quickly smother macroinvertebrate communities, causing significant disruptions to both aquatic and terrestrial food webs. Compounding this, dams historically have starved downstream reaches of the sediment and organic matter essential for maintaining channel morphology, stable riparian zones, and nesting sites like turtle point bars (Kondolf 1997). This sediment starvation contributes to channel incision and the loss of critical inshore habitats. Concurrently, receding water levels force aquatic and semi-aquatic species to migrate, often concentrating them on predictable terrestrial pathways. Without careful planning, this leads directly to mass stranding and catastrophic road mortality (Gibbs and Shriver 2002).

Creating Oxbows and Habitat Features

Post-removal restoration plans should not simply re-create a generic stream channel. They must incorporate retained or engineered habitat feature surrogates, such as backwaters, oxbows, and stable sand deposits, to replace lost impoundment features that resident species may have depended on for decades. Where feasible, explore opportunities to establish oxbows (formed when a river bend is cut off from the main channel) or retain shallow ponded areas within the watercourse. These features can support species that have adapted to



1. When work is being conducted on dams, effort should be made to install WBF and conduct wildlife clearance if impacts will be impacting species. If dewatering is conducted the WBF will restrict movement of species especially rare species.

the wetlands and backwaters created by the original impoundment. Oxbows typically exhibit slower water velocity and warmer temperatures compared to the main channel, creating favorable conditions for turtle basking and mating, amphibian breeding and larval development, and snake foraging. These areas also present suitable locations for installing turtle nesting sites or other habitat features for herpetofauna. Reviewing historic aerial imagery and soil surveys can help identify areas that supported wetlands prior to impoundment. Where possible, locate turtle nesting structures on south-facing slopes to offer replacement nesting opportunities. During dewatering, anticipate that wildlife may attempt to move out of the area and take measures to prevent reptiles and amphibians from accessing nearby roadways. These individuals can be collected and relocated to suitable off-site habitat or temporarily held and later introduced to newly created backwater areas within the project site.

BMPs for Removal Projects

A proactive, phased approach is essential:

1. Install robust exclusion fencing along the entire impoundment perimeter and predicted emigration routes well before dewatering begins.

2. Implement active rescue and relocation: employ trained herpetologists or biologists with demonstrated experience working with wildlife clearance of herpetofauna to systematically capture reptiles and amphibians within the dewatered zone and relocate them to pre-identified, suitable habitats outside the project footprint.

3. Employ seasonally appropriate timing: restrict high-impact activities like dewatering to periods of low herpetofauna activity (e.g., early fall, late summer for many species, avoiding spring emergence and nesting seasons and fall hibernation migrations).

4. Design for functional habitat as described above.

Dam removal projects are inherently complex and require careful coordination across multiple



2. Blanding's Turtle within a recently dewatered aquatic habitat. Typically these species will attempt to migrate out of the area seeking water. Without measure in place they can potentially intersect a road.



1. Dam removal and habitat restoration is a major and laborious undertaking. It requires many people and groups to work collectively and collaboratively.

disciplines. These efforts involve both aquatic and upland environments and must address a range of interconnected elements, including flowing water management, contaminated sediment removal, channel reconstruction, and reestablishment of native vegetation. Additional considerations include the protection of fish and wildlife, as well as standard construction practices like soil erosion control. Given the complexity and site-specific nature of each project, it is essential to consult a professional restoration biologist or other qualified expert before proceeding.

Following dam removal, the newly exposed substrate in formerly impounded areas is vulnerable to colonization by invasive plant species (Orr and Koenig 2006; Collins et al. 2007). This risk is heightened when the substrate contains elevated levels of micronutrients or toxic contaminants, conditions that many native plants are ill-equipped to tolerate. The broader restoration guidelines outlined in this manual, particularly those

addressing soil erosion control, wetland mitigation, and stream and river restoration, are also directly applicable to dam removal efforts.

Streambank Stabilization and Erosion Control

In agricultural landscapes where erosion is problematic, stabilization of active gullies is necessary and can be accomplished by reducing water velocity, trapping sediment, and encouraging vegetation growth through the use of gully erosion control structures.

Natural erosion control methods exist to reduce streambank erosion and maintain critical riparian habitat, including nesting areas. Large woody debris (LWD) can be used in a variety of applications depending on the project. Factors such as stream size, channel stability, flow regime, depth, and the presence of existing LWD can help determine how to most effectively utilize natural methods to meet management goals. LWD can be used to form natural features like pools, reproductive habitat, cover, and foraging areas while also contributing essential erosion control (Fischenich and Morrow Jr. 2000).

Live staking can also be implemented as a stabilization technique. This method involves installing live stakes of woody hydrophytic vegetation (typically Willow and Dogwood) into the soil, where they sprout and develop root systems that further stabilize the banks.

Streamside management zones (SMZ) provide another approach for reducing erosion in riparian habitats that are vulnerable to disturbances such as timber harvests. These SMZs function similarly to agricultural filter strips, which are designed to naturally





1. Placement of logs along the banks of a exposed river bank helps stabilize soils while still allowing for movement of turtles to find nesting areas.

intercept and retain sediment before it can negatively affect water quality. SMZs additionally serve as refugia for amphibians and reptiles, helping to enhance the diversity and complexity of local herpetofauna communities (Foley 1994). While maintaining an appropriate setback is important, preserving open habitat close to and along the river's edge is highly valuable when feasible. Sites that support species like Wood Turtles and Eastern Box Turtles require foraging areas and open canopy nesting sites with diverse native vegetation. These habitats also provide essential resources for numerous species of mammals, ground-nesting birds, and invertebrates. Placement and width relative to the water's edge require careful evaluation of site conditions and slope to avoid erosion or other

damaging landscape impacts.

Caution is warranted when using artificial means to control erosion. Commercial erosion control mesh netting is commonly used to protect water quality, especially in construction settings. Despite being simple to install and advertised as photodegradable, this material can pose significant risks to local herpetofauna. Snake species are particularly vulnerable because they readily become entangled in the material, leading to serious injuries or mortality from overheating, desiccation, and exposure to predators (Walley et al. 2005). Also, poorly timed installation of these erosion control products can entrap hatchling turtles, causing desiccation and death.

Restoring eroded riparian zones in urban riverine systems poses a unique challenge for resource managers. This is due in part to widespread impervious surfaces and associated flashiness, which produce higher and more rapid flow velocities. When planning stabilization

and restoration of these habitats, soil stability can be improved by increasing vegetative structural complexity within the riparian zone and by integrating woody debris into the site (Banville and Bateman 2012).

These actions not only prevent erosion but also enhance the surrounding habitat suitability and site conditions for herpetofauna.



2. Use of natural soil erosion fabric to stabilize soils along a recent stream restoration project.

1. Stabilization structures can achieve the objective, but reduced the connectivity and function of the area. While reduction of erosion is important especially on banks that turtles nest on. Sediment transport, in this case sand, is critical for creating and enriching existing nesting beaches.

Regardless of the streambank stabilization technique employed, it is important to maintain access to upland habitats and nesting sites for herpetofauna like turtles. Efforts to fortify and secure shorelines can often come at the expense of habitat accessibility or, depending on landscape and river type, can reduce the movement of sand and other sediment that are essential for forming nesting areas for species like Wood Turtles.

For a detailed discussion on streambank stabilization practices and erosion control, see Section 6: Ecological Restoration, Mitigation, and Habitat Design.



2. Nesting beaches rely on the deposition of sand to help maintain them. Here a nesting beach dominated by Wood Turtles and Eastern Snapping Turtles provides the only nesting habitat for multiple river miles. This limited resource can impact species recruitment and create a nesting sink with predators.



1. Wind energy is the most abundant source of renewable energy in the state and can both directly and indirectly impact populations of herpetofauna and other wildlife. The shadow flicker, also known as the flicker effect, caused by the shadows of rotating turbine blades can simulate a predator, such as a bird of prey, and over time can decrease anti-predator avoidance and responses to actual threats leaving particular amphibian and reptile species more vulnerable to predation.

Alternative Energy

Alternative energy can provide benefits for wildlife, including the mitigation of damage caused by climate alteration. However, the construction, infrastructure, and operations that are byproducts of renewable energy can alter the landscape detrimentally for herpetofauna. Some steps can be taken to reduce the negative effects of renewable energy on herpetofauna while maintaining the positive impacts.

Wind Energy

Wind energy is the largest source of alternative energy in Michigan, accounting for over 60% of the state’s renewable electricity (U.S. Energy Information Administration 2022). Though the bulk of scientific literature has focused on assessing the direct mortality impacts of wind turbines on bats and birds, wind energy can also directly and indirectly affect herpetofauna. Additionally, wind energy is the most likely source of renewable energy to inflict widespread impacts to herpetofauna given its prevalence in the state. There is evidence of wind farms reducing the density, richness, and anti-predator behavior of herpetofauna (Santos et al. 2010; Keehn and Feldman 2018; Trowbridge 2020). The negative impacts of wind farms can primarily be attributed to the habitat destruction and fragmentation involved with the construction and operation of wind farms (Kuvlesky et al. 2007; Perrow 2017). Additional detrimental effects include mortality and stress from roads, noise effects, vibrations and shadow flicker, electromagnetic pollution and heat effects, microclimate/macrocclimate impacts, predator attraction, and increased fire risk (Perrow 2017).

Wind farms involve the highest land-use intensity per unit output of energy than every other type of renewable energy besides biomass production (McDonald et al. 2009). However, wind energy also allows for the retention of habitat throughout these farms between installed turbines, roads, and other infrastructure. The installation and operation of wind turbines can alter this remaining habitat, including changes in soil densities and composition, water infiltration, erosion, microclimate, and vegetation composition (Lovich and Bainbridge 1999; Lovich and Ennen 2011). Fragmentation caused by degraded habitat and the roads associated with windfarms can potentially disrupt gene flow corridors (Fischer and Lindenmayer 2007) and result in road mortalities (Andrews et al. 2008). Noise from the machinery and blades of wind turbines, as well as their associated roads, may interfere with herpetofauna hearing, phenology, and



1. Species like the Northern Spring Peeper can be disrupted by the vibrations emitted from these pieces of equipment. They are also impacted from habitat loss and fragmentation of access roads.



acoustic communication, particularly in frogs (Brattstrom and Bondello 1983; Lengagne 2008; Vargas-Salinas and Amézquita 2013).

Wind farms produce vibrations that can be broadcast long distances (Styles et al. 2011), which can interfere with the behavior and communication of herpetofauna. All groups of herpetofauna occurring in Michigan (salamanders, frogs, lizards, snakes, and turtles) are known to perceive vibrations and could potentially be affected by the turbines (Perrow 2017). Turbines also produce

light flicker caused by the reflection of sunlight off the blades, as well as shadow flicker caused by the spinning blades interrupting sunlight. The alternating shadows can simulate the shadows produced by birds of prey, common predators of herpetofauna. As such, shadow flicker can increase the predator response of herpetofauna (Cooper 2009). The microclimate of the habitat within windfarms can be affected by vegetation removal, construction, and soil disturbance (Liechty et al. 1992; Chen et al. 1999). Wind turbines themselves can also directly influence the microclimate through the vertical mixing of air from blade movement and the macroclimate through altered wind, precipitation, evaporation, and soil moisture patterns (Abbasi and Abbasi 2000). Lastly, wind farms increase the risk and frequency of fire, which can be damaging to herpetofauna populations (Starr 2010).

Once wind turbines are in place, it is difficult to reduce the negative impacts to wildlife. However, measures can be taken during the placement and construction phases of wind farm development that can mitigate the damages to herpetofauna populations. Strategic planning for wind farm development is crucial to ensure natural resources and the wildlife they serve are protected as much as possible. When selecting the location for wind farms, avoid areas that are within approximately 2,000 feet of wetland complexes greater than 2.5 acres (Ewert et al. 2011). Herpetofauna often disperse long distances between water and this buffer will prevent the loss of essential habitat and help maintain connectivity between breeding and nonbreeding habitat (Ewert et al. 2011). Additionally, the use of HDD or boring during the installation of any cable segments underground can prevent the fragmentation of habitat. Lastly, crossing structures and reduced speed limits can prevent road mortalities within wind farms (Woltz et al. 2008; Walston 2010). During development, crossing structures can also be made temporary to allow for large equipment to access the build side, then restored following project completion. Strategically incorporating existing routes and infrastructure for the large crane walks can reduce the amount of temporary or permanent access roads needed.



1. By incorporating the Woody Biomass Harvesting Guidelines and the Best Management Practices provided within this manual, biomass can be a herpetofauna-friendly source of renewable energy.

2. Leaving behind woody debris and tree tops can provide shelter for herpetofauna and other wildlife following a clearcut harvest.

3. The Northern Ring-necked Snake uses decaying logs and brush as habitat. They also specialize on Eastern Red-backed Salamanders and these species frequently use these habitat also.

Other Alternative Energy Sources (Biomass, Hydropower, Solar)

Biomass and hydropower provide the vast majority of the remaining renewable energy in Michigan, while solar energy produces a relatively small amount of electricity in the state (U.S. Energy Information Administration 2022). The impacts these energy sources inflict on herpetofauna populations vary significantly. Biomass harvesting often occurs in natural communities where the trees provide little ecological value, and the overall habitat does not support a high diversity of herpetofauna (i.e., pine plantations). As a result, biomass harvesting typically creates a neutral, or even positive, impact for herpetofauna (Verschuyl et al. 2011; Homyack et al. 2013; Homyack and Verschuyl 2019).

Adhering to Woody Biomass Harvesting Guidelines (WBHG) can help ensure that biomass harvesting does not negatively affect herpetofauna or other wildlife (Michigan Department of Natural Resources and Environment 2010). Following these types of guidelines increases the retention of downed woody debris, which can provide important shelter for herpetofauna following harvesting (Fritts et al. 2014). Downed, dead woody debris and standing dead trees (snags), as well as the tops of some trees, can be retained to provide important herpetofauna habitat (Michigan Department of Natural Resources and Environment 2010). Avoiding the clearcut harvest of ecologically significant trees and communities can help protect herpetofauna from the negative impacts of biomass harvesting.



1. Positioning solar farms within areas such as former agricultural fields and preserving nearby natural resources is essential for maintaining local amphibian and reptile populations. To increase the value of these sites also consider establishing grassland habitat to provide multiple function values for the site.

2. Eastern Box Turtles will use grassland habitats throughout the active season and have been found within habitats that are boarder proposed solar farms.

Unlike biomass production, hydropower is incredibly detrimental to herpetofauna populations, particularly for turtles and amphibians, and mitigating this damage is incredibly difficult. Changes in river flow can result in reductions of feeding habitat (Tucker et al. 2012) and turtle nesting habitat (Bodie 2001; Norris et al. 2018; Tornabene et al. 2018). Dams also create a physical barrier to movement and can isolate populations of turtles and amphibians, reducing their genetic connectivity (Bennett et al. 2010; Gallego-García et al. 2019; Peek et al. 2020) (Dare et al. 2020) and overall density (Dare et al. 2020). Alterations of reservoir water quality caused by dams include oxygen reductions (Clark et al. 2009) and increases in contaminants such as pesticides (Douros et al. 2015) and mercury (Ferriz et al. 2021).

The mitigation of hydropower impacts on herpetofauna can prove difficult to achieve. One mitigation method involves the conservation, restoration, or creation of habitat within the reservoir (Tornabene et al. 2019; Pitt et al. 2021). The restoration of native vegetation reduces erosion, improves water quality, and encourages the reestablishment of herpetofauna (Santoro et al. 2020). Passes in dams are often used to maintain connectivity of fish populations, though turtles have primarily been observed using these passes for feeding rather than movement (Agostinho et al. 2012). The development of passes appropriate for turtles and other herpetofauna could preserve the genetic connectivity of these riverine ecosystems (Takahashi et al. 2016). Increasing the safety of terrestrial passages around dams through the use of barrier installations and road crossing structures (Bassel 2002; Pelletier et al. 2005; Rees et al. 2009; Heaven et al. 2019) can reduce road mortalities and ensure the connectivity of herpetofauna populations. Lastly, monitoring populations of herpetofauna upstream and downstream of dams can inform whether translocation efforts are required to maintain population connectivity.

Given the increasing shift to implementing more solar farms in Michigan, negative impacts on herpetofauna may likely be increasing and widespread. These facilities are growing in size and number across the state (Solar Energy Industries Association 2022) and are known to negatively impact herpetofauna in regions where solar farms are more common (Lovich and Ennen 2011). The construction of solar plants results in the loss of habitat stemming from the removal of vegetation and surface grading spanning large areas (Harrison et al.





1. Several turtle species will take advantage of these newly exposed landscapes for nesting. This is especially true for Painted Turtles. Consider creating more natural integrative solar farms that account for and consider wildlife as part of the design.

2. Avoid placement of solar farms in or near high quality habitats. Mowing activities can harm herpetofauna. Use of grazers can serve as a surrogate for mowing and can provide an additional economic value and natural resource benefit.

2017; Taylor et al. 2019). Solar farms may also degrade habitat by reducing the availability and quality of water (Bennun et al. 2021). The loss and degradation of habitat can result in barrier effects where herpetofauna populations are fragmented and connectivity is reduced or eliminated (Knutson et al. 1999; Dodd et al. 2003; Bennun et al. 2021). Similar to wind energy, the roads associated with solar facilities can lead to herpetofauna mortalities (Lovich and Ennen 2011). Solar facilities can create microclimate effects by increasing albedo effects and outputting heated air (Lovich and Ennen 2011). The resulting increases in temperature and evapotranspiration can alter vegetation communities, reduce prey availability, and directly impact herpetofauna sensitive to these altered climatic conditions, particularly reptiles (Hulin et al. 2009; Sinervo et al. 2010; Shoo et al. 2011; Barrows et al. 2016). Lastly, pollution, including dust, light, noise, vibration, and solid/liquid waste generated by solar plants, may detrimentally impact herpetofauna (Lovich and Ennen 2011; Bennun et al. 2021; Chock et al. 2021).

The importance of mitigating the negative impacts of solar farms on herpetofauna in Michigan will only increase as this industry continues to grow. The best method to mitigate damages for herpetofauna is to avoid placing solar facilities in ecologically important and sensitive habitats (Cameron et al. 2012; Hernandez et al. 2015; Arnett and May 2016; Agha et al. 2020). Translocating herpetofauna is often used as a solution to mitigate the effects of solar energy development; the success rate of this method is variable and species-dependent (Germano and Bishop 2009; Sullivan et al. 2015; Dickson et al. 2019; Agha et al. 2020). The creation of meadow and prairie habitats within solar farms can help to provide ecological value and habitat for herpetofauna that would otherwise be non-existent (Bennun et al. 2021).





9. Conclusions and Next Steps



1-2. 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 herpetofauna populations. Sensitive species such as the Pickerel Frog (right), Northern Leopard Frog (left) (1), and the Four-toed Salamander will benefit greatly from greater attention (2).

3. Even our more generalist species such as Painted Turtles, who will happily nest on a golf course need our support.

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, those working in land management or development, as well as concerned citizens, can significantly improve habitat conditions and protect amphibians and reptiles. While all the recommendations in this manual may not be feasible or practical at every site, 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 prepared 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 enhance conservation. Gathering comprehensive data on species' status, distribution, and threats establishes the essential baseline needed





to understand the overall ‘big picture’ of herpetofauna community health. This can then be used to help determine the most effective management strategies when formulating a restoration or mitigation plan. Recognizing the importance and value of both current and historic data is paramount to understanding the historical context of species richness and distribution across the state and to reduce the negative effects of shifting baselines. This information is vital for evaluating the success of conservation efforts, identifying priority areas and species, and improving the efficiency and effectiveness of species regulations. Only through a cooperative effort involving people in all fields that influence our natural resources can we protect not only herpetofauna, but all of Michigan’s natural resources.

Measuring Success

1. Long-term monitoring efforts like those conducted by Jim Harding on Wood Turtles in Michigan for nearly 60 years are critical to assess the extent of impacts and trends in threats. Few have been as dedicated as Mr. Harding to his work in amphibian and reptile conservation. His work is a reminder that the decisions we make today for herpetofauna conservation are not measured by the response next season but by the next generation.
2. Education and knowledge sharing is key. Engaging with regulators, managers, and practitioners is essential to effective conservation.

Second Edition of the Michigan Amphibian and Reptile BMP manual continued the original mission of the original publication and further advanced efforts to protect and conserve the amphibians and reptiles of Michigan. The goal of the Third Edition is to build on this work by addressing conservation concerns within a real-time



The original Michigan Amphibian and Reptile BMP manual, conceptually developed in 1999 and published in 2014, was the first step towards an all-encompassing guide for amphibian and reptile conservation in Michigan. The manual was intended to be a living document with planned future revisions to continue to provide the most up-to-date, herpetofauna-friendly solutions to the complex issues Michigan’s ecosystems face. The



1. There is still so much we do not know. The Western Fox Snake is expanding its range across Michigan and now can be found on several Lake Michigan islands. We are still relatively young post-glacially and have the opportunity to learn something every day.

2. Passion, community, and a willingness to say yes when others say no will be the key to adaptive conservation and management. We stand at crossroads to take proactive action to assure that Michigan does not lose any species without a fight.

framework and targeting the specific challenges facing species and landscapes in Michigan. However, this document alone, does not ensure success. Meaningful progress requires a collective commitment to implement these recommendations, encouraging agencies and organizations to prioritize herpetofauna in their decision-making. This means recognizing not just the potential for monetary support or publications these species can provide, but rather their greater intrinsic and ecological importance on the landscape.

For most reading this manual, you can recall a childhood experience where you were forever changed by an experience with a frog, snake, salamander, or turtle. Conservation success is achieved when we see the true role, importance, and value these species, both rare and abundant, have to our ecosystems, as well as their ability to inspire the next generation of herpetologists, wetland ecologists, regulators, stewards, and benefactors of conservation.

Statewide monitoring programs should be established and housed in an organization dedicated to the conservation and best management of these incredible species. Programs like the Michigan Herp Atlas are an incredible tool, but further community engagement, like what once existed with the Frog and Toad Survey, is needed. The loss of such programs not only disconnects us from nature but also creates knowledge and data gaps that can never be retrieved. A monitoring plan should also be developed to assess the success of recommendations described within this manual, integrating the Herp HAT as a key tool. Adopting an adaptive framework could improve the efficacy of the BMP by setting achievable goals with quantifiable targets and defined timeframes, monitoring those metrics, and applying the collected data to periodically reassess and refine the plan. As the strategies and methods recommended in this manual are applied across a wide range of conditions, short and long-term, and from local to landscape-wide scales, the resulting lessons will allow these solutions to be continually refined to become more economically and ecologically sound. We intend for this BMP to continue as a living document, with subsequent revisions and updated versions released online through HRM and project partners websites.

This BMP manual was developed out of a deep passion and concern for Michigan’s herpetofauna. It has been, and will always be, a labor of love. We are currently losing the battle and stand at a critical moment in a state of conservation crisis. We must act quickly and, at times, be willing to try, fail, adapt and grow. For some species, recovery may already be very difficult or perhaps too late. For others, opportunities are limited only by our imagination. We must consider all species and all levels of protection, but we must also devote greater attention and resources to our





most abundant and less charismatic species. Those that often receive little or no funding until they, too, become rare. Working proactively, as this manual is designed to encourage, allows for effective and realistic conservation that can be scaled to available resources, time, and capacity. The key component is action! It can be a small gesture, building a toad-a-tat or treefrog hotel, attending a public comment session to share species richness at a proposed development, or engaging local communities to support ordinances that benefit herpetofauna. It can be constructing hibernacula, providing culverts under transportation projects, headstarting turtles for reintroduction, conducting rescue and relocation efforts on construction sites, or adjusting the timing of burns and other management techniques to account for the most vulnerable species on the landscape. It can also mean enacting policy or regulatory changes that tangibly and effectively conserve and protect Michigan's amphibians and reptiles.

1. Herpetofauna are doing their part and adapting as best they can to our modified and confusing world. Every action we can take to assist them moves us closer to conservation.

2. We must look to the next generation to take on the work we have started. Engage and work with them. Nurture their excitement and enthusiasm for nature as well as their compassion. It is only through exposure that people care.

Every action matters. Every voice/call counts. Success will not be measured within the author's lifetimes, but rather during the lives of their grandchildren or great grandchildren. We must approach conservation with the philosophy of seven generations. This is the concept rooted in Haudenosaunee (Iroquois) philosophy. When we consider our actions, we must consider the impact these decisions will have on the next seven generations. It represents a commitment to long-term sustainability, ensuring that current actions, especially ones regarding the environment, do not harm future generations. Failure will come from a lack of action or following the current trends and accepting the status quo. It will take the collective and collaborative efforts of everyone to shift these trends. To keep common species common, we must first dispel the belief that they are not declining and act now.

Thank you for considering amphibians and reptiles and for taking the time to read and use this BMP manual. Together, we can make a difference now and for the next seven generations!



Appendix A: Community Matrix

	Species	Michigan's Habitat Communities																		
		Federal Status	State Status	Lakes and Ponds	Streams, Rivers, and Floodplain	Emergent Marsh	Emergent Marsh Reed Canary Grass	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 / Old Field
Snakes	Kirtland's Snake (<i>Colaptes kirtlandii</i>)		E										X	X	X	X			X	X
	Blue Racer (<i>Coluber constrictor foxii</i>)		SN							X	X	X							X	X
	Northern Ring-necked Snake (<i>Diadophis punctatus edwardsii</i>)		SN											X				X	X	X
	Eastern Hog-nosed Snake (<i>Heterodon platirhinos</i>)		SN									X	X						X	X
	Eastern Milk Snake (<i>Lampropeltis triangulum triangulum</i>)											X	X						X	X
	Copper-bellied Water Snake (<i>Nerodia erythrogaster neglecta</i>)	T	E	X	X	X	X					X	X	X	X	X		X	X	X
	Northern Water Snake (<i>Nerodia sipedon sipedon</i>)			X	X	X	X	X	X			X	X	X				X		
	Smooth Green Snake (<i>Opheodrys vernalis vernalis</i>)		SC									X	X						X	X
	Eastern Fox Snake (<i>Pantherophis gloydi</i>)		T	X		X	X	X	X				X						X	X
	Black Rat Snake (<i>Pantherophis spiloides</i>)		SC											X	X	X			X	X
	Western Fox Snake (<i>Pantherophis vulpinus</i>)		SN		X													X	X	X
	Queen Snake (<i>Regina septemvittata</i>)		SC	X	X	X														
	Eastern Massasauga Rattlesnake (<i>Sistrurus catenatus</i>)	T	T		X	X	X	X	X		X	X	X	X	X				X	
	Northern Brown Snake (<i>Storeria dekayi dekayi</i>)					X	X		X			X	X		X				X	X
	Northern Red-bellied Snake (<i>Storeria occipitomaculata occipitomaculata</i>)					X	X		X			X	X		X				X	X

SN, Species of Greatest Conservation Need; SC, Special Concern; T, Threatened; E, Endangered

	Species	Michigan's Habitat Communities																		
		Federal Status	State Status	Lakes and Ponds	Streams, Rivers, and Floodplain	Emergent Marsh	Emergent Marsh Reed Canary Grass	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 / Old Field
Snakes (Cont.)	Butler's Garter Snake (<i>Thamnophis butleri</i>)		SC		X	X	X		X					X	X			X	X	X
	Northern Ribbon Snake (<i>Thamnophis sauritus septentrionalis</i>)			X	X	X	X	X	X			X	X		X			X		X
	Eastern Garter Snake (<i>Thamnophis sirtalis sirtalis</i>)			X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Lizards	Five-lined Skink (<i>Plestiodon fasciatus</i>)																		X	X
	Six-lined Racerunner (<i>Aspidoscelis s. sexlineata</i>)		T																X	X
Turtles	Eastern Spiny Softshell (<i>Apalone spinifer spinifera</i>)			X	X				X	X										
	Eastern Snapping Turtle (<i>Chelydra serpentina serpentina</i>)			X	X	X	X	X	X	X	X	X						X		X
	Western Painted Turtle (<i>Chrysemys picta bellii</i>)			X	X	X	X	X	X	X	X	X						X		X
	Midland Painted Turtle (<i>Chrysemys picta marginata</i>)			X	X	X	X	X	X	X	X	X						X		X
	Spotted Turtle (<i>Clemmys guttata</i>)		T	X	X	X					X	X	X			X		X		
	Blanding's Turtle (<i>Emydoidea blandingii</i>)		SC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
	Wood Turtle (<i>Glyptemys insculpta</i>)		T		X														X	X
	Northern Map Turtle (<i>Graptemys geographica</i>)			X	X				X	X										
	Eastern Musk Turtle (<i>Sternotherus odoratus</i>)			X	X	X			X	X										X

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	Species	Michigan's Habitat Communities																		
		Federal Status	State Status	Lakes and Ponds	Streams, Rivers, and Floodplain	Emergent Marsh	Emergent Marsh Reed Canary Grass	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/Old Field
Turtles (Cont.)	Eastern Box Turtle (<i>Terrapene carolina carolina</i>)		T		X	X						X	X	X	X				X	X
	Red-eared Slider (<i>Trachemys scripta elegans</i>)			X	X	X	X			X										
Salamanders, Newts, and Mudpuppies	Blue-spotted Salamander (<i>Ambystoma laterale</i>)		SN			X									X	X	X	X	X	
	Spotted Salamander (<i>Ambystoma maculatum</i>)		SN			X									X	X		X	X	
	Marbled Salamander (<i>Ambystoma opacum</i>)		E												X	X		X	X	
	Unisexual Salamander (<i>Ambystoma sp.</i>)													X	X	X	X	X	X	
	Small-mouthed Salamander (<i>Ambystoma texanum</i>)		E		X										X	X		X	X	
	Eastern Tiger Salamander (<i>Ambystoma tigrinum</i>)		SN	X		X							X		X	X		X	X	X
	Southern Two-lined Salamander (<i>Eurycea cirrigera</i>)		SC		X													X		
	Northern Dusky Salamander (<i>Desmognathus fuscus</i>)		SC		X														X	
	Four-toed Salamander (<i>Hemidactylum scutatum</i>)		SN								X				X	X	X	X	X	
	Mudpuppy (<i>Necturus maculosus</i>)		SC	X	X															
	Central Newt (<i>Notophthalmus viridescens louisianensis</i>)			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Red-spotted Newt (<i>Notophthalmus viridescens viridescens</i>)			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

	Species	Michigan's Habitat Communities																		
		Federal Status	State Status	Lakes and Ponds	Streams, Rivers, and Floodplain	Emergent Marsh	Emergent Marsh Reed Canary Grass	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/Old Field
Salamanders, etc. (Cont.)	Eastern Red-backed Salamander (<i>Plethodon cinereus</i>)													X					X	
	Western Lesser Siren (<i>Siren intermedia nettingi</i>)		E	X	X	X														
Frogs and Toads	Blanchard's Cricket Frog (<i>Acris crepitans blanchardi</i>)		T	X	X	X			X			X	X						X	
	American Toad (<i>Bufo americanus</i>)			X		X	X	X	X			X	X	X	X	X	X	X	X	X
	Fowler's Toad (<i>Bufo fowleri</i>)		SC	X		X		X	X			X	X					X	X	X
	Cope's Gray Treefrog (<i>Hyla chrysoscelis</i>)			X	X	X	X	X	X			X		X	X	X		X	X	X
	Eastern Gray Treefrog (<i>Hyla versicolor</i>)			X	X	X	X	X	X			X		X	X	X		X	X	X
	Northern Spring Peeper (<i>Pseudacris crucifer crucifer</i>)			X	X	X		X	X			X	X	X	X	X	X	X	X	X
	Boreal Chorus Frog (<i>Pseudacris maculata</i>)		SC	X		X			X		X							X		
	Midland Chorus Frog (<i>Pseudacris triseriata</i>)		SN	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X
	Bullfrog (<i>Rana catesbeiana</i>)			X	X	X	X	X												X
	Green Frog (<i>Rana clamitans melanota</i>)			X	X	X	X	X	X		X	X	X	X	X	X	X	X		X
	Pickerel Frog (<i>Rana palustris</i>)		SC	X	X	X					X	X	X						X	
	Northern Leopard Frog (<i>Rana pipiens</i>)		SN	X	X	X	X	X	X		X	X	X		X				X	X
	Mink Frog (<i>Rana septentrionalis</i>)		SC	X		X	X	X			X	X								
	Wood Frog (<i>Rana sylvatica</i>)			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

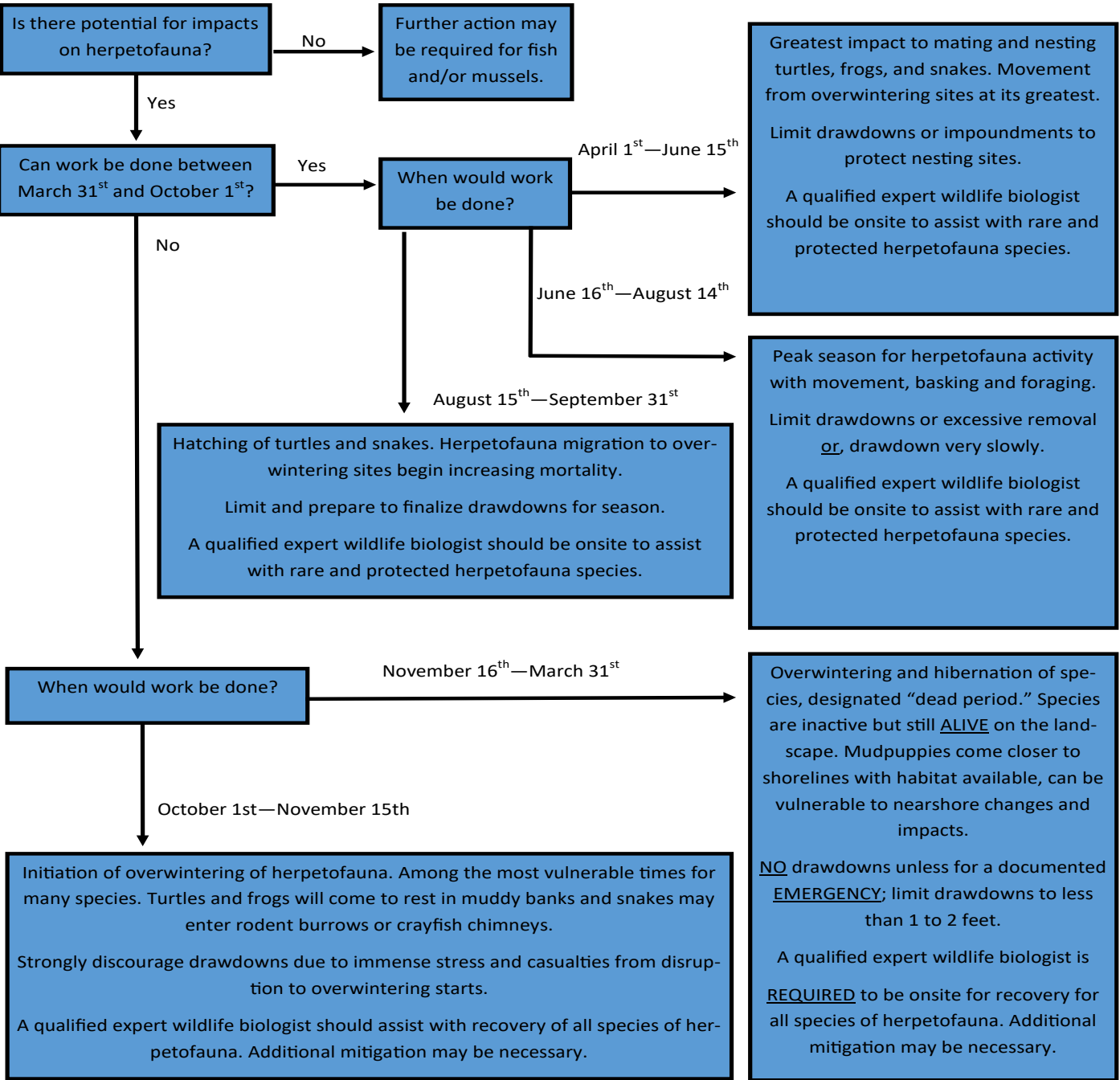
Rana (=Lithobates); Bufo (=Anaxyrus)



Appendix B: Management Timelines

Management or Development Action	January	February	March	April	May	June	July	August	September	October	November	December
Road maintenance												
Herbicide, insecticide, and pesticide application												
Dredging contaminants												
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 activities 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. Highlighted areas represent suggested times for work to be performed based on typical weather variables. Subject to vary based on geographic location. Work outside these time frames would require a herpetologist consultation to minimize impacts and can help created additional BMP's to reduce risk of take.



Impact tree depicting the generalized timeline of ecological impacts associated with dam drawdowns. This serves as a reference and may not capture all site-specific conditions; consultation with subject matter experts should occur for atypical scenarios.



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