INTRODUCTORY TEXT & STATEWIDE ASSESSMENTS

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INTRODUCTION & PURPOSE

Natural resources have helped to define Michigan throughout history. Both the native peoples of Michigan and more recent residents have understood the value of these natural resources and the need for management of Michigan's wildlife and habitats. Beginning as early as 1859, laws were enacted to protect wildlife in Michigan (Petersen 1979). Enforcement of these laws was the first step toward recovery of wildlife populations that had declined or disappeared due to loss of habitat or over-exploitation. The Michigan Fish Commission was established in 1873, the State established the nation's first conservation officer corps in 1887, and it first required hunting licenses in 1895.

Early wildlife management efforts focused on restoration of game species and their habitats. In 1937, the U.S. Congress passed the Federal Aid in Wildlife Restoration Act (commonly known as the Pittman–Robertson Act) to support State efforts in wildlife restoration. In 1950, the U.S. Congress adopted companion funding under the Federal Aid in Sport Fish Restoration Act (commonly known as the Dingle–Johnson Act) to support sport fish restoration. In 1984, the Wallop–Breaux Amendment enhanced this earlier action. For nearly 40 years, these programs, along with State hunting and fishing license revenues, provided the primary financial support for wildlife conservation and restoration in Michigan. During this period, habitat degradation caused by poor lumbering practices and failed agricultural attempts in the late 1800s and early 1900s began to heal, and water quality began to improve due to the provisions of the Federal Clean Water Act (1972) and other environmental legislation. Collectively, these positive changes contributed to successful restorations of fisher, moose, Canada Goose, white-tailed deer, Wild Turkey, walleye, and yellow perch. These successes were possible through partnerships between public agencies, private organizations, and individuals.

Conservation actions directed toward game species also benefited many nongame species by improving habitat conditions. Although these programs have had successes, some species have continued to decline. Limited resources, specifically limited funds and restrictions on the use of funds, have constrained the conservation and management of the full diversity of terrestrial and aquatic wildlife species in Michigan. Additional funding sources provided some assistance with this problem. For example, in 1973, the U.S. Congress passed the Endangered Species Act, providing funding to focus on recovery of federally threatened and endangered species. In 1983, the State passed legislation to create the Nongame Fish and Wildlife Trust Fund. Monies donated to this fund through a State income tax check-off and the sale of specialty vehicle registration plates have supported projects specifically directed toward nongame wildlife conservation, education and recreation. This additional funding has been used to restore the peregrine falcon, trumpeter swan, and American marten and to assist the ongoing recovery of the Kirtland's Warbler. Other species, such as the gray wolf, which have naturally reestablished themselves, have benefited through educational efforts.

However, even with the addition of these funding sources, Michigan, like other States, has struggled to comprehensively conserve and manage the diversity of its wildlife. In general, the availability of funding for nongame wildlife conservation and management has remained insufficient and unpredictable. Uncertainty of funding has resulted in conservation efforts that are opportunistic rather than strategic, especially for declining species which are not yet listed as threatened or endangered, and for taxonomic groups that remain relatively unstudied, such as some snails and insects. Coordination and strategic planning for the conservation and management of the entire range of wildlife diversity in Michigan, with consideration of long-term goals and broad scales, is needed.

Michigan's Wildlife Action Plan

To help address unmet wildlife conservation needs, the U.S. Congress began appropriating Federal funds in 2001 through the State Wildlife Grants (SWG). Michigan has embraced this program by developing a comprehensive strategy that will serve as a coordinated plan of action for all partners

working toward conservation of wildlife and wildlife habitats across the State. The Michigan Department of Natural Resources (DNR), as the designated trustee of the State's natural resources, has been coordinating this planning effort in compliance with its legal mandate to protect and conserve the State's natural resources, including all wildlife species. However, the action plan's development has been, and its successful implementation must be, a collective endeavor of Michigan's conservation partners, which include State, Federal and tribal agencies, local governments, conservation organizations, universities, private landowners, and other interested individuals.

The goal of Michigan's Wildlife Action Plan (WAP) is to provide a common strategic framework that will enable Michigan's conservation partners to jointly implement a long-term holistic approach for the conservation of all wildlife species.

This action plan:

- provides an ecological, habitat-based framework to aid in the conservation and management of wildlife;
- identifies and recommends actions to improve habitat conditions and population status of species with the greatest conservation need (SGCN), which are those species with small or declining populations or other characteristics that make them vulnerable;
- recommends actions that will help to keep common species common;
- identifies and prioritizes conservation actions, research and survey needs, and long-term monitoring needed to assess the success of conservation efforts;
- complements other conservation strategies, funding sources, planning initiatives, and legally mandated activities;
- incorporates public participation to provide an opportunity for all conservation partners and Michigan residents to influence the future of resource management;
- provides guidance for use of SWG funds; and
- provides a clear process for review and revision as necessary to address changing conditions and to integrate new information as it becomes available.

Definition of Wildlife

For the purposes of this action plan, 'wildlife' is defined as 'any species of wild, free-ranging animal, including, but not limited to, mussels, snails, crayfish, insects, fish, amphibians, reptiles, birds and mammals.' Wildlife also includes animals in captive-breeding programs designed to reintroduce individuals of a depleted native species into a previously occupied range.

State Wildlife Grants

State Wildlife Grant funds are appropriated on an annual basis and distributed to States and Territories according to a formula based on land area and population. At this time, the SWG program is not a continuous or guaranteed funding source. This program is administered by the U.S. Fish and Wildlife Service (USFWS) and provides funds to be used with matching non-Federal funds (or in kind match) for programs and projects that benefit wildlife species, especially SGCN. One of the goals of the SWG program is to keep common species common, thereby preventing additions of species to Federal and State threatened and endangered species lists.

This additional funding source complements funds already received by the DNR through the Pittman–Robertson and Dingell–Johnson Acts, by filling gaps between these and other funding sources. To date, Michigan has used SWG funds to initiate and expand efforts that address existing priorities for nongame wildlife. The WAP represents a more comprehensive framework for identifying and directing

future activities for wildlife conservation in Michigan.

Congress provided the following guidelines for using SWG funds:

- Priority should be placed on those species in the greatest need of conservation.
- Funds should be used to address the life needs and habitat requirements of species to preclude the need to list them as threatened or endangered under the Federal Endangered Species Act.
- Funds are intended to supplement, not replace, existing wildlife funding sources.
- Currently, funds are to be used for conservation-related programs and projects only, and may not be used for recreational, law enforcement or educational activities, unless these are deemed critical to the conservation of the species in question.

As a requirement of accepting SWG funds (and funds received earlier through the Wildlife Conservation and Restoration Program: WCRP), each State and Territory agreed to develop a plan or strategy, by October 1, 2005, that provides guidance on how these funds will be used. Michigan's WAP fulfills and exceeds this requirement.

The U.S. Congress identified, and the USFWS adopted, eight required elements to be addressed by State conservation strategies (Appendix A). Strategies must identify and focus on SGCN, yet address the full array of wildlife and wildlife-related issues. The USFWS, in cooperation with the International Association of Fish and Wildlife Agencies (IAFWA), provided guidance to States and Territories on meeting these requirements. Further assistance and planning tools were provided by numerous conservation organizations throughout the country. Review of strategies was completed by a National Acceptance Advisory Team, composed of USFWS and State wildlife agency representatives. This team offered, to the Director of the USFWS, recommendations regarding whether strategies should be approved, conditionally approved, or not approved.

Value of the WAP to Michigan

Value to Michigan's Wildlife

As programs and projects are successfully implemented, fulfilling conservation needs identified in the WAP, Michigan's wildlife will benefit in numerous ways. Status of many species with declining populations will improve, making it unnecessary to include them on lists of State and federally threatened or endangered species. Additional support for ongoing efforts to restore currently listed species and eventually remove them from these lists will improve probabilities of success. Species presently considered common will benefit from the conservation of all of the varied habitats that cover Michigan's diverse landscapes. New information acquired and generated will also improve conservation of these landscapes and associated wildlife. Reducing the rate of occurrence of invasive species introductions and establishments, landscape fragmentation, habitat conversion and other broad-scale threats will benefit many species and landscapes. Perhaps most importantly, communication and cooperation between conservation partners will be improved, leading to more effective management of Michigan's lands and waters, which will benefit the full diversity of Michigan's wildlife and the landscapes it uses.

Value to Michigan's Conservation Partners

Non-governmental organizations (NGOs), other interest groups, and private individuals participated in developing this document, and their assistance in implementing its vision is anticipated. This action plan identifies priorities to help guide use of funds for addressing the needs of species, and landscapes they use, that have not been the primary targets of past conservation efforts. The WAP creates a collaborative framework for wildlife conservation that addresses the needs of all wildlife in the State, with an ultimate objective of protecting biodiversity. Protection of biodiversity has been a goal of many

conservation partners for many years.

Coordination and exchange of information is critical to the conservation of wildlife. This action plan provides a baseline assessment of the current status of Michigan's wildlife and habitats to which future assessments can be compared. The WAP provides a framework for describing, assessing, evaluating and addressing the efforts needed to conserve and manage for the diversity of ecosystems and wildlife in Michigan, and it provides specific recommendations for conservation actions, research and monitoring within the framework. Many of these recommendations were drawn from the ongoing efforts of conservation partners across the State. Coordination within this framework will decrease redundancies between conservation partners and will result in more effective and efficient conservation efforts. Ultimately, successful holistic conservation of wildlife can only be achieved through partnerships between public agencies, private organizations, and private individuals.

This action plan is a tool that provides additional information for planners and managers to use in making informed decisions, regardless of the location or extent of the land or water they manage. The intent is not to provide operational objectives, but to provide strategic goals on which operational plans can be based. The action plan provides a snapshot of wildlife conditions today, and, when used with other plans, inventories and projects, will give managers additional insight to help identify options and make decisions.

Value to the DNR

The Constitution of the State of Michigan of 1963 (as amended), Article 4, § 52 states: 'The conservation and development of the natural resources of the State are hereby declared to be of paramount public concern in the interest of the health, safety and general welfare of the people.' To address this concern, the Michigan Legislature enacted Public Act 451, Natural Resources and Environmental Protection Act (as amended) and established the DNR and assigned its duties ('The department shall protect and conserve the natural resources of this State…'). Under the public trust doctrine, the DNR holds all wildlife, including mussels, snails, crayfish, insects, fish, amphibians, reptiles, birds and mammals, in trust for the benefit of the people of Michigan. This action plan is a tool that will aid the DNR in complying with this mandate, and can be integrated, as appropriate and applicable, into the DNR's many public trust responsibilities and management efforts. Many recommendations for conservation actions, research, surveys and monitoring presented within this action plan were drawn from existing DNR efforts.

Many DNR programs address the conservation of natural resources on a wide range of scales. At a statewide scale, planning efforts produce strategic analyses that provide direction for desired future condition of the landscape and suggest programs and activities required to fulfill diverse societal needs. At a regional scale, planning efforts identify the unique contributions of a particular region within Michigan to the desired future condition of the state's landscape and help to adapt programs and activities to that region. At an operational scale, managers determine how their management activities contribute to the strategic direction set forth at the regional level. The framework presented within the WAP, as an organizing tool for understanding SGCN and their habitats, links and integrates DNR planning efforts conducted at these different scales.

In addition, DNR programs reflect the broad range of benefits and values that people desire from natural resources. Natural resources and human needs change over time; the challenge of natural resource management is to adapt and adjust plans and activities in response to these changes while ensuring the health of natural resources into the future. This action plan is designed to change over time as the resource, human interests and societal needs change.

Value to Michigan's Residents, Visitors & Future Generations

This action plan provides information that can be used by any individual to assist in making decisions

about how to manage land and water in ways that will benefit wildlife.

As this action plan is implemented, Michigan's citizens and visitors will potentially benefit from: enhanced wildlife-related recreational activities and experiences, such as bird watching, hunting and fishing; improved quality of life by having diverse and sustainable wildlife and habitats; and economic rewards associated with increased opportunities for nature tourism. Implementation of this action plan will also help to ensure sound management of our ecosystems, resulting in healthy and functioning natural systems that provide ecologically and economically important services such as flood control, nutrient and contaminant processing, soil maintenance, and carbon sequestration.

This action plan is expected to improve the allocation and use of Federal and State funds. Conservation and restoration of threatened and endangered species tends to be an expensive and controversial process. Actions recommended within this action plan can help reduce these costs to Michigan's taxpayers by improving the status of species listed as threatened or endangered, assisting species in decline before they are listed, addressing potential threats before they become severe, and leveraging State dollars through partnerships with non-State entities.

In the short term, individuals will gain the satisfaction of having had an opportunity to influence the scope and future of resource management by providing input into this action plan. In the long term, success of this action plan will enable residents and visitors to experience the diversity of Michigan's natural resources in perpetuity.

APPROACH

Ecosystem Management

This action plan adheres to the principles of ecosystem management, as described by the Ecological Society of America (Appendix B, Christensen et al. 1996). This approach to conservation planning is increasingly common in natural resource management, and is the management paradigm already adopted by the DNR and many other conservation partners. The WAP is one of many tools that work together within an ecosystem management process to integrate ecological, social and economic factors into a comprehensive approach aimed at protecting and enhancing sustainability, diversity and productivity of natural resources. Because many different views must be represented within this comprehensive perspective, a large and diverse group of conservation partners were asked to participate in development of this document. Information presented herein is based on the best scientific data available, and recommendations for additional research are offered to help address knowledge gaps and poorly understood natural resource relationships at various ecological levels. This action plan recognizes that ecosystem processes operate over a wide range of spatial and temporal scales. Implementation of recommended conservation actions should proceed with recognition that ecosystem processes are dynamic, and change and evolution are inherent in ecosystem sustainability. Therefore, the WAP incorporates adaptability to aid in conservation of these processes over the long term and to maximize benefits to Michigan citizens, visitors and future generations.

Coarse Filter/Fine Filter Approach

Historically, wildlife conservation efforts have tended to focus on single species. However, as humans continue to change the landscape, a species-by-species approach may not be the most effective means to conserve biodiversity (Franklin 1993). Maintenance of ecological processes rather than management for individual taxa may be a more effective way of using limited resources to benefit the greatest number of species. The WAP was developed upon this premise. A comprehensive planning effort for each of the SGCN was not feasible, nor would that approach have achieved the goal of addressing the full array of wildlife in Michigan. Additionally, species have requirements for survival that are inextricably tied to their habitats, and degradation or loss of habitat is often the primary threat to species viability. Therefore, the WAP primarily uses a coarse-filter approach based on the habitat needs of wildlife (by definition, both aquatic and terrestrial species) to more effectively conserve rare, declining and common species statewide.

Individual wildlife species, however, cannot be ignored, and the set of SGCN provides a complementary fine-filter approach. Some species' needs may not be sufficiently met through habitat- or ecosystem-based approaches (Herkert 1994, Swengel & Swengel 1997), and the goal of this action plan is to address conservation needs of all wildlife species in Michigan. When particular species do not respond positively to habitat- or ecosystem-based conservation approaches, additional management specifically directed toward their unique requirements will be necessary. These unique species include those that respond to very specific changes within their habitat or ecosystem, species for which degradation or loss of habitat is not the primary threat, and species that do not share habitat associations with other SGCN, and, therefore, may not be adequately conserved through efforts for species assemblages. Using a species-based fine filter to assess and address the needs of these species in conjunction with the habitat-based coarse filter will allow comprehensive conservation of Michigan's wildlife diversity.

Additionally, the coarse filter is applied within a regional context (ecoregions for terrestrial systems and basins of Great Lakes for aquatic systems; see Methods for more details), and high priority wildlife conservation issues are identified and addressed at a statewide level. These considerations add even more potential broad-scale filters for identifying and addressing conservation needs of wildlife and

wildlife habitats.

Coarse Filter: Landscape Features

The primary organizational units for this action plan are 'landscape features,' which are broadly defined as 'components of the overall landscape used by wildlife, differentiated by vegetative, geologic, hydrologic, and structural elements, which may occur at various scales.' Landscape features may be equivalent to ecosystems, they may incorporate multiple ecosystems, or they may be components of ecosystems, including isolated structures within a diverse matrix. Different landscape features are often divergent in scale and are not necessarily spatially exclusive; together they therefore provide the variety of characteristics, both structural and spatial, that are essential for wildlife. They include broad ecosystems such as prairies and ponds, as well as small-scale structural characteristics that species require, such as snags or gravel substrates (Fig. 1). Where landscape features overlap, they act as multiple variables that together describe a place on the landscape.

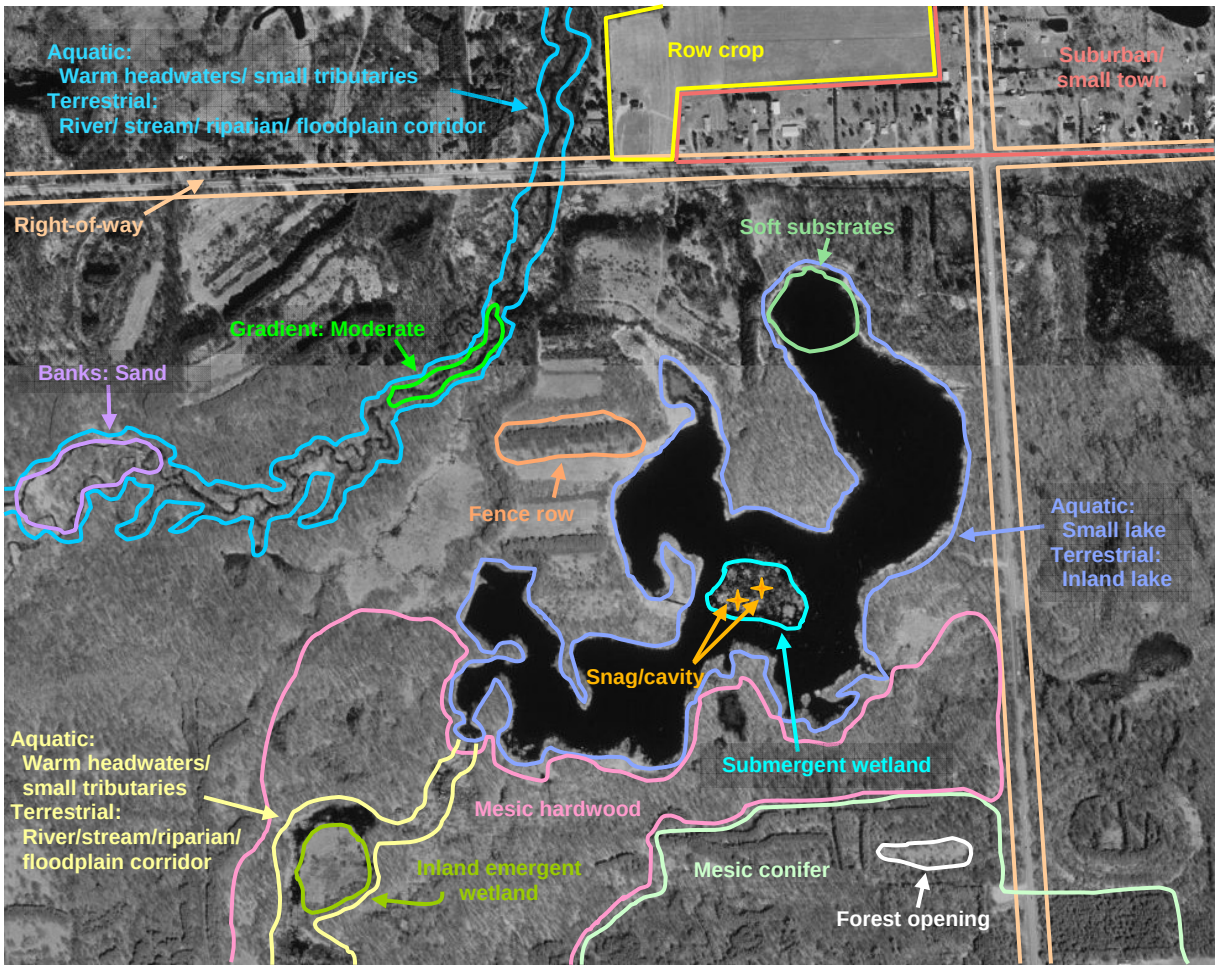

Figure 1. Example of spatial distribution of landscape features

Landscape features provide a common denominator between existing classifications used by conservation partners in Michigan. Existing classifications include Natural Communities (Michigan Natural Features Inventory 2003), U.S. Environmental Protection Agency (USEPA) general wetland types (USEPA 2005a), River Valley Segments (Seelbach et al. 1997), and the multi-scaled vegetation inventory (Donovan et al. 2004) used by the Michigan Gap Analysis Project and the DNR's Integrated Forest Monitoring, Assessment and Prescription (IFMAP) system. The landscape features are not

proposed as a new classification system, but as an organizing tool that can be used by any planner or manager to focus conservation efforts at a relevant spatial scale. They describe current, rather than potential or desired, conditions on the landscape, and as a result, include human-influenced systems that are used by wildlife, even if they do not represent the preferred habitat.

The use of existing classification systems was considered; however, no single system available at the time of action plan development was sufficient for the purposes of the document. Existing classification systems were either too fine or too coarse in scale, did not include heavily human-influenced systems that wildlife use (e.g., agricultural lands), or did not include key characteristics important to wildlife. Additionally, the action plan needed a coarse filter that could be applied in a similar manner for both aquatic and terrestrial systems, and no such classification system was available. Furthermore, one objective of this action plan is to provide location/distribution maps of habitats used by SGCN to build a knowledge base for all conservation partners in Michigan, and to provide easily measured metrics for long-term monitoring. Therefore, the organizational unit for the action plan must be as spatially explicit and comprehensive as possible. Few classification systems have currently been mapped for the entire State. Even though landscape features are not necessarily spatially exclusive, most can be individually mapped, and the conditions of many are routinely monitored as part of ongoing statewide inventories and assessments (see Methods chapter for a detailed description of data sources for landscape features).

Throughout the remainder of this document, use of the terms 'habitat' and 'habitat-type' is minimized, because these terms refer to the needs of specific species and may be confusing when used in a broader context. Instead, the term 'landscape feature' is used to identify components of the landscape used by wildlife, the conditions of which can be managed and monitored. The WAP identifies 43 terrestrial and 48 aquatic landscape features within broad categories (Table 1; see the Methods chapter for complete lists and descriptions of landscape features).

Table 1. Basic landscape feature framework

Terrestrial			Aquatic		
Category	**# Features**	**Examples**	**Category**	**# Features**	**Examples**
Grassland	9	Prairie, pasture	Great Lakes	3	Shoreline, offshore
Shrubland	2	Lowland shrub, upland shrub	Inland lakes	4	Ponds, large lakes
Forest	7	Lowland hardwood, dry conifer	Lake characteristics	7	Eutrophic, stratified
Inland wetlands/water	10	Bog, swamp	Rivers	13	Cold medium rivers, very large rivers
Great Lakes/ coastal	6	Coastal emergent wetland, coastal dune and beach	River characteristics	8	Slow gradient, intermittent
Other features	5	Cave/mine, suburban/small town	Wetlands	6	Bog, swamp
Terrestrial characteristics	4	Snag/cavity, down woody debris	Aquatic characteristics	7	Rock substrates, woody structures

The bulk of this document addresses each individual aquatic and terrestrial landscape feature within each lake basin or ecoregion, respectively, of the defined ecological frameworks. This information, in the Landscape Features & Conservation Needs section, will be most valuable to conservation partners working within a particular region or at a specific site, regardless of the ownership type or spatial extent of the area of focus. Each of these landscape feature summaries includes information on distribution, location, general condition and associated SGCN for a particular landscape feature in a particular

region. Each summary identifies threats to the landscape feature and associated wildlife and recommends conservation actions to address those threats. Additionally, research and survey efforts needed to address gaps in knowledge are identified. Each summary also outlines the monitoring necessary to assess conditions and trends associated with each landscape feature and to evaluate the success of conservation actions.

Like ecosystems, landscape features are diverse, with regional differences in composition and combinations of natural communities, species and other characteristics. Conserving this biological diversity and structural complexity will help to protect landscape features and the wildlife species that depend on them (see the Statewide Conservation chapter for a more detailed discussion of the need for conservation of representative systems).

Fine Filter: SGCN

Species of greatest conservation need are defined as wildlife species with small or declining populations or other characteristics that make them vulnerable. They include species currently federally or State listed as threatened or endangered, and other species identified through analysis of available data and recommendations from experts on particular taxa of Michigan (see the Methods chapter for further details about identification of SGCN).

To address SGCN needs not addressed within the landscape feature summaries, supplemental information on each SGCN is provided in the SGCN Status & Species-Specific Issues section of the action plan. The SGCN summaries will likely be most valuable to conservation partners focusing on a particular species or group of species. Each species summary includes information on distribution, relative abundance, associated landscape features, threats, and any information gaps or special concerns that must be addressed to effectively conserve the species.

The WAP identifies 404 SGCN within nine major taxonomic groups: mussels, snails, crayfish, insects (aquatic and terrestrial), fish, amphibians, reptiles, birds and mammals (Table 2). Data required to evaluate conservation needs were not available for many groups and, therefore, those groups were not included. The need for further research to fill these knowledge gaps is described in more detail in the Statewide Conservation chapter.

Table 2. Numbers of Michigan wildlife species in each of nine major taxonomic groups State listed as threatened or endangered, special concern*, and SGCN.

Taxonomic Group	Total number	Threatened/ endangered	Special concern*	SGCN
Mussels	77	10	8	28
Snails	180	4	29	36
Crayfish	6	0	0	2
Insects	15,000–20,000	19	75	138
Fish	152	15	11	44
Amphibians	23	2	2	14
Reptiles	29	4	6	16
Birds	414[+]	21	21	99
Mammals	66	6	4	27
Totals		**81**	**156**	**404**

* Special concern species are not legally protected, but have been identified by Michigan Natural Features Inventory (MNFI) as being of concern because of declining or relict populations in the State.

[+] This number includes the 233 species known to breed in Michigan, as well as species which migrate through the State.

Currently, the set of SGCN is limited to wildlife species and does not include plants. This action plan focuses predominantly on the needs of wildlife and wildlife habitats because SWG funds, which are the primary monetary support for implementation of the WAP, may not currently be used for projects that are solely for conservation of plants. However, future editions of the action plan will explore inclusion of plants that have obligate relationships with wildlife SGCN, that are indicators of high quality natural communities, or that are in need of conservation for other reasons, because they are also essential elements of the systems in which Michigan's wildlife exists.

Comprehensive & Cooperative Conservation

By considering all landscape features in all ecoregions and lake basins and as many taxa as currently possible given available information, the resulting conservation framework, including all potential filter levels, addresses much of the diversity and health of Michigan's wildlife. However, as this is the first edition of the WAP, gaps are present. The information and management approach presented within the action plan will require continued review and revision to fill the gaps and incorporate new information resulting from implemented conservation actions, research and monitoring, and additional data contributed by conservation partners.

Although this action plan has been developed for use by all conservation partners, no implication of individual or organizational/agency accountability should be construed. Although some public agencies may have legal mandates to protect and conserve wildlife, the conservation actions recommended herein are completely voluntary and non-regulatory, even though some suggested actions pertain to regulatory changes. Each conservation partner, whether government, tribe, organization or individual, will determine for itself which actions are most appropriate to help fulfill its mission and goals. Some of these decisions have already been made; that is, many of the actions proposed in this document were drawn from existing strategies and plans, and implementation may already be in progress. In this way, Michigan's conservation partners have already started on the path toward ensuring representation of the full diversity of Michigan's wildlife species and their habitats. Success will require continued coordination, cooperation and a common vision for the conservation of natural resources in Michigan.

METHODS

Ecological Frameworks

Terrestrial and aquatic species use Michigan's spatial landscapes in significantly different ways. Thus, the WAP presents aquatic and terrestrial landscape feature data within two different but overlapping ecological frameworks.

The ecological framework for aquatic landscape features is defined by the four Great Lakes drainage basins (Lake Erie, Lake Huron, Lake Michigan and Lake Superior) within the State (DNR 2005a; Fig. 2). The DNR and other agencies currently use this framework for planning, research and management activities. It also corresponds to conservation activities being conducted at the watershed scale within these lake basins.

The ecological framework for terrestrial landscape features is defined by Albert (1995; Fig. 3). The ecoregions identified by this framework are similar to those defined by Bailey et al. (1980). Again, many conservation partners in Michigan are already using this framework, and the DNR is using it to direct ongoing ecoregional planning activities.

The State Overview chapter provides brief descriptions of terrestrial ecoregions and lake basins, whereas the Landscape Features & Conservation Needs section provides detailed descriptions.

Figure 2. Lake basins framework.

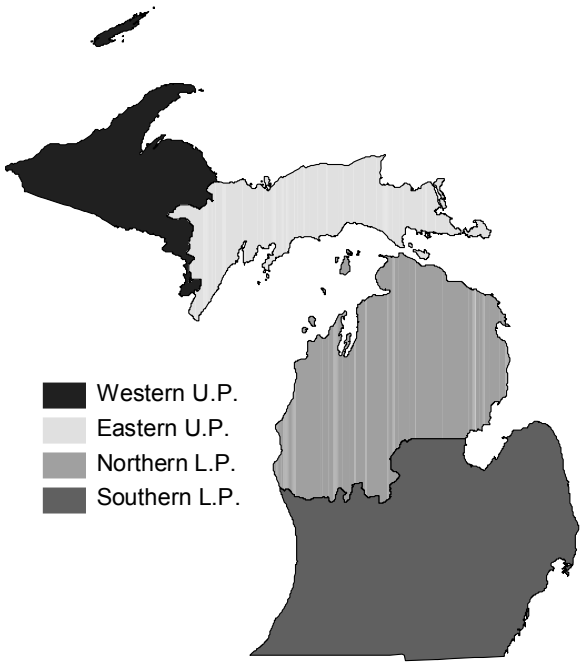

Figure 3. Terrestrial ecoregions framework.

Landscape Features

Identification

The 48 aquatic landscape features (Table 3) were based on an existing stream classification for Michigan (Seelbach et al. 1997), general wetland types (USEPA 2005a), lake features (Wetzel 2001,

Kalff 2002), and other landscape components or characteristics identified through scientific literature review as important to a significant number of aquatic SGCN. Location/distribution maps of aquatic landscape features were generated using spatial data from several sources, including the DNR (Seelbach et al. 1997, Breck 2004, DNR 2004a, DNR 2005a), Detroit Zoological Institute (2005), Environmental Systems Research Institute (ESRI 2000), MNFI (2005), the National Ocean and Atmospheric Association (NOAA 2004), The Nature Conservancy (TNC; DePhilip 2001), the University of Michigan (2005), USFWS (USFWS 2005) and the U.S. Geological Survey (USGS 2005a). The maps are included in the Landscape Features & Conservation Needs section.

Table 3. Aquatic landscape features

Category	Landscape feature	Description
Great Lakes	Shoreline	0–3 m deep
	Nearshore	3–30 m deep
	Offshore	>30 m deep
Inland lakes	Ponds	Open water ≤5 acres
	Small lakes	Open water 5–99 acres
	Medium lakes	Open water 100–999 acres
	Large lakes	Open water ≥1000 acres
Lake characteristics	Wave-washed shore	
	Trophic status: eutrophic	
	Trophic status: mesotrophic	
	Trophic status: oligotrophic	
	Stratified	
	Connectivity: drainage	
	Connectivity: seep	
Rivers	Cold headwaters/small tributaries	<40 mi^2 catchment area
	Cool headwaters/small tributaries	<40 mi^2 catchment area
	Warm headwaters/small tributaries	<40 mi^2 catchment area
	Headwaters/small tributaries	<40 mi^2 catchment area
	Cold medium	40–179 mi^2 catchment area
	Cool medium	40–179 mi^2 catchment area
	Warm medium	40–179 mi^2 catchment area
	Medium	40–179 mi^2 catchment area
	Cold large	180–620 mi^2 catchment area
	Cool large	180–620 mi^2 catchment area
	Warm large	180–620 mi^2 catchment area
	Large	180–620 mi^2 catchment area
	Very large	>620 mi^2 catchment area
River characteristics	Gradient: slow	0.0–4.9 ft/mi
	Gradient: moderate	5.0–9.9 ft/mi
	Gradient: fast	10.0–69.9 ft/mi
	Gradient: very fast	≥70.0 ft/mi
	Banks: sand	
	Banks: clay	
	Banks: rock	
	Intermittent	
Wetlands	Bog	Characterized by floating or surface vegetative mats, such as sphagnum moss mats, and most of water is provided by precipitation

Category	Landscape feature	Description
	Fen	Nutrient-rich wetland fed primarily through ground and surface waters
	Ephemeral wetland	Semi-permanent wetlands that vary dramatically seasonally or annually
	Inland emergent wetland	Areas with permanent water dominated by non-woody vegetation that breaks the surface (e.g., marshes)
	Swamp	Areas with permanent water dominated by woody vegetation
	Floodplain	
Aquatic characteristics	Rock substrates	Bedrock, rock, cobble and gravel substrates
	Soft substrates	Sand, silt, mud and organic substrates
	Clay substrates	
	Vegetation	
	Woody structure	
	Turbid water	
	Clear water	

Land cover types common to several existing terrestrial classification systems were the basis for most of the 43 terrestrial landscape features (Table 4). Natural communities (MNFI 2003), the DNR's multi-scaled vegetation inventory (Donovan et al. 2004), general wetland types (USEPA 2005a), and other information were considered in the development of terrestrial features.

A description of the relationships between natural communities and terrestrial landscape features (Appendix C) was completed to help conservation partners identify how landscape features correspond with ongoing conservation efforts. These relationships also are described in the Landscape Features & Conservation Needs section. Many terrestrial landscape features correspond closely to higher-level natural community groupings (e.g., lowland shrub, savanna, bog). Review of scientific literature revealed that some land cover types not incorporated within the natural community classification are important to SGCN (e.g., agricultural lands) or highly prevalent within the State (e.g., urban and suburban/small town).

The terrestrial landscape features also correspond to many classes in the DNR's multi-scaled vegetation inventory (e.g., upland conifer forest, upland shrub, urban). However, some classes, including many forest classes, were too fine for use within this edition of the WAP because the information needed to differentiate their importance to SGCN was unavailable in the scientific literature. Other classes, such as 'herbaceous open land,' were too coarse; for example, the importance to SGCN and the susceptibility to threats of native grasslands differ from those of agricultural grasslands.

In addition to the land covers already discussed, several other landscape components and characteristics were identified through scientific literature review as important to a significant number of SGCN and at risk to threats. These landscape features, such as 'down woody debris' and 'large contiguous natural landscape,' are not captured by land covers and generally occur at scales much larger or smaller than the previously discussed terrestrial landscape features.

Location/distribution maps of terrestrial landscape features were generated using DNR and MNFI spatial data (DNR 2003a, DNR 2003b, Donovan et al. 2004, MNFI 2005) and are included in the Landscape Features & Conservation Needs section.

Table 4. Terrestrial landscape features

Category	Landscape feature	Description
Grassland	Prairie	Natural grassland with <5% canopy cover
	Idle/old field	Grassland community of opportunistic species that colonized following cessation of long-term human disturbance (e.g., agriculture)
	Hayland	Agricultural grassland from which the 'grass' is harvested (including small grain crops)
	Pasture	Agricultural grassland used for grazing of livestock
	Row crop	Agricultural fields planted with a single species in evenly spaced rows and harvested annually
	Right-of-way	Linear grassland associated with roadways, railways, powerlines, pipelines and other linear human structures
	Fence row	A linear area of idle vegetation that interrupts large blocks of continuous grassland
	Savanna	Non-agricultural grassland with 5–60% tree canopy cover
	Orchard	Agricultural land with linear rows of fruit-bearing or early harvested trees, such as Christmas tree farms
Shrubland	Lowland shrub	Dominated by woody shrub vegetation in seasonally or permanently saturated soils
	Upland shrub	Dominated by woody shrub vegetation in moist to dry soils
Forest	Lowland hardwood	Seasonally or permanently saturated area dominated by moisture-tolerant hardwood trees and hydric soils
	Mesic hardwood	Hardwood forest characterized by moist soils
	Dry hardwood	Hardwood forest characterized by dry (xeric) soils
	Lowland conifer	Seasonally or permanently saturated area dominated by moisture-tolerant conifer trees and hydric soils
	Mesic conifer	Conifer forest characterized by moist soils
	Dry conifer	Conifer forest characterized by dry (xeric) soils
	Forest opening	Area of little to no canopy cover surrounded by forest; may be grassland or wetland
Inland wetlands/ water	Bog	Characterized by floating or surface vegetative mats, such as sphagnum moss mats, and most of water is provided by precipitation
	Inland emergent wetland	Area frequently or continually inundated with water and dominated by non-woody vegetation that breaks the surface (e.g., marshes)
	Submergent wetland	Area with permanent water dominated by vegetation that does not break the surface, generally occurring at edges of ponds, lakes and rivers
	Fen	Nutrient-rich wetland fed primarily through ground and surface waters
	Ephemeral wetland	Semi-permanent wetlands in which water levels vary dramatically seasonally or annually
	Swamp	Areas dominated by trees or shrubs with saturated soils during part of the year and standing or slowly moving water at other times
	Pond	Open water <5 acres
	Inland lake	Open water ≥5 acres
	Inland island	Island within an inland lake or river
	River/stream/riparian/ floodplain corridor	River or stream and the linear vegetation zone that borders and interacts with it
Great Lakes/coastal	Great Lakes offshore	Great Lakes area >30 m deep
	Great Lakes nearshore	Great Lakes area 3–30 m deep

Category	Landscape feature	Description
	Coastal emergent wetland	Great Lakes shoreline 0–3 m deep with vegetation dominated by non-woody plants (e.g., bulrush, cattail)
	Coastal dune/beach	Great lakes coastal, open landscape with minimal to moderate vegetation; includes sand, gravel and cobble substrates
	Alvar/rock	Various rocky shoreline along the Great Lakes, including bedrock lakeshores and rocky cliffs
	Great Lakes island	Island within a Great Lake
Other features	Edge	Transitional area between feature types
	Inland rock/cliff/ledge	Rocky area not located along the Great Lakes, such as cliffs or a rock outcropping
	Urban	High-density urban area
	Suburban/small town	Low-density urban area
	Cave/mine	Natural or artificial subterranean structure
Terrestrial characteristics	Snag/cavity	Standing dead trees or live trees with cavities
	Large contiguous unfragmented landscape	A relatively large area of a particular land-cover or a mosaic of land-covers that is unfragmented by industrial, residential or urban (low- or high-density) development
	Late successional forest	Characterized by a multi-layered canopy and complex structure, with trees of a diverse age-class distribution
	Down woody debris	Characterized by decaying wood matter of multiple decomposition classes and sizes

General Condition

Information about the general condition of each landscape feature throughout the applicable ecoregion or lake basin was solicited from attendees at Regional Technical Workshops (see Table 7 in the Participation & Outreach chapter). Attendees were asked to estimate the percentage of each landscape feature across the entire ecoregion or lake basin within each of five relative condition categories (Excellent, Good, Fair, Degraded, Highly Degraded). Averages of these values were used to provide the general condition information for each landscape feature in the Landscape Features & Conservation Needs section. When applicable, regional and global statuses of associated natural communities are also provided as a measure of condition. Regional workshop participants were sometimes uncomfortable evaluating the general condition of landscape features, because many landscape features are broadly defined, participants found the term 'condition' to be ambiguous, and the information necessary to determine general condition for most features is currently unavailable or insufficient.

Species of Greatest Conservation Need

Identification

Species of Greatest Conservation Need are limited to wildlife species (by definition, both aquatic and terrestrial) that have been documented within Michigan, and that depend on resources available within the State during any life stage or phenological stage (e.g., breeding, migration, wintering). Species documented within the State, but believed to be accidental or infrequent visitors, were excluded.

Species federally or State listed as threatened or endangered or identified by MNFI as 'special concern' (MNFI 2002) have already been recognized through their respective review and listing processes as being in need of conservation. Therefore, each of these 237 species was automatically included in the set of SGCN, even if the species is believed to be extirpated from Michigan. An additional 167 species also were identified as being in greatest need of conservation due to declining populations or other characteristics that may make them vulnerable.

A draft set of SGCN was compiled from suggestions made by DNR and MNFI staff, and from review of: U.S.D.A. Forest Service (USFS) 'sensitive species' for national forests in Michigan (USFS 2004); Michigan species included on the International Union for Conservation of Nature and Natural Resources (IUCN) 'Red List' (IUCN 2003); birds identified as 'primary focus' species in TNC's 'Great Lakes bird ecoregional planning' report (Ewert 1999); birds identified through an analysis of the Partners in Flight's Species Assessment Database (Rocky Mountain Bird Observatory 2002); information available on Nature Serve's web site (Nature Serve 2004); and the Michigan Odonata Survey Master Database (University of Michigan Museum of Zoology 2003).

Individuals who were asked for SGCN recommendations were provided with a set of criteria for identifying species of greatest conservation need, suggested by the IAFWA Teaming with Wildlife Committee. Under the provided criteria, SGCN should include:

- Imperiled species (globally rare)
- Declining species
- Endemic species
- Disjunct species
- Vulnerable species
- Species with small, localized 'at-risk' populations
- Species with limited dispersal
- Species with fragmented or isolated populations
- Species of special (conservation) concern
- Focal species (keystone species, wide-ranging species, species with specific needs)
- Indicator species
- 'Responsibility' species (i.e., species that have the center of their ranges within a State)
- Concentration areas (e.g., migratory stopover sites, bat roosts/maternity sites)

Information was not available to fully address some groups, such as spiders and beetles. The need for further research to fill these and other knowledge gaps is provided in more detail in the Statewide Conservation chapter.

A list of Michigan wildlife species experts was compiled based on recommendations of DNR and MNFI staff and species experts themselves. This list of individuals (Appendix D) continued to grow throughout the action plan development process. These species experts were associated primarily with academic institutions, but also included DNR biologists, Michigan Department of Environmental Quality (MDEQ) employees, USFWS biologists, NGO-affiliated individuals and other non-affiliated individuals. Species experts were consulted throughout the action plan development process.

A revised set of SGCN was developed based on comments received at SGCN Workshops (see Table 7 in the Participation & Outreach chapter), comments from individual species experts, and information collected at the suggestion of species experts. Species experts were asked to make recommendations based on information from research and projects focused on Michigan wildlife, as well their personal observations and knowledge. Clarifications and additional suggestions were requested when necessary.

The revised set of SGCN was distributed for review and comment. Reviewers included species experts, DNR staff, individuals on the action plan listserve group (see the Participation & Outreach chapter), 120 Michigan conservation organizations, and attendees at public meetings. Additionally, the set of SGCN has been available for review and comment on the action plan website.

The set of Michigan wildlife species identified as SGCN is expected to change over time. As the action plan is implemented and goes through further review and revision, species will be added or removed

when new data indicate changes are warranted. During the development process, several species were added or removed due to availability of new information. An example of a late addition to the list is the evening bat. Until recently, this species had not been documented in Michigan since 1969 and was considered to be extirpated. In August 2004, however, an evening bat maternity colony was discovered in southern Michigan by Dr. Alan Kurta, one of our species experts. Because the evening bat is an edge-of-range species and little is known about its habitat needs in Michigan, it was added to the set of SGCN.

The process of identifying SGCN is not part of the State's official threatened and endangered species listing process; rather, it identifies species and their habitats that will be the focus of funds, conservation actions, research and monitoring associated with implementation of Michigan's WAP. However, information about SGCN acquired during development and implementation of the WAP may be referenced during future reviews and revisions of the State's threatened and endangered species list.

Additional information on each SGCN, including distribution and abundance, is given in the SGCN Status & Species-Specific Issues section. Spatially explicit data were not available for all known locations of SGCN and, therefore, some locations may not be included on distribution maps, even when mentioned in the accompanying text. Available data were of a variety of types, from a variety of sources. Aquatic distribution maps are based completely on documented locations of species, whereas the terrestrial maps are based on a mixture of documented locations and current range, with the data type reflected in the map legend. When location data for a species were limited, historical and more recent locations were combined to create a distribution map that more accurately represents the potential distribution of the species. When the distribution represented on the map differs significantly from the known current locations, this difference is recognized in the accompanying text.

Associating SGCN to Landscape Features

Each species in the set of SGCN was placed in one of three categories: Aquatic, Crossover or Terrestrial. Crossover species, such as dragonflies and amphibians, use both aquatic and terrestrial landscape features during all or some of their life cycles. Therefore, their associations with both terrestrial and aquatic landscape features were considered in discussions and analyses throughout development of the action plan.

Within each ecoregion and lake basin, the importance of each landscape feature to each SGCN was assessed based on information found in the scientific literature. The categories of importance assigned to each region/landscape feature/species association were:

- Principal: landscape feature is primarily used, essential, optimal and/or most preferred by the species in this ecoregion/lake basin
- Occasional: landscape feature is sometimes used and/or less preferred than the Principal landscape features in this ecoregion/lake basin
- Infrequent: landscape feature is rarely used and/or only used if the Principal or Occasional landscape features are not available in this ecoregion/lake basin
- Unknown: landscape feature is potentially used, but its importance to the species and/or frequency of use is unknown in this ecoregion/lake basin
- Not used: landscape feature is not used by the species in this ecoregion/lake basin

Some importance associations were later refined based on review by species experts and comments received at Regional Technical Workshops (see Table 7 in the Participation & Outreach chapter). The Associated Landscape Features listed in the SGCN Status & Species-Specific Issues section include all categories of importance, except "Not used." The Associated Species of Greatest Conservation Need included in the Landscape Features & Conservation Needs section are those species that were

found to have Principal, Occasional or Unknown importance associations with each landscape feature.

Threats

Identification

The Core Development Team (see the Participation & Outreach chapter) identified standardized threat categories and individual threats to landscape features and wildlife by modifying previously existing threat classifications for terrestrial and aquatic systems (Richter et al. 1997a, Salafsky et al. 2003). The same categories were used for both terrestrial and aquatic features, but the threats within these categories reflect the differences between these systems (Tables 5 & 6).

Table 5. Aquatic threats

Category	Threats	Examples
Habitat conversion	Wetland modifications	Draining wetlands, filling wetlands
	Riparian modifications	Marinas, seawalls, shoreline development, shoreline structures, vegetation clearing, habitat simplification, forest clearing, and other modifications along rivers, streams or lakes
	Dredging and channelization	Channelization, dredging, habitat simplification, navigation/shipping
	Dams	Hydroelectric dams, impoundments, beaver dams
	Incompatible natural resource management	Beaver management, trout management, management to convert habitat
Consumptive biological resource use	Mining practices	Inorganic (e.g., ore), organic (e.g., peat moss harvesting)
	Forestry practices	Removal of trees from forests and associated activities that have a direct influence on wildlife and landscape features, regardless of how well or poorly the practices are implemented (e.g., road construction, soil compaction, sedimentation, loss of interior forest habitat)
	Removal of wildlife	Legal harvest, illegal harvest, incidental harvest
Non-consumptive biological resource use	Macrophyte removal	De-vegetation of shoreline
	Non-consumptive recreation	All-terrain vehicles, snowmobiles, biking, jet skis
Pollution	Altered sediment loads	Siltation, stream bank erosion, riparian erosion, bed sediment-load changes, turbidity
	Altered nutrient inflows	Increases in nutrient inputs, changes in organic matter inputs, municipal pollution/waste, dissolved oxygen changes, fertilizers, changes in organic matter inputs
	Pesticides and herbicides	Agricultural, golf course, molluscicides/lampricides
	Urban, municipal and industrial	Urban runoff (e.g., oil, chloride), municipal pollution, industrial pollution (chemical), acid rain, oil and gas drilling/mining, gas stations
	Thermal changes	Surface runoff (urban, agricultural, golf courses), industrial pollution (thermal), water temperature increases (due to riparian vegetation removal, channelization)
Biological interactions	Invasive plants and animals	Invasive fish, invasive zooplankton, invasive molluscs, invasive plants, other invasive animals; includes native and exotic species

Category	Threats	Examples
Modification of natural processes	Disease, pathogens and parasites	largemouth bass virus, bacterial kidney disease, priscirickettsia, and yellow grub (fish); water mites & trematodes (mussels); and other diseases, pathogens and parasites
	Other biological interactions	Fish predators, hybridization, lack of predators, loss of key predators
	Climate change	Natural processes, human-influenced changes
	Altered hydrologic regimes	Water temperature changes, changes in flow regimes, surface runoff, interbasin water transfer, water withdrawal/dewatering
	Fragmentation	Dams, water temperature changes, highway projects, construction, bridge and pipeline crossings
Education	Lack of scientific knowledge	Lack of management or inappropriate management due to lack of knowledge
	Social attitudes	Persecution, ignorance, apathy
Unknown	Unknown	Unknown threats to landscape feature or species

Table 6. Terrestrial threats

Category	Threats	Examples
Habitat conversion	Industrial, residential and recreational development	Housing, industrial development, golf courses, ski areas, cell towers, wind farms, roads
	Wetland modifications	Tiling for agriculture, wetland filling for development
	Conversion to agriculture	Farms, plantations
	Dams	Impoundments, beaver dams
	Dredging and channelization	Changes to riparian corridors
	Incompatible natural resource management	Prescribed burn patterns and frequency, wetland and water-level manipulation, vegetative planting and manipulation, floodings and dam maintenance/removal
Consumptive biological resource use	Removal of wildlife	Legal harvest, illegal harvest, incidental harvest
	Forestry practices	Removal of trees from forests and associated activities that have a direct influence on wildlife and landscape features, regardless of how well or poorly the practices are implemented (e.g., road construction, soil compaction, sedimentation, loss of interior forest habitat)
	Removal of non-timber flora	Scientific collection, wildflower collection, mushroom harvest
	Mining practices	Oil and gas drilling, mineral extraction, peat moss mining
Non-consumptive biological resource use	Non-consumptive recreation	All-terrain vehicles, snowmobiles, hiking, biking, equestrian activities, jet skis
	Scientific research	Non-consumptive research
	Military maneuvers	Heavy artillery training, heavy equipment movements, bunker construction
Pollution	Urban, municipal and industrial	Solid waste, acid rain, oil and gas drilling/mining
	Pesticides and herbicides	Agriculture practices, golf course practices, mosquito control, gypsy moth control
Biological interactions	Invasive plants and animals	Expanding ranges, introduced plants, introduced animals, introduced predators, cats and dogs; includes native and exotic species

	Disease, pathogens and parasites	West Nile Virus, Duck Virus Enteritis (duck plague), Leucocytozoonosis, Brainworm, Chytridiomycosis, Bovine tuberculosis and other diseases, pathogens and parasites
	Other biological interactions	Hybridization, loss of key predators
Modification of natural processes	Climate change	Natural processes, human-influenced changes
	Grazing and mowing patterns	Frequency of mowing, high-intensity grazing
	Altered fire regime	Fire suppression, challenges to using fire as a conservation tool
	Altered hydrologic regimes	Water withdrawal, drains, tiles, added water
	Fragmentation	Transportation infrastructure, rights-of-way
Education	Lack of scientific knowledge	Lack of management or inappropriate management due to lack of knowledge
	Social attitudes	Persecution, ignorance, apathy
Unknown	Unknown	Unknown threats to landscape feature or species

Threats to one species or landscape feature are sometimes the result of management actions intended to aid another. The intent of this action plan is not to resolve these conflicts, but to recognize they exist and to explore a process for resolving them.

Associating Threats to Landscape Features

Associations between threats and landscape features within each ecoregion and lake basin were based principally on the informed opinions of natural resource professionals because the scientific literature rarely presented information on regional susceptibility to threats by landscape features or wildlife species. Regional Technical Workshops (see Table 7 in the Participation & Outreach chapter) were attended by natural resource professionals from State, Federal and local agencies, NGOs, and universities. Attendees were asked to identify significant threats to landscape features within their ecoregion or lake basin of expertise. A list of potential threats, based on identified threats to SGCN associated with the landscape feature, was used as a starting point for discussion. The 'Associated Threats' and related comments given in the Landscape Features & Conservation Needs section are primarily the results of discussions at, and written comments from, the Regional Technical Workshops and subsequent contact with natural resource professionals, but also draw from previously existing strategies and plans, and reviewed scientific literature.

Threats at Regional and Statewide Scales

Natural resource professionals attending the Regional Technical Workshops were asked to give each threat a severity rank (high, medium, low, none, unknown) for their ecoregions or lake basins of expertise. These ranks were given numerical values and averaged to develop a mean severity value for each threat within each ecoregion and lake basin (Appendix E). Those threats with mean severity values at a medium to high level in all four ecoregions (10 threats) or all four lake basins (12 threats) were considered to be significant at the statewide scale and are described in greater detail in the Statewide Conservation chapter.

Discussions and feedback received at meetings and workshops, written comments from species experts and natural resource professionals, and reviews of scientific literature identified several other issues important to Michigan's wildlife. They were usually not associated with specific landscape features; most were larger scale issues, such as the need for landscape mosaics, the importance of bird migration stopover sites and wintering areas, hybridization, rarity, lack of knowledge on certain species and taxonomic groups, and the need for conservation and restoration of representative natural communities and systems. These issues are described in greater detail and addressed at a statewide scale in the Statewide Conservation chapter.

Identifying Conservation Action, Research, Survey & Monitoring Needs

Conservation actions are those programs, projects or activities needed to address threats to wildlife species and their habitats. Research and survey needs generally address gaps in the collective knowledge of Michigan's conservation partners regarding species natural-history, natural resource relationships, or the effects of threats on landscape features and species. Monitoring addresses the need to periodically and systematically measure and assess changes to landscape features and species to determine whether their condition/status is changing and whether implemented conservation actions have been successful.

The conservation action, research, survey and monitoring needs for each landscape feature are discussed in the Landscape Features & Conservation Needs section. This information was primarily generated through discussion and comments at Regional Technical Workshops (see Table 7 in the Participation & Outreach chapter). The conservation actions discussed in the Statewide Conservation chapter were identified from four general sources: previously existing strategies and plans developed by State and national conservation partners; discussions at meetings and workshops; information and suggestions provided by species experts and natural resource professionals; and reviewed scientific literature. The description of recommended conservation actions, research, surveys and monitoring does not differentiate between efforts that may already be ongoing and those yet to be initiated. An analysis to clarify these differences is needed (see Identifying Priorities below for more details).

Conservation actions in the Landscape Features & Conservation Needs section and in the Statewide Conservation chapter are categorized according to a previously existing conservation action taxonomy (Salzer and Salafsky 2004) that was slightly modified for use in this action plan.

Identifying SGCN Needs Not Associated with Landscape Features

The species summaries in the SGCN Status & Species-Specific Issues section were developed to provide basic natural-history information on SGCN and to address specific threats that cannot be addressed through conservation of landscape features alone. The susceptibility of each SGCN to each threat was primarily assessed based on information found in scientific literature. The categories of susceptibility assigned to each threat–species association were High, Medium, Low, None (not a threat to the species) and Unknown (a threat, but susceptibility of the species to the threat is unknown). The Associated Threats described in each species summary include all categories of susceptibility, except "None." Some susceptibility values were later revised based on review by species experts and discussions with natural resource professionals.

The Comments provided in the SGCN summaries include conservation actions, research, surveys and monitoring needed to address the associated threats that will not be addressed at the landscape feature scale, as well as other issues important to conservation of the species.

Identifying Priorities

This action plan has been developed for use by all of Michigan's citizens and conservation partners, who have different scopes of interest and different sets of available resources. As implementation of the action plan begins, these partners will need to make decisions about their own priorities and abilities for implementing the recommended conservation actions, research and monitoring. As the scale of planning and implementation becomes finer, determining priorities for specific sites will become easier because the threats to be addressed will likely become more limited in number.

The introductory text that precedes the landscape feature summaries for each ecoregion and lake basin (Landscape Features & Conservation Needs section) identifies threats that natural resource professionals indicated as most severe in that ecoregion or lake basin. Additionally, the introductory

text lists conservation actions that were most frequently recommended within each category of landscape features for that ecoregion or lake basin. If implemented, these conservation actions will likely have the greatest overall effect, as each will address multiple landscape features. Although there is some consistency between ecoregions and between lake basins, the priority conservation actions identified generally reflect the highest priority threats for that ecoregion or lake basin. Those threats that are consistently recognized as being the highest priority threats across most or all ecoregions or lake basins are addressed at a statewide level.

The general introduction to the SGCN Status & Species-Specific Issues section also identifies recommended conservation needs most frequently repeated in different species summaries.

The Statewide Conservation chapter also addresses priorities at a statewide level. Threats addressed within the 'Priority Threats' discussion were identified by natural resource professionals as being of at least Medium severity in all four ecoregions or all four lake basins, or greater than Medium severity in three of the four ecoregions or lake basins; conservation actions, research and monitoring implemented to fulfill conservation needs that address these threats will have a great influence on wildlife conservation statewide. Issues addressed within the 'Other Priority Issues' discussion were identified by participants at meetings and workshops as being of high importance to conservation of wildlife in Michigan; again, implementation of conservation efforts to fulfill identified conservation needs will have a substantial positive effect on wildlife statewide.

The final part of the Statewide Conservation chapter, 'Priority Conservation Needs,' provides additional priorities at the statewide scale, based on the information presented in the first two parts of the chapter, and priorities identified at workshops and through scientific literature review. As with the landscape feature and SGCN summaries, conservation needs repeatedly identified to address multiple threats and issues are recognized as priorities, because, successful implementation of conservation actions, research and monitoring to fulfill these needs would have a broader influence on wildlife conservation. Additional information for establishing priorities came from discussions with and comments received from conservation partners involved in the development of this action plan.

One of the first actions that must be completed following development of this document is an analysis of the extent to which conservation partners are already addressing particular conservation needs and implementing recommended conservation actions, research and monitoring. Gaps in coverage will become priorities for the DNR or other conservation partners with the resources to address them. Further analysis to determine which conservation partner is best able to implement each of the recommended efforts would also be valuable.

Review & Revision (revised 10/01/08)

A full review and revision of this action plan will be completed ten years after the final release of this first edition following the federal requirements tied to SWG funding, which mandates reviews of the action plan are not to exceed ten years.

Although a full review and revision will not occur until the 10th anniversary, this action plan should be considered a living document. As conditions in Michigan change, the recommended conservation actions, research and monitoring must be updated as needed to adapt to these changes and integrate new information that becomes available. The immediacy of existing and emerging threats may warrant amendment prior to the next scheduled review and revision process. Additionally, addressing gaps identified during the initial project period will be a high priority.

The action plan will be adapted as appropriate, integrating information from conservation actions, research, surveys and monitoring as implemented. New information is anticipated from several sources, including: additional conservation partners; new research and publications, such as the

Breeding Bird Atlas, Herp Atlas and Biodiversity Atlas; planning processes occurring during the intervening years, such as the currently ongoing review of State listed threatened and endangered species, watershed assessments, State forest certification, and the Michigan Bird Conservation Initiative's development of priority bird species; and an additional full review of more recently published scientific literature. The incorporation of this information will improve the common knowledge base of conservation partners, fill information gaps in the action plan, and continue to increase the value of the action plan to Michigan.

Updates of landscape feature and SGCN summaries may be required to incorporate new information. To reflect these changes, priorities will be re-assessed at statewide, ecoregion, lake basin, and species levels. Any future evaluation of priorities must also include results of the analysis to determine gaps in coverage as described in the Identifying Priorities text above. Gaps that remain unaddressed should become progressively higher priorities with each edition of the action plan.

The review and revision process followed will be very similar to that used to develop this first edition. As well as those steps described above, this will include: a full review of the set of SGCN, with the assistance of species experts; an evaluation of the landscape feature and threat frameworks, with consideration of feedback received from participating conservation partners that have been involved with implementation of the action plan; and attempts to encourage participation in workshops and workgroups from additional conservation partners (as described earlier, conservation partners include State, Federal and tribal agencies, local governments, conservation organizations, universities, private landowners, and other interested individuals). Additionally, each edition will incorporate program assessment information and evaluate the effectiveness and success of the action plan thus far.

Next Steps (revised 10/01/08)

The vision represented by the WAP can only be achieved through the continued cooperation of Michigan's conservation partners. Initially, these cooperative efforts should focus on the following actions.

- Begin implementation of actions, research and monitoring to fulfill identified priority conservation needs and support continuation of efforts for those already ongoing
- Continue building a common knowledge base by increasing information sharing between conservation partners
- Deliver the information in the action plan to those who need it, in a format they can use
- Identify and engage additional participating partners
- Identify gaps in the first edition of the action plan that can be addressed prior to the formal review, revision and development of a second edition
- Discuss potential changes to the action plan that will improve the value of the next edition to conservation partners
- Begin collecting data necessary for the ten-year formal review and revision of the action plan

To be most effective, these actions will require extensive and ongoing coordination between conservation partners. As the coordinating conservation partner in the strategic planning process, the DNR has the responsibility to develop a management review structure that will:

- ensure and oversee integration of the WAP with related DNR programs/initiatives and those of other conservation partners;
- complete an analysis to determine the extent to which conservation partners are already addressing particular conservation needs and to identify gaps in this coverage, as described

above within Identifying Priorities;

- oversee program assessments to ensure the conservation actions, research and monitoring identified in the action plan are being implemented;
- develop an outreach and education strategy to provide information to those who would benefit, to develop public support, and to continue soliciting participation of additional conservation partners in ongoing development and implementation of the WAP;
- develop a process for identifying priority issues for use of SWG funds, with consideration of other funding sources; and
- coordinate the formal ten-year reviews and updates needed between full reviews.

PARTICIPATION & OUTREACH

Meetings & Workshops

Several meetings and workshops were held during development of this action plan. The purpose of these events was to solicit and receive input from species experts, natural resource professionals and the general public. The participants and specific goals for each event are described in Table 7.

Table 7. Meetings and workshops (dates, locations and individual participants are provided in Appendix F)

Meeting/workshop participants and goals	Partners Invited	Public Invited
Introductory Information Meeting • Participants: conservation organizations, DNR Divisions • Goals: provide information about why an action plan is being developed and solicit suggestions for action plan components and participants	✓	✓
Follow-up to Introductory Meeting • Participants: conservation organizations (those from the introductory meeting and others identified at that meeting), DNR Divisions, USFWS • Goals: introduce the WAP Coordinator, present a potential process for action plan development, solicit sources of data, identify issues of greatest importance, and identify other potential participants	✓	
Species of Greatest Conservation Need Workshops • Participants: species experts from conservation organizations, DNR, MDEQ, USFWS, universities and non-affiliated individuals • Goals: provide information on action plan development and SGCN, solicit review of draft set of SGCN, and request feedback on action plan approach	✓	✓
Public Information Meetings • Participants: USFWS, USFS, conservation organizations, universities, conservation districts, DNR, non-affiliated individuals • Goals: provide information on action plan development, solicit information about threats to wildlife and resources to assist action plan development, and promote interest in participation	✓	✓
Conservation Partner Workshop • Participants: some of Michigan's most influential conservation organizations • Goals: provide information on action plan development, solicit information about threats to landscape features, and develop conservation actions to address these threats	✓	
Regional Technical Workshops • Participants: natural resource professionals from conservation organizations, State and Federal agencies, and universities • Goals: provide information on action plan development and solicit information at the terrestrial ecoregion and lake basin scales on threats to landscape features and wildlife, general condition of landscape features, and needs for conservation actions, research, surveys and monitoring	✓	
WAP 'Kick-Off' Workshop • Participants: conservation organizations, State and Federal agencies, Native American tribal organizations, universities, and non-affiliated individuals • Goals: present information about the soon-to-be-released-for-public-review WAP, solicit information about priorities for implementation, and promote interest in participation during action plan implementation	✓	✓

Meeting/workshop participants and goals	Partners Invited	Public Invited
Public Meetings • Participants: conservation organizations, State and Federal agencies, local governments, universities, and non-affiliated individuals • Goals: provide information about the draft WAP and solicit formal review and feedback on the draft	✓	✓

DNR Participation

The DNR Wildlife Division coordinated development of the action plan with substantial participation from Fisheries Division staff and many others within the Department, as well as a few others closely associated with the Department. Appendix G provides the names of individuals involved with each of the DNR working groups described below.

WAP Core Development Team

- composed of Wildlife Division and Fisheries Division staff and one MNFI employee on contract to the Fisheries Division
- responsible for coordination of action plan development, data collection, coordination of non-DNR participation, primary writing of the document, and coordination of review and revision

WAP Steering Committee

- established in August 2004
- composed of representatives from Wildlife Division, Fisheries Division, Forest Mineral and Fire Management Division and MNFI
- offered guidance on action plan development, content-related issues, and communication at the Department level

WAP Mapping Support Team

- composed of representatives from Wildlife Division, Fisheries Division, MNFI and the University of Michigan
- coordinated mapping efforts, identified appropriate data sources, created metadata for mapping products, and provided general GIS support

WAP Internal Review Team

- composed of representatives from Wildlife Division, Fisheries Division, Parks and Recreation Bureau, Forest Mineral and Fire Management Division and MNFI
- reviewed the action plan prior to its release to all DNR employees to ensure it appropriately addressed issues important to their respective Divisions

Habitat Planning Workgroup

- composed of DNR Wildlife Ecologists and other Wildlife Biologists involved with planning efforts at landscape scales
- assisted with discussions on the appropriate planning approach, identification of terrestrial landscape features, provision of information and feedback at various meetings and workshops, and review of written materials at several stages in the development process

DNR Employees

- assisted with identification of SCGN, species experts, landscape features and threats; attended public meetings and Regional Technical Workshops; and participated in writing, map production, editing, and review of written materials
- received email updates on the progress of action plan development and were provided opportunities to comment on a draft list of SCGN and a draft version of the entire action plan prior to public release

Non-DNR Participation

Federal, State and local agencies, tribes, and other conservation partners, including NGOs, universities and private individuals, participated in action plan development. Their continued participation will be necessary for effective implementation of the action plan and for review and revision of future editions. Appendix H provides names of the 203 conservation partners (agencies, organizations and non-affiliated individuals) who were solicited for participation and actively participated in development of the WAP.

Federal Agencies

- Representatives of several Federal agencies, especially USFWS and USFS, participated as species experts, attended meetings and workshops, provided information and data, and participated in the formal public review.
- The Region 3 USFWS Development Assistance Team provided information to help States better understand and fulfill the Federal requirements for the SWG and WCRP plan/strategies.

State Agencies

- An MDEQ specialist involved with water quality monitoring programs, which include the monitoring of macroinvertebrates, participated as one of our species experts for aquatic invertebrates.
- A Michigan Department of Transportation (MDOT) specialist involved with mitigation effects and monitoring transportation project effects on environmental indicators and wildlife participated in multiple Regional Technical Workshops and as a species expert.

Local Agencies

- Representatives from several Conservation Districts, and county and city governments attended public meetings and/or Regional Technical Workshops, and remained apprised of continued action plan development through the action plan listserve group (see Outreach below).

Native American Tribes

- All recognized Native American Tribes with management authority over significant land areas within Michigan were contacted via letter in July 2004 and were invited to identify any issues, concerns or suggestions they believed should be considered in development of the action plan.
- The letter also invited tribal representatives to attend public information meetings and to join the action plan listserve group.
- Subsequent letters sent to conservation partners included tribal contacts.
- Representatives of two tribes joined the listserve group, one of whom attended the 'Kick-Off' Workshop.

Non-Governmental Organizations

Many NGOs were involved throughout development of the WAP. They participated in early discussions about the potential processes and products, meetings and workshops, writing, and review of written materials. Because MNFI, IAFWA and the species experts were deeply involved throughout the entire development process, they are individually recognized below:

Michigan Natural Features Inventory (MNFI, a program of Michigan State University Extension)

- represented on the Core Development Team by an employee on contract with the DNR Fisheries Division
- represented on the Steering Committee by the Director of MNFI
- assisted with identification of SGCN, species experts and terrestrial landscape features, analysis of spatial data, writing, map production, development of an overall monitoring concept, and reviews of multiple drafts, through contracts with the DNR Wildlife Division; attended Regional Technical Workshops

The International Association of Fish and Wildlife Agencies (IAFWA)

- coordinated and provided financial assistance to allow plan/strategy coordinators to attend national meetings
- provided information, data and products from other national conservation partners
- aided in coordination and information flow between States, communication at national levels, and clarification of Federal requirements

Species Experts

- provided assistance throughout development of the action plan, including identification of SGCN and verification of species associations with landscape features and threats
- primarily non-DNR individuals representing many academic institutions in Michigan, as well as various other public and private organizations

Outreach

Web Page (http://www.michigan.gov/dnrwildlifeactionplan)

- established early in the action plan development process
- provides information on the action plan and its development, information on State Wildlife Grants, contact information, and an electronic feedback form that allows individuals to send comments directly from the web pages

Listserve Group

- an email update list created to provide participants and other interested individuals updates on progress and opportunities for participation in action plan development
- included attendees at meetings and workshops and others who indicated an interest
- more than 120 individuals are currently included in the listserve

Public Presentations

- invited presentations for various conservation partner organizations and meetings (Appendix F)

Public Information Meetings

- held in August 2004 in five locations throughout Michigan (Appendix F)

- advertised through a DNR press release, the official DNR Calendar and website, the listserve group, and a direct mailing to 120 Michigan conservation organizations

Public Review

- final draft released for public review in May 2005
- information provided through DNR press releases, the DNR web site, and public meetings held in four locations (Appendix F)
- feedback and comments requested and received through public meetings and electronic and hardcopy communications (Appendix L)

STATE OVERVIEW

The purpose of this chapter is to provide an overview of current conditions and trends in Michigan that may affect wildlife (by definition, both aquatic and terrestrial species) and our ability to conserve species and the landscapes that they use. Additionally, this chapter identifies some regional differences which will provide context for differences between regions in the landscape feature summaries found in the Landscape Features & Conservation Needs section. Some headings from this chapter are repeated in the next chapter, Statewide Conservation. This State Overview chapter is intended to offer context, by providing information on historical and current conditions and documented changes in Michigan. Discussions of similar issues in the next chapter will specifically address how wildlife and landscape features are threatened in a statewide context and recommend conservation actions to abate the threats.

Value of Wildlife to Michigan

The history of Michigan, subsequent to the arrival of Europeans in North America, is inextricably linked to the value of its natural resources. The abundance of wildlife fostered by the varied landscapes found across the State and the surrounding Great Lakes set the stage for Michigan to become a crossroads for commercial trade in wildlife (e.g., beaver and muskrat pelts).

As early as 1658, French furtraders were exploring and developing trade routes in the Great Lakes region (DNR 1990). The fur trade drove early exploration and settlement of the State: ease of access for processing and shipping pelts determined the location of settlements like Sault Ste. Marie, Detroit, Mackinac City and St. Joseph. During this period, animal fur was an important basis for trade among Native Americans and settlers.

Michigan also gained prominence as a source of wild meat for large eastern and midwestern markets. Market hunters removed a wide variety of animals including deer, waterfowl, shorebirds, passenger pigeons and small game for meat. Other birds were taken for their plumage to adorn hats or for stuffing in bedding or pillows (Peterson 1979). By 1876, market hunters were killing approximately 70,000 white-tailed deer and untold numbers of birds each year.

Intensive commercial fishing on the Great Lakes began in 1820 on Lake Erie and quickly spread to the other lakes (Garling et al. 1995). By 1905, approximately 47.5 million pounds of fish were being removed each year. The catch was dominated by species such as lake herring, lake whitefish, lake trout and suckers. Noticeable declines in the Great Lakes fish harvest first began to occur around 1862. By the 1960s, many commercial fish stocks had crashed due to overexploitation and the introduction and population explosion of the parasitic sea lamprey.

The list of species in Michigan whose extinction can be partially linked to commercial exploitation, through intentional take and incidental capture, includes (with date of last record): passenger pigeon (1898), blue pike (1965), longjaw cisco (1957), blackfin cisco (1969) and deepwater cisco (1951). Many other species, including wild turkey and lake sturgeon, experienced severe population declines.

With the advent of the industrial age and modern agricultural methods, the reliance on wildlife for meat and revenue declined and, due to severe population declines, commercial harvest of some species was no longer economically viable. During the same time period, people began to recognize the importance of sustaining wildlife populations for other economic purposes.

Near the turn of the last century, sport hunting and fishing largely replaced commercial harvest. The monetary value of an animal no longer depended exclusively on its market price; the value became recreational, and could be measured by the amount of money expended for licenses, equipment and

other amenities necessary for its pursuit. In 1955, the USFWS began measuring these expenditures. The 10th survey, conducted in 2001, found the total estimated annual value of sport fishing and hunting-related activities in Michigan by U.S. citizens (16 years old and older) to be $838,558,000 and $490,254,000, respectively (USFWS and U.S. Department of Commerce 2001).

Currently, bird watching, wildlife viewing and nature photography represent the fastest growing segment of all wildlife-related recreation. Surveys conducted in 1980 and 1990 indicated a 63% growth in trips related to these activities (Duda and Young 1994). Recent estimates place the annual value of these non-consumptive activities in Michigan at $692,757,000 (USFWS and U.S. Department of Commerce 2001).

Wildlife can still hold great value for people participating in neither consumptive recreation nor other outdoor recreation activities. A recent survey found that more than three-fourths of Michigan citizens strongly agreed with the statement 'whether or not I see wildlife, just knowing that wildlife exists in Michigan is important' (Koval and Mertig 2002). This result supports the premise that wildlife possesses intrinsic value. Intrinsic value is recognized as the worth of a resource for its own sake (Callicot 1986). In a national survey (Belden et al. 2002) respondents affirmed the intrinsic value of wildlife when they agreed with the following statements: 'one of the most important things to me, in my life, is living in a world with a wide variety of plants and animals' (90% agreed); and 'nature provides me with inspiration and peace of mind' (94% agreed).

Whether wildlife or landscapes are measured simply as commodities for their value to an economy or for their non-market values, the conservation, restoration and protection of wildlife and the landscapes they use, for future generations, remains a critical mission for Michigan's conservation partners and citizens.

Social & Economic Overview

Population Distribution

On average, Michigan has approximately 175 people per square mile, but this population is disproportionately distributed: residents of the 14 Upper Peninsula counties represent 3% of the total State population, whereas the three southeastern Detroit-metro counties (Oakland, Macomb and Wayne) account for 40% of the total State population (U.S. Census Bureau 2005). Other significant population centers in southern Michigan include: Kent County (6%), Genesee County (4.4%) and Washtenaw County (3.4%). This distribution imposes a much greater demand on the resources in the southern portion of the State, increasing threats to wildlife species and the landscapes they use.

Results from the 2000 U.S. census estimate Michigan's population to be just under 10 million people. This number reflects an increase of 6.9% since 1990, which is less than the national average of 13.1% (U.S. Census Bureau 2005). Impacts on the landscape have been disproportionate to this growth. 'Built' (developed) land area increased 25% from 1980 to 1995, a rate that is eight times the estimated population growth rate (3%) during the same period (Public Sector Consultants 2001). This change is evident in the decline of average population density in developed areas, from 3.8 persons per acre in the early 1980s to 2.8 persons per acre in the late 1990s (Norris and Soulé 2003). This shift has accelerated the rate of land conversion, because low-density housing developments in the suburbs require more area for each individual household. Development is a leading source of fragmentation in Michigan's landscapes.

Another issue associated this change is 'urban sprawl,' a circumstance in which city populations experience a population decline, while outlying areas see unprecedented development. Between 1990 and 2000, several Michigan cities experienced significant emigration (with percent population decrease): Flint - 12%, Saginaw - 11.6%, and Detroit - 7.5% (Michigan Land Use Leadership Council

2003).

Economic Drivers

Michigan's economy in the 19th century was dominated by fur trapping, farming, lumbering and mining, but became highly industrialized after 1900 as it grew to be the major center of the U.S. automobile industry. Manufacturing continues to be an important industry in the State, comprising 20.7% of the Gross State Product in 2002 (U.S. Department of Commerce 2005). Other major industries include agriculture and tourism (Michigan Economic Development Corporation 2005).

Industry employment forecasts produced by the Michigan Department of Labor and Economic Growth (2005) predict a small decrease (2.3%) in the overall number of individuals employed in manufacturing from 2000 to 2010, but an increase (7.6%) of those employed in manufacturing of lumber and wood products. The forecasts also predict a decrease in mining (3.7%) and increases in construction (13.6%), agricultural services (19.2%), amusement and recreation services (26.6%), real estate (10.0%), and transportation, communications and utilities (6.8%), including an increase in water transportation (6.1%). These are indicators of change in the industries that are primary sources for many of the threats to wildlife and the landscapes they use in Michigan.

Land Ownership and Use

Michigan has a greater total acreage of public land than any State east of the Mississippi River. Approximately 20% of Michigan's 36.4 million acres are managed by Federal, State or local governments. More than seven million acres are in State and Federal ownership.

The DNR manages 4.5 million acres as State Forests, State Wildlife Areas, and State Parks and Recreation Areas. These lands provide wildlife habitat, outdoor recreational opportunities such as hunting, wildlife viewing and boating, and resources for timber and mineral extraction. An additional 375,000 acres are managed by MDOT and the Michigan Department of Military and Veterans Affairs. The State government also holds title to approximately 25 million acres of Great Lakes bottomlands.

The Federal government manages 3.1 million acres for a variety of purposes, including provision of wildlife habitat, protection of rare natural features, provision of recreational opportunities, and resource extraction. These lands include 2.85 million acres of National Forest managed by USFS, 730,000 acres within two National Lakeshores and one National Park managed by the National Park Service, and 115,000 acres within three Federal Refuges managed by USFWS.

Local governments manage approximately 114,000 acres in Michigan, primarily for recreational purposes and to support utility services.

Approximately 80% (29 million acres) of land in Michigan is privately owned, and when southern Michigan is considered alone, 97% of land is in private ownership. Because most of the observed and predicted changes in land-use have occurred or are expected to occur on private lands, these lands will play a pivotal role in achieving the goals of the WAP. Planning and use regulations affecting these lands occur at local levels; State law grants authority to local governments to determine the extent, rate and types of development that will occur in individual municipalities and counties. Compared to other states, local land-use planning in Michigan is especially fragmented. Whereas most States have between 300 and 500 local government units possessing authority to engage in planning, Michigan has more than 1,800 of these units (Public Sector Consultants 2002). Local governments typically do not coordinate at regional levels; as of 2002, only 25 of 83 counties had adopted countywide zoning ordinances (Public Sector Consultants 2002). Consequently, local planning for private lands in Michigan tends to produce a patchwork of disparate development and land-use schemes across the landscape, increasing fragmentation and inhibiting wildlife movements.

From the early 1800s through the middle of the 20th century, Michigan acreage in agricultural production steadily and rapidly increased. Following this boom, farmlands began to decline due to conversion to urban and suburban areas and abandonment of farmlands, which were often allowed to succeed to forested lands. In 1978, 29% of Michigan acreage was in agricultural production (Smyth 1995). Between 1982 and 1997, farmland acreage decreased by almost 1.5 million acres, or 13.3% (Norris and Soulé 2003). Between 1997 and 2002, Michigan lost an additional 3% of its farmland (U.S. Department of Agriculture 2002). If current trends continue, Michigan will lose 25% of its fruit-producing land and 1.9 million acres of other farmland in the next 40 years (Public Sector Consultants 2002).

In 1978, 6% of Michigan's land area was defined as urban (Smyth 1995). Since that time, the acreage of developed land has increased by more than 30% (Public Sector Consultants 2002). This expansion of urban and suburban areas has been fueled by urban sprawl, as described in 'Population Demographics' above. If present development trends continue, between 1.5 and 2 million additional acres of unbuilt land could be urbanized by 2020 and the acreage of developed land could increase by 178% by the year 2040 (Public Sector Consultants 2001). If this growth is poorly planned, or occurs without any planning, the detrimental effects on Michigan's wildlife will be severe.

Social Attitudes

Interest in wildlife conservation has changed dramatically over the last several decades. Whereas a small number of groups primarily influenced early wildlife conservation efforts, more than 70 new organizations addressing wildlife and animal interests were created in the U.S. during the 1950s and 1960s (Witter 1990). One consequence of this broader citizen interest and participation has been an increase in the number and breadth of issues. Interest in the protection of nongame species has increased as the constituency base has grown. However, growth in public participation also increased the potential for expression of disparate views, and, as a result, conflicting information and differences in public values have frequently polarized individuals and groups. This situation makes identification of a common vision and goals for all conservation partners more challenging.

The populace has also become more urbanized (or suburbanized) and less individually engaged in the practices of crop production, animal husbandry and land stewardship. A significant gap now separates many people from a functional understanding of their relationship to the natural environment. A healthy sustainable environment depends, in large part, on whether present and future generations become aware of and value the interconnected and interdependent aspects of all life. A recent series of Michigan surveys, measuring the attitudes of the public toward resource management and the agencies involved in implementing management actions, found that Michigan's citizens still highly value their State's natural resources: 84% of respondents identified active promotion of ecological health as either the highest or second highest priority when asked to rank natural resource management goals in Michigan; 68% of respondents identified supporting resource development for greater economic growth as a low priority (Koval & Mertig 2002). These results are similar to an earlier national survey that found 71% of respondents considered environmental protection vastly more important than economic development (National Environmental Education & Training Foundation and Roper Starch Worldwide 1998).

The Michigan surveys also found that most respondents mildly or strongly disagreed with the statement, 'the balance of nature is strong enough to cope with impacts of modern industrial nations,' recognizing the need for management of natural resources. However, when the environmental concerns are put in head-to-head competition for time investment, funding, and other commitments, they fall below social issues including crime, education and healthcare (Belden and Russonello 1996).

Population demographics, especially age, educational and gender characteristics, have been found to be associated with attitudes about natural resources and the management of natural resources. The Michigan surveys mentioned above found attitudes toward the DNR were significantly more positive in

women, older people, urban dwellers, residents of southern lower Michigan, and individuals who participate less frequently in camping, boating, fishing and hunting. Responses to several questions in these surveys revealed significant differences among different demographic groups. Recognition and knowledge of these differences may help to focus education efforts.

The field of 'human dimensions,' including issues such as those mentioned above, is becoming an increasingly larger part of the overall picture which must be considered by conservation partners when making decisions about the management of wildlife species and the landscapes they use.

Non-consumptive Recreation

Non-consumptive recreation is defined as recreational activity where the take (removal, harassment, harm) of a resource is incidental to the purpose of the activity. These activities include, but are not limited to, off-road vehicle (ORV) use, snowmobiling, non-fishing related boating (including use of personal watercraft), canoeing, tubing, horseback riding, mountain biking, hiking, cross-country skiing, rock climbing, camping, mine and cave exploration, wildlife viewing, and photography.

Recent reports indicate activity in outdoor recreation continues to increase. Over the last ten years, snowmobile registrations have increased from 213,347 to over 290,000 (DNR 2004b). During the last five years, ORV license sales have increased from 146,000 to nearly 174,000 (DNR data) and personal watercraft registrations have increased by 40,000 in five years (DNR data). As early as the 1970s, non-consumptive recreation was found to exceed consumptive recreation on southern Michigan public lands (Belyea and Lerg 1976).

Although information on activities not requiring registration is more difficult to obtain, national trends in equipment sales and recreation area visitation indicates a broad increase across outdoor recreation activities and, therefore, more potential threats to wildlife and the environment. See the discussion of non-consumptive recreation in the Statewide Conservation chapter below for more details about the threats posed by these recreational activities.

Ecological Overview

Terrestrial Overview

Michigan contains a broad diversity of terrestrial ecosystems that are differentiated by variations in regional climate, physiography (glacial landform and geologic parent material), soils and vegetation (Albert 1995). In an effort to better understand and communicate information on this diversity, researchers have developed a hierarchical classification of regional landscape ecosystems that divides the State into four major sections or ecoregions, each containing additional levels of differentiation (Albert et al. 1986, Albert 1995). This ecoregional classification provides a framework for understanding broad patterns of natural community and species occurrences, natural disturbance regimes, and land-use patterns across the State. Because the distribution of plants and animals in Michigan is influenced by the factors that shape ecoregions (climate, geology, soils, vegetation), these ecoregions are a useful tool for integrated resource management, planning, and biological conservation. The four major ecoregions in Michigan are the Southern Lower Peninsula, Northern Lower Peninsula, Eastern Upper Peninsula, and Western Upper Peninsula (Albert 1995).

The Southern Lower Peninsula (Southern Continental Michigan) Ecoregion (Section VI) is characterized by rolling moraines and flat lake plains. This ecoregion experiences the warmest climate and longest growing season in Michigan. Historically, much of Southern Lower Michigan supported open oak savannas and prairies, which were maintained in a non-forested condition by frequent fires (Albert 1995). Dry upland ridges supported oak–hickory complexes. Also common were forests of American beech and sugar maple and a diversity of wetland natural communities including prairie fen, lakeplain prairie, southern wet meadow, southern swamp and floodplain forest. Today, much of the

region is dominated by agricultural and urban development.

The Northern Lower Peninsula (Northern Lacustrine-Influenced Lower Michigan) Ecoregion (Section VII) is characterized by extensive, sandy outwash plains and large moraines. Although the climate of the ecoregion is strongly moderated by the Great Lakes, the interior portions experience the greatest temperature extremes in Lower Michigan. Historically, the ecoregion supported extensive northern hardwood forests of sugar maple, American beech, eastern hemlock and white pine. In addition, the ecoregion supported large areas of fire-dependent ecosystems such as jack pine barrens, oak–pine barrens, and white pine–red pine forest. A diversity of wetland natural communities, including bog, northern fen, northern wet meadow, hardwood–conifer swamp and rich conifer swamp, continues to thrive. Today, much of the ecoregion remains forested by northern hardwood, aspen, oak, pine plantations, and lowland conifer.

The Eastern Upper Peninsula (Northern Lacustrine-Influenced Upper Michigan) Ecoregion (Section VIII) is characterized by relatively flat lake plain and areas of exposed bedrock. The climate is strongly influenced by the Great Lakes and experiences warmer temperatures than the western Upper Peninsula. Historically, most of the ecoregion was forested and remains so today. As in other ecoregions in northern Michigan, the original northern hardwood forests in the Eastern Upper Peninsula generally supported a greater diversity of conifers, which provided structural complexity and a diversity of wildlife habitats. Smaller areas of fire-dependent ecosystems such as white pine–red pine forest and jack pine barrens also occurred within this ecoregion. The region continues to support a diversity of wetland natural communities including bog, northern fen, northern wet meadow, hardwood–conifer swamp, rich conifer swamp, and extensive areas of muskeg and patterned fen.

The Western Upper Peninsula (Northern Continental Michigan) Ecoregion (Section IX) is characterized by a diverse landscape of moraines, lake plains, outwash channels, outwash plains, and glacially scoured bedrock ridges. This ecoregion experiences the most extreme winter temperatures and shortest growing season. Historically, a diversity of forest types occurred throughout the entire ecoregion. Northern hardwood forests dominated by sugar maple, eastern hemlock, basswood, yellow birch, and in some locations white pine were the most prevalent forest community. The ecoregion contains numerous bogs, tamarack–black spruce swamps, and hardwood–conifer swamps. Today, most of the region is managed as either private or public forest. Prevalent forest types today include northern hardwood, aspen, pine plantations, and conifer swamp.

Aquatic Overview

Aquatic ecological frameworks in Michigan were derived through analysis of climate, geology, soils and vegetation, using a similar approach to that of the terrestrial classification system (Albert et al. 1986). Although aquatic and terrestrial frameworks share the same environmental variables, distinct and different classification schemes are used because aquatic species, unlike terrestrial species, tend to be more limited in their dispersal pathways between waterbodies. This difference requires a different classification framework because the watersheds that compose the Great Lakes basins and that form these pathways cross multiple terrestrial ecoregions (Seelbach et al. 1997).

Michigan resides in the Arctic–Atlantic subzone within the Nearctic zone of North America, as defined by Maxwell et al. (1995). It occurs in three subregions of the Mississippi region: Superior, Michigan–Huron and Erie–Ontario. These subregions can be further divided into the Great Lakes basins of Superior, Michigan, Huron and Erie. Each basin consists of the Great Lake itself and all lakes, rivers, streams and other hydrologically significant resources that flow into it. These basins provide the broad framework for understanding aquatic communities, species and habitats in Michigan.

The distribution of aquatic animals and plants in Michigan has been most strongly influenced by the last glaciation period, the Wisconsinan. Approximately 4,000 years ago, the Great Lakes first began to

assume their present shapes. Rebound of the earth's crust after the last glacial retreat determined the current drainage pattern: Lake Superior drains through the St. Mary's River; Lakes Huron and Michigan drain through the St. Clair River at Port Huron into Lake Erie (Farrand 1988).

Land-cover Change Trends

Estimates of pre-settlement conditions indicate that forests comprised approximately 90% of the Michigan land area. Unsustainable logging practices, extensive conversion to agriculture, and the occurrence of catastrophic fires nearly eliminated all of these forests by the early 20th century. With implementation of sustainable forestry practices and abandonment of farms, which allowed ecological succession to forested lands, Michigan's forests began to recover. Currently, forest covers approximately 50% of the acreage of the State (Smyth 1995). Although this percentage has remained relatively stable since the 1950s, the standing timber volume has more than doubled (Harrison 2003). The volumetric increase is due both to maturation of naturally regenerated and planted trees, and suppression of natural fire regimes. Changes have also been seen in the composition of Michigan's forests, with a gradual transition toward more shade-tolerant, late-successional tree species and a corresponding decline in some wildlife species dependent upon early successional landscapes. From 1982 to 1997, forest acreage on non-Federal lands in Michigan increased by approximately 538,000 acres (U.S. Department of Agriculture 1997), primarily due to further loss of farmed acreage. However, many Michigan forests are being replaced by residential and commercial development, and if current patterns of development continue, forest acreage in Michigan may decrease by 2 to 7% by 2040 (Public Sector Consultants 2001).

Historically, Michigan contained approximately 11 million acres of wetlands. The perception that these areas should be converted to a 'better' use predominated most of the nation's history. Accordingly, Federal and State governments enacted legislation to promote the conversion of these habitats. Prior to World War II, most wetland loss resulted from filling and draining for agricultural purposes. After World War II, commercial, industrial and residential development became the major cause of wetland loss. In 1978, 6.2 million acres of the original 11 million acres of wetlands remained in Michigan (Smyth 1995). Federal and State legislation enacted during the 1970s slowed the rate of loss, but small wetlands (<5 acres) on private lands continue to be lost at a rapid pace; projections indicate Michigan may lose an additional 10% of its remaining wetlands by 2040 (Public Sector Consultants 2001).

Coastal wetland losses have been particularly substantial, declining 70% from historic levels (Comer et al. 1995). The Great Lakes are the largest freshwater system in the world, supporting extensive coastal wetland complexes along the shoreline and in conjunction with drowned river mouths, connecting waters and other tributaries, and embayments. At least six types of Great Lakes wetlands have been identified: lagoon and barrier, ridge and swale, shoreline, embayed, riverine and delta (Michigan Sea Grant 2002). Coastal wetlands are important aquatic habitats and also provide recreational, cultural and economic benefits. Although the importance of coastal wetlands has been well documented, they continue to be lost under increasing development pressure. Wetland modifications due to development include artificial manipulation of water levels, shoreline alteration, pollution, vegetation removal, and other forms of habitat fragmentation. Another associated threat to coastal wetlands is modification through establishment of invasive species such as reed grass. See the discussion of wetland modifications in the Statewide Conservation chapter below for details on how loss of and modifications to wetlands threaten wildlife and wildlife diversity.

In specific areas of the Southern and Northern Lower Peninsula, oak savanna, tall grass prairie, and barrens dominated the landscape in the early 1800s. Although the exact number of prairies that existed prior to European settlement is unknown, researchers have identified 39 known prairie areas, mostly in the southern Lower Peninsula. These areas ranged in size from less than 100 acres to 25 square miles, and may have covered 2.3 million acres (Sargent and Carter 1999). European settlement converted most of the grassland sites to agriculture. Fire suppression allowed additional

acreage to follow successional pathways and become forested. Residential development is now threatening what remains of this community type. More than 99% of Michigan's grasslands are gone, and the remnants that persist are primarily small, isolated patches.

Invasive Species

Since the first European settlers began arriving on the North American continent, hundreds of new species of plants, animals and pathogens have been either intentionally or accidentally introduced. Although many have been incorporated into the landscape with little or no effect, others are more aggressive and threaten both species and landscapes (MDEQ 2003a). Additionally, changes caused by European settlement have altered the landscape, allowing species such as alewives, sea lamprey and Cowbirds to expand their ranges. Without natural predators or parasites, invasive species often outcompete and displace indigenous populations. As the number of introductions continues to increase, so do the potential ecological and economic consequences. See the discussion of invasive species within the Statewide Conservation chapter below for details about these consequences.

The Great Lakes waterways have experienced an extremely high rate of non-indigenous species introduction and establishment (Mills et al. 1994, Ricciardi 2001). The earliest recorded aquatic invasive species in the Great Lakes was the sea lamprey, which gained access from the Atlantic Ocean through the Erie Canal in the 1820s. Since then, more than 160 additional aquatic invasive species have been introduced into the Great Lakes basin (Harrison 2003). More than one-third of these species were introduced in the second half of the 20th century following expansion of the St. Lawrence Seaway. Ballast water from ocean-going ships is believed to be one of the primary vectors of aquatic introductions, including that of the zebra mussel.

Hundreds of non-indigenous plant and insect species now occur in Michigan. As many as one-third of our plant species may now be non-native (Herman et al. 2001). In the Great Lakes basin, at least 37 terrestrial plant species and seven terrestrial insect species are invasive (Harrison 2003) and pose threats to natural communities in Michigan. Several of the plants, including buckthorn, purple loosestrife and garlic mustard, were introduced deliberately for use as ornamentals or herbs.

Aquatic Contaminants

With 95% of the surface fresh water in the U.S., 11,000 inland lakes and 36,000 miles of streams, Michigan's waters are one of the State's greatest resources. Water quality standards and pollution controls implemented in the 1970s continue to successfully reduce some contaminants. However, chemicals, such as polychlorinated biphenyls (PCBs), mercury, lead and other toxins, are persistent in the environment; they take a long time to break down and may still occur in high or increasing concentrations, posing serious threats to natural communities and human health. The Michigan Department of Community Health recently issued advisories for all inland Michigan lakes, recommending that people limit their ingestion of wild-caught fish due to health concerns related to contamination with mercury, dioxins and PCBs. See the discussion of urban, municipal, and industrial pollution in the Statewide Conservation chapter below for details about how contaminants are threatening wildlife species and the landscapes they use.

When present in the environment, PCBs, mercury and other toxins can bioaccumulate (accumulate and concentrate) in the tissues of animals at the top of the food chain, such as Bald Eagles and predatory fish. PCBs were previously used more commonly in manufacturing processes, and although in many cases they have been replaced by other materials, their use has not been completely eliminated. Analyses of Bald Eagle, lake trout and chinook salmon tissues show significant decreases in PCB levels between the late 1980s and the late 1990s (Harrison 2003), indicating a decease in environmental levels. Since the mid 1990s, PCB levels in sampled fish have remained relatively stable; however, these toxins often remain captured in sediments, and re-suspension in water is a concern.

Mercury may occur naturally in the environment, but the primary sources for contamination are human-induced, and include mining and smelting of mercury ores, industrial processes using mercury, and combustion of fossil fuels. Unlike PCBs, mercury levels in Bald Eagles did not change significantly between 1985 and 2001. In 2002, mean mercury levels exceeded the Michigan water quality standards (1.3 parts per trillion) in 19 of 24 Michigan rivers sampled (Harrison 2003), and monitoring between 2000 and 2002 indicated increased mercury levels in eight Michigan rivers, four of which occur in the Upper Peninsula (MDEQ 2003b).

Historically, lead was used in fuel and manufacturing processes, and was introduced into the environment through leaking underground storage tanks, fuel spills, spent lead shot and fishing tackle left by anglers. Accumulation rates of lead into lake sediments increased from 1900 through the 1970s, but began to decline following the ban of leaded gasoline in the 1970s. Southern Michigan has shown and continues to show higher rates of lead accumulation than northern areas (Harrison 2003).

Agriculture is yet another source of contamination, introducing fertilizer, herbicides and pesticides into Michigan's water systems through run-off and soil percolation. Since first used in the mid 1940s, application of pesticides throughout the world has grown from 50 million kilograms per year to approximately 2.5 billion kilograms per year (Kiesecker et al. 2004).

Disease and Pathogens

The potential effects of infectious and zoonotic (transmitted between animals and humans) wildlife diseases on wildlife conservation, as well as domestic animal and human health, have long been recognized. However, interest in recent years has increased for several reasons: modification and loss of habitat can result in increased population densities, with associated increases in risk of disease transmission; increasing speed and intensity of international trade in wildlife has meant more rapid spread of diseases and pathogens worldwide; wildlife re-introduction efforts are being limited by disease concerns; human encroachment into wildlife habitats has increased the potential for zoonotic disease transmission; and recognition of the possible use of wildlife species as indicators and sentinels for potential human and domestic animal health threats is growing (National Biological Information Infrastructure 2005).

Overall, the past ten years has shown some changes in fish health in Michigan, including elimination of infectious pancreatic necrosis virus (IPN) in wild fish, and reduction of bacterial kidney disease (BKD) in chinook and coho salmon, as well as the emergence of new diseases such as heterosporis, piscirickettsia and largemouth bass virus (LMBV). New diseases are discovered regularly and are suspected of being transported into Michigan by freighter ballast water, introduced with released infected aquarium fish or baitfish, introduced with illegally stocked or imported fish, or introduced through recreational boat bilge water transported from outside Michigan. Little is known about diseases to aquatic organisms other than fish, but epizootic events, with similar sources, are probably occurring throughout the aquatic ecosystem.

New disease threats affecting terrestrial wildlife are also increasing. Some of the causes of amphibian declines have been linked to disease and pathogens (Kiesecker et al. 2004). Although not currently known to affect Michigan's wildlife, avian influenza and raccoon rabies are other examples of potential threats. The bovine tuberculosis epidemic that threatened Michigan's deer herd is now showing signs of decline. An increasing number of diseases affecting forested landscapes are being found in Michigan, including beech bark disease and oak wilt. Wildlife species that have obligate relationships with the affected tree species, or depend on the structure they provide within an ecosystem, will also be indirectly affected by these diseases. See the discussion of disease and pathogens within the Statewide Conservation chapter below for more information about specific disease threats and associated conservation needs.

Altered Natural Processes

Various natural processes are required to maintain certain landscape features that are used by wildlife in Michigan. Over time, many of these processes have seen changes, both in the spatial extent affected and the rate at which they occur or return. In many cases, these changes are due to human-influenced alterations or disruptions, but in others, may be the result of natural fluctuations and variation or the activities of wildlife species. Human activities have both increased undesirable disturbances and decreased desirable disturbances at different temporal and spatial scales. Examples of natural processes that may be intricately tied to the survival of certain wildlife include hydrologic regimes, fire regimes and climate change (e.g., glacial cycles and other changes). The following discussion focuses on the first two of these processes, because alterations to them are identified as statewide priority threats in the next chapter.

Altered Hydrologic Regimes

Following wetland drainage, extensive stream channelization, groundwater withdrawals, dam construction, and large-scale changes in land use, much of Michigan has experienced considerable changes in hydrologic processes. These alterations include changes in streamflow patterns, lake levels, and groundwater hydrology.

People use streams for drinking water, navigation, municipal and industrial uses, irrigation, hydroelectric power, sewage treatment (and dilution), recreation and aesthetic benefits. These values of flowing water attract people who subsequently build homes, factories and cities on riverbanks, but development often modifies stream channels and alters stream functions, negatively affecting natural processes and ultimately reducing stream values (Annear et al. 2004). Harnessing streams and rivers for human purposes has incurred significant ecological costs.

Many other practices have also altered or reduced connectivity within hydrologic regimes. In the late 1800s and early 1900s, logging deforested entire watersheds, causing tremendous volumes of sediment to erode into rivers and streams. This was compounded by early agricultural practices that caused extensive soil erosion and contributed additional quantities of sediment far above the load generated by natural processes. Construction of drains and addition of drainage tiles to prepare lands for agricultural efforts and modification of wetlands in preparation for development have changed surface and groundwater regimes. The use of impervious surfaces, such as asphalt roads, buildings and parking lots, has further altered surface and groundwater regimes.

Changes in populations of beaver can influence the distribution and intensity of their activities across the landscape and alter previously existing hydrologic regimes. Beaver affect hydrologic flows by damming and slowing water, which creates wetland habitat beneficial to some species, but creates impediments to movement for other species. These activities can also alter water temperatures in these systems.

All of these changes have created disruptions in the natural movements of water through Michigan's lands, lakes, rivers, streams and wetlands. More details about threats resulting from these changes and conservation actions, research and monitoring needed to address them are provided in various places throughout the Statewide Conservation chapter below.

Altered Fire Regime

Many of Michigan's landscape features, including certain grasslands, forests and wetlands, were historically maintained through natural (e.g., lightning) or human-induced (i.e., set purposely by Native Americans) fires. Fire is likely as important an element as climate in the establishment and maintenance of Michigan's grasslands; fire helps prairies to grow by stimulating grass and wildflowers to reproduce, reducing competition from weeds, and discouraging the encroachment of shrubs and trees. For thousands of years, tree growth in tall grass prairies and shrublands was discouraged by the

occasional wildfires that cleared the landscape every two to 50 years (Sargent and Carter 1999). Native Americans discovered that fire killed woody plants, but encouraged fruit-bearing shrubs and forage-producing grasslands. Albert (1994) identified no less than 16 ecological units where evidence of fire was a significant notation of the original Michigan land surveyors.

However, fire was greatly feared by many European settlers and continues to be feared by many of the more recent residents. This fear has resulted in a pattern of fire suppression, both of naturally caused wildfires and human-induced fires that are used as management tools for improving and maintaining habitats. This suppression has influenced both the rate of occurrence and the spatial extent of fires that occur. As a result, many of Michigan's fire-dependent systems have undergone considerable structural changes, or have completely succeeded to something else.

As a management tool, fire can benefit wildlife in many ways, including: maintenance and restoration of native grasslands; recycling of nutrients tied up in old plant growth; control of woody plants and herbaceous weeds; improvements in forage quality; increased plant growth; reduced risk of large wildfires; and other improvements to certain fire-dependent systems used by wildlife (Sargent and Carter 1999).

STATEWIDE CONSERVATION

The purpose of this chapter is to provide information and priorities for the conservation of wildlife (by definition, both aquatic and terrestrial species) and its habitat at a statewide scale. This chapter addresses conservation needs that are specific to threats and issues identified as priorities throughout Michigan, as well as overall research and monitoring needs for conservation of landscape features and wildlife species. Some headings are repeated from the previous State Overview chapter. That chapter was intended to provide the context in which threats and issues are occurring. This chapter identifies specifically how these threats and issues are affecting wildlife and landscape features.

This chapter is divided into four parts:

1. 'Priority Threats' identifies and addresses 14 threats to wildlife and landscape features that were evaluated by natural resource professionals as medium to high severity throughout the State. They are a subset of the 50 aquatic and terrestrial threats outlined in the Methods chapter.

2. 'Other Priority Issues' addresses six other issues that were identified as important to wildlife and landscape features, but are not adequately addressed in the landscape feature summaries or SGCN summaries. They generally occur at scales considerably larger than most individual landscape features, ecoregions and lake basins, or are associated with multiple SGCN.

3. 'Research, Monitoring & Adaptive Management' provides information on research and monitoring that will help to address wildlife threats and issues, and information on how the effectiveness of recommended actions should be evaluated.

4. 'Priority Conservation Needs' identifies conservation actions, research and monitoring that, if implemented, have the potential for the widest-reaching benefits for wildlife in Michigan.

Priority Threats

The following 14 threats are a selection of the 50 threats to aquatic and terrestrial wildlife and systems outlined in the Methods chapter (see the Methods chapter for an explanation of how the threats detailed here were identified as statewide priorities). Effects of each statewide priority threat on wildlife and landscape features are detailed, and conservation actions, research and monitoring to address these threats are identified.

Because many of these issues overlap, addressing them individually is difficult and some repetition is necessary. When possible, similar terrestrial and aquatic issues have been addressed jointly. Some identified priority threats have been broken into multiple issues to address them more effectively (e.g., Dredging and Channelization). These priority threats (and others not identified as statewide priorities) are also addressed by ecoregion, lake basin, and landscape feature within the Landscape Features & Conservation Needs section. There they are addressed at a finer scale, in the context of recommended conservation actions, research and monitoring for individual landscape features within specific ecoregions or lake basins.

Whereas most of the following statewide priority threats ('Priority Threats') are given in association with their previously described standardized threat categories (see Methods chapter), two threats ('Highest Priority Threats'), invasive species and fragmentation, have been brought to the front for emphasis, because they were repeatedly identified, through the ranking process and discussion at meetings and workshops, as being the highest priority threats to wildlife and landscape features in both aquatic and terrestrial systems throughout Michigan.

Highest Priority Threats: Invasive Species

An estimated 209 or more invasive species have been either accidentally or intentionally introduced into the Great Lakes basin. Introduced plants, such as purple loosestrife, garlic mustard, autumn olive, common reed grass and Eurasian milfoil, and animals, such as gypsy moth, zebra mussels and round gobies, have resulted in major ecological and economic costs (Mills et al. 1994, Schloesser et al. 1998, Edsall 1998, Madenjian et al. 2002). See the Economic Overview in the State Overview chapter above for more information about the kinds of invasive species in Michigan and vectors for introduction.

Displacement of indigenous populations by invasive species cause altered food webs, nutrient dynamics, natural processes and life-history patterns of the native fauna and flora. Invasive species are recognized as a significant factor in the decline of at least 46% of federally listed endangered species (Pimental et al. 1999). Many invasive plants form dense monocultures that deprive native species of space, light and nutrients, altering the structure and composition of natural communities; consequently, wildlife species are deprived of native food sources and other necessary habitat elements.

The monetary effects of invasive species are also substantial, due to property damage, loss of economically viable resources, and the cost of control and restoration efforts. Estimates place the total cost of invasive species in the United States at more than $123 billion dollars annually (Pimental et al. 1999). During the next ten years, an estimated three million dollars will be spent on monitoring and control of zebra mussels alone (Harrison 2003).

A recent assessment of invasive species policy at the national level concluded, "Existing legislation on non-indigenous species is fragmented, reductionist, and lacks comprehensive coverage and policy philosophy. Research is needed into how best to develop a policy, what it should look like, and how it could be enforced. At this point prevention of further introductions of invasive non-indigenous species is unquestionably the most prudent policy, one that could save billions of dollars in damage as well as prevent extensive perturbations to native ecosystems and endangered species" (Williams and Meffe 1998).

To address these issues, a 1999 Executive Order created the National Invasive Species Council (NISC). The NISC completed a national management plan for invasive species (NISC 2001), but invasive species continue to be a major threat.

The following examples illustrate Michigan's vulnerability to invasive species.

Brown-headed Cowbirds
Once limited to the great prairies of central United States, Brown-headed cowbirds spread eastward as forests were removed and became fragmented and the land was developed for farming. In its original range, other bird species had developed behavioral defenses to the cowbird's nest parasitizing activities, but new species encountered did not have these defenses. In Michigan, cowbirds became a significant threat to the Kirtland's warbler. Prior to implementation of cowbird controls, nearly 70% of Kirtland's warbler nests contained one or more cowbird eggs, measured net reproductive rates fell to less than 40%, and in some locations, successful reproduction was completely eliminated (USFWS 1985). Cowbirds are also suspected in reducing the success of numerous other songbird species (Robinson et al. 1993).

Asian Carp
While the Great Lakes continue to be susceptible to new introductions of exotics via international commerce through the St. Lawrence Seaway (Kolar and Lodge 2002), they are also threatened with the potential movement of four Asian carp species from the Mississippi/Illinois River System through the Chicago Ship Channel. Bighead and silver carp, which currently occur in very large numbers in the

Illinois River (Koel et al. 2000, Pegg et al. 2002), grow to very large sizes and consume large volumes of zooplankton throughout their long lives. These species would have a significant effect on production of native fish throughout the Great Lakes by limiting zooplankton, a primary food source for native fish during early life stages. Black carp were recently discovered in the Illinois River (Chick et al. 2003). Introduction and proliferation of this species, which feeds on molluscs, would cause further declines in native mussel and snail populations (Strong and Pemberton 2000), and greatly reduce productivity in coastal wetlands by limiting fingernail clams, an important food source for several waterfowl species. Grass carp have increased throughout the Mississippi and Illinois rivers through natural reproduction (Raibley et al. 1995, Koel et al. 2000). They feed voraciously on vegetation and have the potential to substantially alter vegetated Great Lakes coastal areas, which are critical to fish and wildlife diversity and productivity.

Emerald Ash Borer

Although first discovered in southeast Michigan in 2002, the emerald ash borer (EAB) is believed to have been introduced to Michigan 6–10 years ago in packing crate material from eastern Asia. EAB larvae girdle trees as they feed under the bark, which has led to the destruction of millions of ash trees in Livingston, Macomb, Monroe, Oakland, Washtenaw and Wayne counties. Recent surveys have identified EAB in additional counties throughout the Lower Peninsula. An intensive management effort is underway to prevent further spread of this species within the State, because it could significantly change the forested landscape in areas where ash is a major component. Preliminary findings by the USFS estimate the potential timber value loss of ash resources across the U.S. at $20–60 billion (U.S. Department of Agriculture 2003).

Conservation Needs to Address Invasive Species Threats:

Conservation actions, research and monitoring identified here are patterned after the national management plan developed by the NISC (2001).

Land, Water & Species Management

- Develop and implement strategies to prevent new introductions of aquatic invasive species into the Great Lakes Basin by predicting the next likely invasive species threat
- Develop a statewide strategy using an Integrated Pest Management approach, to identify invasive species in Michigan, their potential to affect native landscapes and species, and opportunities for control
- Identify and develop environmentally safe biological agents which can be employed to control invasive species
- Identify, develop and implement management techniques (e.g., prescribed burning, pesticides, water control) to control or eliminate invasive species
- Develop land management practices and training to deter invasive species establishment and spread
- Prioritize and implement invasive species control actions using accepted methods
- Identify areas of significant invasive species concentrations
- Develop restoration plans for sites where invasive species have been controlled

Law & Policy

- Develop and implement invasive monitoring and inspection systems for private aquaculture, the bait industry, the ornamental fish and plant industries, the shipping industry, and recreational boaters
- Develop and implement a legal strategy that compensates the State of Michigan for natural resource damages from the introduction of invasive species

- Establish State regulations or actions that work to negate or restrict potential introduction pathways
- Provide incentives for propagation and use of native plants as the preferred alternative for landscape developments
- Develop and implement regulatory structures that assist in preventing the introduction of aquatic invasive species from bait and private aquaculture industries
- Develop, enact and enforce legislation requiring Great Lakes shipping vessels to disinfect ballast water prior to entering the Great Lakes or when loading and unloading in Great Lakes ports
- Develop and implement effective policies and regulatory structures to prevent the introduction of aquatic invasive species from the ornamental fish and plant industry and to provide for proper disposal of unwanted exotic species
- Seek regulatory changes designating aquatic invasive species as injurious organisms whose release is directly regulated under the Federal Clean Water Act

Education & Awareness

- Conduct an educational awareness campaign on invasive species in the State and prevention of their spread
- Provide landowners with information and tools to control invasive species
- Develop informational material that promotes use of native species in landscaping

Capacity Building

- Develop an inter-State strategy to improve legislation and enforce existing policies
- Coordinate efforts between agencies, NGOs, businesses and individuals to develop a response strategy to contain and prevent establishment of newly introduced invasive species
- Encourage private landowner participation in restoration projects through professional assistance, tax incentives and project funding

Research, Surveys & Monitoring

- Develop techniques to identify potential effects of future invasive species on native species and landscapes, and opportunities for control
- Establish monitoring and protocols to detect newly introduced species and new occurrences of known invasive species
- Develop models to predict the next likely invasive species threats to help monitoring efforts
- Determine whether linear landscape features and human-created disturbance aid in range expansion of invasive species
- Develop invasive species monitoring and inspection systems for private aquaculture, the bait industry, the ornamental fish and plant industries, the shipping industry, and recreational boaters
- Conduct research on known invasive species to identify their effects on native species and landscapes, and to provide information critical to control and restoration efforts
- Conduct research and monitoring efforts to develop and test management techniques (e.g., prescribed burning, hydrologic management, pesticides) for invasive species control
- Conduct research to develop environmentally safe biological agents to control invasive species
- Conduct research to develop and test land and water management practices that will deter the establishment and spread of invasive species

- Develop science-based priorities for invasive species control
- Conduct research to provide information critical to restoration plans
- Track the abundance, distribution and initial appearance of invasive species

Highest Priority Threats: Fragmentation

Fragmentation is caused by natural disturbances or land-use changes that divide previously contiguous landscapes into separate fragments (habitat patches). As a result of fragmentation, fluctuations in and movements of solar radiation, wind, water and nutrients across a landscape are significantly altered (Convention on Biological Diversity 2004). Direct threats to wildlife resulting from fragmentation are reduction in the size of individual habitat patches, isolation of habitat patches, and creation of barriers to species movements (Noss and Cooperrider 1994, Pringle 1997, Armantrout 1998, Morrison et al. 1998).

Fragmentation in Terrestrial Systems

Reductions in habitat patch size can be detrimental to species requiring large areas of similar habitat, such as Scarlet Tanagers, Wood Thrushes, Eastern and Western Meadowlarks, and American marten (Robbins et al. 1989, Rosenburg et al. 2003). Fragmentation can also influence the size of a landscape feature patch necessary to support species. For example, studies of Scarlet Tanagers found that in landscapes with 70% forest cover, the minimum habitat patch size for breeding was 66 acres. In landscapes with 40% forest cover minimum habitat patch size for breeding increased to 605 acres (Rosenberg et al. 1999). Smaller isolated habitat patches have increased edge to interior ratios and have been found to increase predation rates and brood parasitism, and reduce pairing success for some birds (Gates and Gysel 1978, Faaborg, et al. 1993).

For less mobile species, fragmentation may result from a spatial disturbance as minimal as placing a road through a home range area, separating an animal from the resources it needs. Telemetry studies on massasauga rattlesnakes in southern Michigan indicate a high reluctance to cross an asphalt-paved access road recently constructed through an area frequented by the snakes (Kingsbury et al. 2004). Isolation of populations of less mobile species will lead to reduced breeding potential, disruption of dispersal patterns, and diminished genetic variability (Whitcomb et al. 1981, Kingsbury and Gibson 2002).

Fragmentation also poses significant threats to terrestrial ecosystems and landscape features by disrupting necessary ecological processes. The construction of a drain through a lakeplain prairie will lower the water table, disrupting the natural hydrologic regime and altering periodic disturbance created by seasonal flooding (Albert and Kost 1998). The lack of disturbance will allow invasion by woody plants (Hayes 1964, Roberts et al. 1977).

Michigan's Environment and Relative Risk report (DNR 1992), prepared by the Michigan Environmental Science Board, identified lack of land-use planning as one of the greatest threats to the State's environment. Changes in land-use that are poorly planned, or not planned at all, drastically increase fragmentation of landscapes and disrupt ecosystem integrity.

Fragmentation in Aquatic Systems

In aquatic systems, the most obvious effects of fragmentation are seen in highly migratory species (Edwards 1978, Holden 1979). However, even non-migratory fish species need to move over large areas to use different kinds of landscape features for various reasons (e.g., reproduction, over-wintering, nursery; Schlosser 1993, Schlosser 1995a, Fausch et al. 2002). Similarly, other aquatic organisms also require connectivity across larger scales and experience population declines when isolated (Watters 1996). Human-induced fragmentation of aquatic systems is common throughout Michigan and includes dams, culverts that create velocity, jump, or exhaustion barriers for aquatic

organisms, thermal pollution discharge, channelization and hardening of rivers and streams, and stream enclosures.

Dams fragment and alter most of a river's ecological processes by altering flow regimes, sediment transport and distribution, nutrient cycling and availability, energy inflows, and biota (Ligon et al. 1995). Dams transform long river reaches into impoundments with shorter riverine reaches and cause streambed degradation immediately below the dam (Kohler and Hubert 1993; see Habitat Conversion: Dams for more information.)

Like dams, improperly constructed stream crossings may alter water depths and velocities and limit or prohibit passage of aquatic organisms. For example, water flow constricted through an undersized structure will often impound upstream water and increase downstream flow velocity and turbulence. These changes can erode a streambed below the fixed elevation of the outlet, creating a physical barrier. Other causes of partial or total barriers to upstream fish migration at stream crossings may include sediment accumulation in the crossing structure, insufficient water depth, debris collection and ice accumulation.

Numerous industries discharge cooling water into rivers and lakes throughout the state. Discharge of heated water may create thermal barriers for aquatic organisms throughout the entire year or during specific seasons. Aquatic organisms may avoid these areas because temperatures may not be in their preferred temperature range; some species may suffer mortality from thermal shock. These differences in thermal temperature effectively act as barriers to dispersal. Similarly, degradation of water quality through contaminants and eutrophication can create stream reaches that are impassable to many aquatic organisms (Pringle 1997).

Conversion of a natural stream channel to a trapezoidal shape or hardened channel can fragment the aquatic environment by creating velocity barriers, reduced depths and increased distance, which result in exhaustion barriers for aquatic organisms.

Enclosure of a stream results in a loss of ecological connectivity and creates an ecological barrier. An enclosed stream segment is isolated from natural inputs of sunlight, groundwater, surface water and organic terrestrial material. The absence of sunlight deters movement of some fish into or through enclosures (Pinkham 2000). Enclosures also alter channel processes and change adjacent channel character and shape by affecting flow path and velocity of water, movement of debris, sediment, and flood flows.

Conservation Needs to Address Fragmentation Threats:

Many of the following conservation actions, research and monitoring were patterned after recommendations in the 2003 Michigan Land Use Leadership Council Report (prepared for Governor Jennifer Granholm and the Michigan Legislature) that were designed to minimize negative effects of current and projected land-use patterns on Michigan's environment and economy.

Land & Water Protection

- Develop statewide land-use goals
- Protect identified large tracts and systems
- Provide assistance and incentives to private landowners to conserve larger habitat patches and corridors
- Consolidate ownership of high quality natural assets by eliminating in-holdings

Land, Water & Species Management

- Incorporate identified areas of high biological significance into local, regional and statewide

planning and management efforts

- Improve coordination between natural resource conservation organizations and transportation planners at local, regional and statewide scales
- Address thermal pollution issues to eliminate or minimize fragmentation
- Promote closure of non-essential resource management roads and seek other road closure opportunities that do not conflict with appropriate uses
- Incorporate identified linkage areas (between isolated patches of priority landscape features) into local, regional and statewide planning and management efforts

Law & Policy

- Initiate local, regional and statewide planning efforts or regulations that encourage retention of larger landscape blocks and promote establishment of corridors between landscape fragments
- Improve collection, analysis and access of data used for local, regional and statewide land-use and transportation planning
- Enhance ecosystem planning efforts by coordinating management of adjacent public and private lands
- Minimize new dam construction, including lake-level control structures, and promote removal of old dams that have exceeded their useful life
- Incorporate passage facilities at dams to increase movement of aquatic organisms
- Incorporate best management practices in construction, repair and replacement of stream crossings
- Promote policies and requirements for drainage and channel modification practices that ensure stream form, function, continuity and aquatic organism passage are maintained
- Implement requirements of the Biological Diversity Act, Part 355 of the Natural Resources and Environmental Protection Act (Act 451, P.A. 1994), including interdepartmental coordination requirements
- Provide example and model ordinances/regulations for local, regional and statewide planning efforts

Education & Awareness

- Educate the public, land-use planners, transportation planners, planning commissioners and local government officials about the consequences of habitat fragmentation
- Improve accessibility of information to local, regional and statewide land-use and transportation planners
- Initiate and support programs that identify the importance of the natural environment and how it contributes to economic prosperity and the quality of life of all citizens
- Provide training and education in the means and methods of managing land-use change, transportation systems and community development at multiple scales
- Provide information to private landowners on opportunities to support land conservation, including management, easements, land donations and local or State land conservancy purchase
- Develop initiatives that promote urban green space and other activities to encourage repopulation of urban areas and reduce population out migration
- Initiate and support programs that explain the role and value of protecting particular landscapes (e.g., wetlands protection, natural river designation, critical dune protection), as well as the role of other local, regional and statewide environmental land-use programs, in protecting and

enhancing natural environments

Research, Surveys & Monitoring

- Develop science-based land-use goals
- Identify large tracts and systems to target for protection
- Identify areas of high biological significance
- Identify lands that serve as important linkages between isolated patches of priority landscape features
- Test the effectiveness of local, regional and statewide planning efforts in retention of larger landscape blocks and corridors
- Test the assumption that remnant natural landscape features are widely dispersed and becoming more fragmented, resulting in a loss of species diversity
- Develop and test techniques for passage of aquatic organisms at dams
- Identify practices that fragment stream systems and develop best management practices and policies to prevent and reverse fragmentation
- Conduct research to determine whether linear landscape features act as corridors for native species, reducing negative effects of fragmentation
- Conduct research to determine whether mosaics of similar features (e.g., prairie, hayland, old field) have the same wildlife value as similarly sized patches of a single feature

Priority Threats: Habitat Conversion - Wetland Modifications

Wetlands are an interface between terrestrial and aquatic systems and have been identified as one of the most diverse and productive systems on earth, with average annual production comparable to that of tropical forests. They are distinguished by their unique soils, water-tolerant plants, and hydrologic regimes. These components differ dramatically between various types of wetlands; consequently, wetlands support many different assemblages of plants, fish, insects, birds and other wildlife. Additionally, wetlands provide a wide range of direct benefits to Michigan's citizens and visitors, including recreational opportunities, flood and storm water storage, groundwater protection and recharge, erosion control, and water quality protection by filtering sediment and removing nutrients (Cwikiel 2003). These functions are extremely difficult to restore or artificially replicate, which makes it critical to expend considerable efforts to minimize losses of wetland systems. Estimates of the monetary value of wetlands, including services such as water regulation, nutrient cycling, and recreation, are as high as $598.30 per acre per year (Costanza et al. 1997). See the Ecological Overview text in the State Overview chapter for more information about the extent of wetlands that have been lost in Michigan and sources of wetland modification.

Wetlands are vital for a variety of Michigan species: they provide important breeding, spawning and nursery habitat for many fish species; nearly all of Michigan's amphibians are dependent on wetlands, particularly for breeding; they provide resting sites for migrating waterfowl and nesting or foraging sites for a variety of landbirds, waterbirds and waterfowl; and they are preferred by mammals such as muskrats, otter and beaver. Although wetlands make up only 3.5% of the United States' land area, more than one-third of threatened and endangered species are dependent on wetlands to meet their habitat needs (Mitsch and Gosselink 1993). Federally threatened or endangered animals that are wetland obligates in Michigan include Mitchell's satyr butterfly, Hine's emerald dragonfly and copperbelly water snake. Several federally threatened or endangered plants in Michigan are also wetland dependent, including the eastern prairie fringed orchid, Michigan monkey flower, Hall's bulrush and Houghton's goldenrod.

Effects of wetland loss extend well beyond the conspicuous loss of acreage. As wetlands are lost from

a watershed, storage capacity is lost and downstream streamflows experience more severe flooding during spring and drought during late summer and early fall. More intense flooding increases soil erosion and sediment loads (see Pollution: Altered sediment loads).

Excess nutrients that accumulate when a wetland's ability to filter nutrients and contaminants is compromised can cause undesirable increases in algae and aquatic plant growth. In turn, increased respiration by plants reduces dissolved oxygen levels, potentially killing aquatic organisms. In an attempt to mimic these important functions, many communities have constructed artificial wetlands and have incorporated them into their waste treatment systems.

Michigan's 3,200 miles of Great Lakes shoreline have experienced fluctuating water levels since first measurements were taken in the 1860s (Hoagman 1998). Due to recent decreases in water levels, Michigan has experienced an increase in the amount of coastal wetlands as new wetland vegetation has grown where the lake bottom has been exposed. Recent legislation has allowed certain beach maintenance and grooming activities (such as leveling of sand, grooming, mowing, path construction) to occur without an MDEQ permit, if done between the ordinary high water mark and the current water edge (MDEQ 2003a). However, removal of this vegetation may further threaten coastal wetlands and must be monitored.

Conservation Needs to Address Wetland Modification Threats:

Land & Water Protection

- Increase regulatory protection for small, isolated wetlands

Land, Water & Species Management

- Explore development alternatives that avoid affecting wetlands, including selection of alternative project sites
- Consider all feasible and prudent efforts to avoid wetland alteration before using wetland mitigation
- Ensure that mitigation occurs on-site or contiguous to the remaining wetland
- Develop recommended strategies and designs that have the best potential to create functioning wetlands in mitigation projects
- Develop wetland loss mitigation strategies that ensure retention of the existing variety of wetland types
- Implement best management practices that protect wetlands
- Implement wetland restoration on private lands
- Maintain or enhance processes that support wetlands in a landscape, including establishing buffer zones
- Preserve cross drainage at road and trail crossings in wetlands
- Maintain the existing diversity of wetland resource types across a landscape

Law & Policy

- Strengthen current regulations and enforcement to encourage no net loss of wetland resources and reduce the rate of loss of natural wetlands
- Provide tax or other incentives for retention, restoration and development of wetlands on private lands

Education & Awareness

- Provide private landowners with information regarding available Federal funding sources for

restoration of wetlands, including the Wetland Restoration Program, Landowner Incentive Program and Wildlife Habitat Incentive Program

- Encourage use of best management practices to protect wetlands

Research, Surveys & Monitoring

- Develop a common classification system to describe wetlands and ensure that all representative wetland types present across a landscape are identified and maintained
- Complete a statewide wetland inventory
- Conduct research to better understand the functions of wetland features, especially bogs and fens
- Conduct basic research on remediation and water recharge
- Develop and test best management practices to protect wetlands
- Conduct research to develop guidelines for wetland buffer zones and connectivity needs
- Identify wetlands not currently regulated and determine their importance to maintaining wildlife diversity
- Conduct research to develop and test strategies and designs for functional wetlands in mitigation projects
- Monitor wetland creations and restorations to ensure they provide the anticipated wetland benefits
- Conduct research to determine whether there are differences in wildlife value between: natural and human-made wetlands; intensively managed and passively managed wetlands; and beaver-created wetlands and other wetlands

Priority Threats: Habitat Conversion - Dredging

Dredging involves removal of accumulated bottom sediments in waterways to maintain adequate depth for navigation or to remove environmental contaminants. In the Great Lakes, navigational dredging may be required due to wind and wave action, which deposits sandy sediments in harbor mouths. In other instances, navigational dredging is conducted in response to soil erosion resulting from agriculture and development (Great Lakes Commission 1999). Although not as common as navigational dredging, environmental dredging is conducted to reduce the threat of contaminated sediments to ecological and recreational functions.

The need for sediment removal must be balanced against the critical need to protect the aquatic resources of Michigan's waters. Direct effects of dredging to the aquatic environment include destruction of spawning habitat, mortality of aquatic organisms, potential release of contaminated sediments, and destruction of near-shore habitat. Furthermore, dredging can re-suspend sediment, disrupt nesting birds, and result in the entrainment of aquatic organisms by hydraulic dredges (Great Lakes Commission 1999).

Conservation Needs to Address Dredging Threats:

Land, Water & Species Management

- Minimize dredging activity to the extent necessary to retain current navigation uses
- Develop and adhere to standards for timing of dredging activities to minimize adverse effects to spawning and migrating Great Lakes fish and nesting birds
- Discourage open water disposal of dredged materials
- Avoid freshwater mussel beds during dredging activities, or, if unavoidable, relocate beds to a suitable location

Law & Policy

- Require best management practices to limit escape of sediment (e.g., specialized dredge equipment and techniques)

Education & Awareness

- Encourage soil conservation practices such as vegetation cover, conservation tillage, and educational activities to reduce soil erosion and, therefore, the amount of dredging necessary over the long term
- Protect and promote naturally vegetated riparian corridors, thus reducing the need for rapid drainage

Capacity Building

- Provide financial incentives to private landowners to encourage soil conservation practices and conservation of naturally vegetated riparian corridors

Research, Surveys & Monitoring

- Continue to conduct research to determine timing and habitats used during spawning and migration for Great Lakes fish species to assist in minimizing adverse effects of dredging activities
- Conduct surveys to identify freshwater mussel beds that should be avoided during dredging activities
- Monitor freshwater mussel beds that have been relocated due to dredging activity to determine success of these mitigation efforts
- Develop and test best management practices to limit sediment escape during dredging

Priority Threats: Habitat Conversion - Channelization

Channelization is the alteration of streams and rivers usually by deepening and straightening an existing stream channel or creating a new channel to facilitate movement of water (Armantrout 1998) off land and roads, above and beyond the natural capacity. This includes removal of woody structure, as well as the artificial containment of rivers and streams to restrict the natural movement of the channel. While effective locally in removing water quickly, constructed channels can lead to increased water velocities and flooding downstream. A constructed channel also results in removal of streamside vegetation, disturbance of the natural stream bottom, increased sediment and thermal loading, and additional water quality degradation. The result of these activities is loss of both terrestrial and aquatic habitat and a corresponding loss of species diversity.

The traditional drainage channel design of a trapezoidal cross-section has proven to be inefficient because of its tendency to aggrade (fill in) and increase sedimentation (Schwab et al. 1993). As a result, an improperly designed drainage channel requires repeated maintenance to retain function. Drain construction should incorporate natural channel processes (Rosgen 1996) by allowing streams to efficiently manage sediment and flow and by integrating dedicated areas for water storage, such as created wetlands or ponds.

Conservation Needs to Address Channelization Threats:

Land, Water & Species Management

- Review alternatives prior to the construction of new drains
- Incorporate natural stream channel stability in engineered drainage channels, mimicking natural channel dimension, pattern and profile

- Preserve natural stream structure and function to promote healthy aquatic and terrestrial environments
- Use existing wetland areas near natural drainage courses to provide flood control

Law & Policy

- Follow existing best management practices for channelization
- Provide opportunities for local planning authorities to influence drain code decisions and activities

Research, Surveys & Monitoring

- Conduct research to identify alternatives to current drainage practices
- Test engineered drainage channel designs for their ability to maintain ecological function

Priority Threats: Habitat Conversion - Riparian Modifications

Natural riparian areas provide extremely valuable wildlife habitat, as well as important water quality benefits such as nutrient uptake, bank stabilization, and erosion control (Karr and Schlosser 1978, Gregory et al. 1991, Osborne and Kovacic 1993). Natural riparian areas help protect fish spawning beds and instream habitat, protect water quality, and moderate temperature changes, all of which helps maintain productive, self-sustaining aquatic communities (Gregory et al. 1991). Riparian areas also provide critical habitat for many wildlife species and are important corridors for wildlife movement (Goforth et al. 2002).

Land-use adjacent to streams and lakes has accelerated in recent decades, particularly in association with residential development, including construction of docks and boat wells. Many areas are subject to indiscriminant removal of riparian vegetation, construction of seawalls, and installation of riprap or sand in place of native vegetation. In many cases, vegetative growth is subsequently prevented and, where it does occur, is often limited in species diversity. Historically, many streams were cleared of large woody structure to facilitate recreational and commercial navigation and enhance flow. These changes have significantly degraded riparian ecosystems (TNC 1999).

Conservation Needs to Address Riparian Modification Threats:

Land, Water & Species Management

- Review permit applications that include modification of riparian zones and include recommendations to preserve and enhance riparian areas
- Exclude stream crossings and riparian corridors when practical during planning of road, trail, and pipeline systems
- Use the best available science, including best management practices, to protect riparian resources

Law & Policy

- Implement zoning regulation and develop information that encourages retention and enhancement of natural riparian vegetation

Education & Awareness

- Develop information and educational materials that identify the importance of riparian zones to the proper functioning of aquatic systems
- Promote riverine recreation to create economic incentives for riparian protection and awareness of riverine/riparian values

- Promote participation in watershed groups

Capacity Building

- Provide financial incentives to private landowners to restore, create and conserve riparian areas

Research, Surveys & Monitoring

- Develop and test best management practices to protect riparian resources
- Assess effects of storm water influx on riparian systems
- Continue research to clarify the importance of riparian zones to the proper functioning of aquatic systems
- Conduct research to determine the long-term success of efforts to provide financial incentives to private landowners for restoration, creation and conservation of riparian areas
- Develop restoration techniques for areas that are disconnected from rivers

Priority Threats: Habitat Conversion - Dams

Adverse effects of dams on river and stream ecosystems have been well documented (Petts 1980, Cushman 1985, Bain et al. 1988, Ward and Stanford 1989, Benke 1990, Doppelt et al. 1993, Ligon et al. 1995, Shuman 1995). For example, water quality may decline in impounded streams when excessive nutrients, sediments and aquatic plants accumulate in an impoundment. Flow patterns reflecting normal high and low water conditions may also be fundamentally altered, affecting stream channel configuration, wildlife habitat, and many other physical and biological processes. Dams also limit normal movement of aquatic organisms and organic material.

Additionally, improper maintenance can increase the risk of failure during flood events, resulting in fish kills, habitat destruction, and release of large amounts of sediment that may contain toxic contaminants. The MDEQ has inventoried 2,503 dams across the State, ranging in size and function from large actively generating hydropower dams to small earthen dams. Approximately 70% of Michigan's inventoried dams are small, privately owned, non-power-generating dams. Of the inventoried dams, more than 50% are more than 50 years old, or past the average life expectancy of a dam (American Rivers et al. 1999). As evidenced by dam safety reports, many older dams are deteriorating due to age, erosion, poor maintenance, flood damage, ice damage and poor design. Dams such as these are at significant risk of failure, particularly during high flow events. Dams that no longer serve any useful purpose should be removed to avoid catastrophic failure, eliminate dam maintenance and liability costs, and restore natural river functions. Adverse effects of dams on the health and viability of rivers and streams can be reversed with dam removal.

Conservation Needs to Address Dam Threats:

Land, Water & Species Management

- Review any new dam recommendations for societal benefits and ecological effects
- Implement dam operation recommendations that mimic natural riverine conditions and temperatures, protect and maintain desired aquatic communities, protect recreational uses, and, where possible, rehabilitate natural resources degraded by the dam
- Schedule impoundment drawdowns to minimize adverse effects to wildlife species that use impoundment areas

Law & Policy

- Seek modification or voluntary removal of dams when natural resources have been affected, but can be mitigated through modification

- Seek removal of dams where they serve little or no purpose and there is a reasonable expectation that removal will benefit the environment and aquatic resources

Research, Surveys & Monitoring

- Continue to develop and test dam operations that best mimic natural riverine conditions and temperatures, protect and maintain desired aquatic communities, and protect recreational uses
- Conduct research on the effects of timing and extent of impoundment drawdowns to help minimize adverse effects to wildlife species that use impoundment areas
- Track dam location and function for use in providing recommendations for dam retention or removal

Priority Threats: Non-Consumptive Biological Resource Use - Non-Consumptive Recreation

The Legislature, agencies, and organizations provide laws, rules, and guidelines for recreationists, but , it is essential that recreationists also undertake voluntary stewardship activities. To help conserve wildlife habitat, they must recognize that their activities affect landscape features and species and act in a manner that minimizes or eliminates adverse effects. See the Social & Economic Overview text in the State Overview chapter above for more information about non-consumptive recreation and observed trends. The following test discusses issues of concern that can occur as a consequence of non-consumptive recreational activities.

Soil Disturbance

Recreational activity can significantly disturb soils. The degree of disturbance depends on a variety of factors, such as soil type, slope, and manner and intensity of recreational activity. Sandy or wet organic soils can be negatively affected by a one-time activity, whereas heavy clay or gravel sites can withstand heavier activity. Given the same soil type, the effects of a single pass of an ORV can also be caused by hikers over an extended period.

Soil erosion is the most commonly identified threat resulting from heavy recreational use. Erosion is most pronounced when soils are particularly susceptible to damage or erosion, or when recreation intensity is high. Dunes are particularly vulnerable because of their sandy soils and low organic content. The vegetation that holds dunes in place is easily damaged. Recognizing potential for damage, many public areas have constructed boardwalks and other trail improvements. Particularly sensitive areas include steep slopes, vegetated rocky areas, wetlands and riparian areas. On steep slopes, eroded areas often channel water from rain storms and cause increased erosion, which may damage large areas of vegetation. As soil from affected sites begins to erode, it can flow into nearby waterways, increasing sedimentation (see Pollution: Altered Sediment Loads below).

Recreational activities can literally squeeze air out of spaces that typically surround soil particles by compacting soil, resulting in reduced water retention within the soil, reduced water and nutrient uptake by plants, reduced availability of oxygen and other gases used in respiration, and prevention of plant root spreading. Exposure of plant roots as soil is compacted or eroded around them, and subsequent damage, can make trees more susceptible to wind by affecting their anchoring ability, by impeding nutrient flow through the roots, and by providing a conduit for insects or disease. Compacted soils can also deter tunneling of fossorial animals. Each of these effects can lengthen the normal recovery of a site by keeping it open and vulnerable to additional damage.

Introduction and Spread of Invasive Plants

Recreational vehicles and even hiking boots can transport soil containing invasive plant seeds to unaffected sites. It is suspected that some purple loosestrife stands were established in this manner (M. Penskar, personal communication). Seeds can also be transferred when attached to clothing or when ingested by horses and transported in their manure. Eurasian milfoil, zebra mussels and many

other invasive species can be transferred to unaffected waters by boats and in bait buckets. Veligers and young zebra mussels can survive temporarily out of water. Eurasian milfoil can reestablish itself by vegetative propagation of plant stems. Non-consumptive activities that remove or trample native vegetation can further promote the spread of invasive species by reducing competition and providing opportunities for new establishments.

Direct Threats to Wildlife

Some reptiles use exposed trails for sunning, making them more susceptible to direct mortality from recreational traffic. Continuous use of avian nesting areas or intentional harassment by outdoor recreationists can cause indirect mortality through brood abandonment. For example, beach use on Great Lakes shorelines by ORVs and humans has frequently caused adult Piping Plovers to abandon nests and broods. On inland lakes, nest and brood abandonment by Common Loons has been observed in response to heavy boating activity. As a preventative measure, the DNR commonly closes Piping Plover and Kirtland's Warbler nesting sites to humans to reduce the potential for nest site disturbance. ORV traffic through streams can directly destroy fish nesting areas or damage nests downstream through increased sedimentation.

Winter is a critical time for many species; energy is directed at a few essential activities. Repeated disturbance by non-consumptive recreational activities can cause organisms to expend reserved energy and reduce their likelihood of successfully surviving through winter. Bats hibernating in caves are particularly vulnerable to repeated disturbance.

Conservation Needs to Address Non-Consumptive Recreation Threats:

Land, Water & Species Management

- Incorporate areas containing fragile/easily disturbed landscape features or species into planning and management activities to reduce recreational effects on these areas
- Develop restoration plans for areas with significantly affected resources due to non-consumptive recreation
- Develop management strategies and decision models to implement practices that reduce or eliminate non-consumptive activities that conflict with species needs
- Construct boardwalks and other trail improvements to prevent damage in highly sensitive areas
- Create additional recreational opportunities in less sensitive environments to disperse effects

Law & Policy

- Increase enforcement of existing regulations

Education & Awareness

- Provide information on the potential effects of recreational vehicle use (including personal watercraft) on landscape features and species to organized outdoor users and outdoor supplies retailers
- Promote stewardship of natural areas

Research, Surveys & Monitoring

- Conduct research to determine whether recreational watercraft affect wildlife use of landscape features
- Quantify the vulnerability of different landscape features to different forms of recreation
- Identify areas of ecological significance and determine whether they contain fragile/easily disturbed landscape features or species

- Identify areas with significantly affected resources
- Conduct research to determine the long-term effectiveness of creating additional recreational opportunities in less sensitive environments to disperse effects

Priority Threats: Pollution - Altered Sediment Loads

Accelerated erosion from human sources has been described as the most significant cause of pollution in the Midwest region (Waters 1995). Poor soil erosion control methods during construction and other earth disturbing activities, operation of hydropower facilities, poorly designed and maintained road crossings in stream and wetland systems, and recreational activities on stream banks all lead to high sediment loads in aquatic systems. When sediments overwhelm a system, the geomorphology (pattern, dimension and profile) may be disrupted, leading to undesirable changes and further instability of the system (Rosgen 1996).

In Michigan, instream sediment tends to be sandy in nature. Excess sand bedload can cover and bury more productive gravel and cobble substrates. Productivity declines significantly as sand fills interstitial spaces in the coarser substrates, reducing habitat for macroinvertebrates. Sediment can also smother fish eggs or fry deposited on the stream bottom. Increases in trout production have been documented following removal of excess instream sand bedload (Alexander and Hansen 1982).

Excess sediment in riverine systems can cause a stream bed to aggrade, resulting in accelerated bank erosion and streams that are shallow and overly wide. In coldwater systems, these changes can lead to increased temperatures that negatively affect temperature-sensitive aquatic species. Once stream morphology becomes unstable, excess sediment load tends to convert meandering streams with pool–riffle complexes into long homogeneous runs. This subsequent loss of stream bed diversity can adversely affect many populations of aquatic organisms (Hynes 1970).

Dams often have an opposite effect on stream sediments. Water released from dams is free of sediment, because the impoundment has captured the upstream sediment load. These 'sediment-starved' conditions increase stream power (the ability of the system to move sediment, based on flow, sediment load and gradient). This increase accelerates erosion immediately downstream of the dam and causes excess sediments to accumulate at the first area of slow water further downstream, leading to stream aggradation. In sections immediately below a dam, excessive down-cutting can cause stream armoring due to decreased sediment load, resulting in reduced habitat.

Conservation Needs to Address Altered Sediment Load Threats:

Land, Water & Species Management

- Implement and enforce soil erosion prevention measures at soil disturbance locations
- Use best management practices for design and maintenance of road stream crossings, installing clear span bridges when possible
- Require run-of-river operations of dams to retain natural hydrography and prevent excess erosion downstream

Law & Policy

- Establish zoning ordinances which require native vegetative buffer zones along all water courses

Education & Awareness

- Educate recreationists about activities on stream banks that can lead to an imbalance of sediments in the aquatic system

Capacity Building

- Provide financial incentives to private landowners to encourage soil conservation practices

Research, Surveys & Monitoring

- Continue to conduct research to determine the effects of runoff from agricultural landscape features on lowland and aquatic features
- Inventory and track erosion sites to prioritize remediation activities
- Monitor soil erosion prevention measures at soil disturbance locations
- Conduct research to determine long-term success of efforts to provide financial incentives to private landowners to encourage soil conservation practices
- Develop and test best management practices for design and maintenance of road stream crossings to reduce erosion

Priority Threats: Biological Interactions – Disease and Pathogens

With the rapid changes in the speed of transport of live organisms from all parts of the world, new and unseen pathogens (bacteria, viruses, fungi and parasites) and disease (together, epizootics) will be a major threat to Michigan's natural resources. Wildlife may be particularly susceptible to disease and infection when it is stressed by other factors, such as habitat loss and contamination (Kiesecker et al. 2004). Substantial resources will be required to monitor the status of, understand the ecology of, and develop control or containment strategies for epizootics when they threaten wildlife and natural communities. See the Ecological Overview text within the State Overview chapter above for background and trends associated with pathogens and disease.

Disease and Pathogens in Aquatic Systems

Up to five years ago, little was known about the distribution and occurrence of pathogens in aquatic wildlife in Michigan waters. This lack of information greatly impaired the ability of resource managers to understand and respond to epizootics. Initial pathogen surveys, started in the mid 1990s, gave an initital glimpse into the range of pathogens occurring in Michigan. In 2004, these surveys were first integrated with other intensive waterbody surveys. However, these surveys do not fully sample all elements of aquatic communities, and additional resources are needed for a complete inventory. When coupled with GIS databases containing both past and present pathogens, these surveys will be a powerful tool to help understand this component of aquatic ecosystems.

Disease outbreaks, also known as epizootic events, in wild fish populations as well as in hatchery production are of great concern in the Great Lakes region. These events have caused large-scale mortality in fish populations. Currently, BKD in salmon and whitefish, whirling disease in trout, heterosporis in yellow perch, piscirickettsia in muskellunge, and LMBV are diseases of concern for wild fish populations. In addition, Furunculosis is re-emerging as a disease in Pacific salmon at this time. Similar epizootic events for other aquatic organisms probably occur throughout the aquatic ecosystem, but little is known about diseases other than those of fish. Even for fish, current knowledge about diseases, beyond those of trout and salmon, is limited.

Disease and Pathogens in Terrestrial Systems

Although large-scale disease events directly affecting Michigan's terrestrial wildlife have been rare (bovine tuberculosis, West Nile Virus), proactive efforts and monitoring to identify new pathogen and disease threats that may affect wildlife or the plants on which they depend is required. Past conservation efforts to address terrestrial wildlife diseases have concentrated on game species; knowledge of pathogens and disease in nongame terrestrial wildlife is more limited. Known direct threats posed to terrestrial wildlife by disease and pathogens include West Nile Virus, Duck Virus Enteritis (duck plague), Leucocytozoonosis, and cerebrospinal nematodiasis caused by Brainworm

(*Parelaphostrongylus tenuis*). Additionally, amphibians are experiencing an ongoing pandemic of a newly discovered fungal disease, chytridiomycosis, which is adding to the overall amphibian crisis worldwide (Kiesecker et al. 2004).

Additionally, disease and pathogens that affect plants will have a negative effect on wildlife species that have obligate relationships with the plants or that depend on the structure the plants provide within landscape features and ecosystems. Beech bark disease threatens Michigan's 7.2 million acres of Maple-Beech-Birch type forests. Ironically, the spread of beech bark disease has been slower in areas with more highly fragmented forest systems. Additionally, incidence of oak wilt continues to increase in Michigan (DNR 2004c).

Conservation Needs to Address Disease and Pathogen Threats:

Land, Water & Species Management

- Implement newly developed diagnostic tools that rapidly determine the pathogen status of aquatic organisms in a non-lethal manner
- Implement newly developed methods to measure fish and other aquatic organism health and quality to increase effectiveness of pathogen surveys for wild and hatchery organisms

Law & Policy

- Require that all fish stocked in Michigan waters are certified free of disease as specified in the Model Fish Health Program developed by the Great Lakes Fish Health Committee
- Implement all possible and practical biosecurity measures at all private and State hatcheries, other wildlife facilities, and nurseries, in conjunction with the Michigan Department of Agriculture
- Develop and implement pathogen and disease survey systems for private aquaculture, the bait industry, the shipping industry, recreational boaters, nurseries and other private/captive wildlife industries
- Develop and implement importation inspection and certification requirements for the aquaculture industry, bait industry, nursery industry, biological control industry (e.g., predatory wasps and lady bugs) and other captive wildlife industries, in conjunction with the Michigan Department of Agriculture
- Develop and implement strategies at all hatcheries, private and State, to achieve A-1 or A-2 status in conjunction with the Michigan Department of Agriculture

Research, Surveys & Monitoring

- Conduct research on containment strategies for pathogens which pose significant threats to Michigan's wildlife species or the plants on which they depend
- Develop new spatial databases for pathogen survey data that include all new and historical pathogen information
- Develop treatments for diseases which threaten forest health (e.g., oak wilt, ash decline, beech bark disease)
- Develop and implement a pathogen and disease monitoring system for all types of wildlife and plants
- Develop and test new diagnostic tools that rapidly and non-lethally determine the pathogen status of aquatic organisms
- Develop and test new methods to measure fish and other aquatic organism health and quality to increase effectiveness of pathogen surveys for wild and hatchery organisms
- Conduct research to investigate and produce decision support models for understanding, controlling, and eliminating or containing epizootic events

Priority Threats: Modification of Natural Processes - Altered Hydrologic Regimes

Stream Hydrologic Regimes

Streamflow patterns are a major feature of stream ecosystems and are critical in shaping aquatic communities (Resh et al. 1988, Poff and Ward, 1989, Poff et al. 1997). In Michigan, considerable hydrologic diversity exists across the State, with many rivers receiving considerable groundwater contributions (Richards 1990, Wiley et al. 1997, Zorn et al. 1998). The structure and function of riverine systems are based on five components affected by flow: hydrology, geomorphology, biology, water quality and connectivity. The objective of maintaining an adequate flow should be to sustain, rehabilitate or restore ecosystem processes through seasonal and annual regimes. Stream flow regimes must address instream and out-of-stream needs and integrate biotic and abiotic processes (Annear et al. 2004). As a consequence of changes in streamflow patterns, many rivers no longer support native species or sustain healthy ecosystems that can provide important goods and services (Poff et al. 1997).

When altered, streamflows exhibit changes in magnitude, timing, duration, frequency, and rate of change (Poff et al. 1997). Loss of water retention capacity within a watershed through land clearing, increased impervious surfaces (e.g., urban development), wetland drainage, and stream channelization leads to increased magnitude and frequency of high flows, more extreme low flows, and generally flashier conditions (Karr and Schlosser 1978, Menzel 1983, Poff et al. 1997). Groundwater pumping can also result in more extreme low flows and can generally destabilize streamflow (Poff 1997, Wiley et al. 1997). Dam operation for flood control results in reduced magnitude and frequency of high flows (Poff 1997), which results in the loss of floodplain connectivity and habitat diversity (Copp 1989, Sparks 1995). Dam operation for hydropower generation can result in large daily changes in water releases (hydropeaking), which can have severe effects on aquatic ecosystems and organisms (Cushman 1985, Gislason 1985, Bovee et al. 1994, Freeman et al. 2001).

Lake Hydrologic Regimes

Water levels in many lakes throughout Michigan fluctuate naturally as a result of changes in precipitation, snow melt, groundwater inflow, and evaporation. In some instances, lakeshore property owners prefer a fixed lake level to ensure recreational access or to protect property vulnerable to water level changes. Michigan currently has more than 300 lakes with regulated lake levels. Lake levels are maintained through the use of either lake-level control structures or augmentation wells.

Natural fluctuation of water levels in lakes and streams contributes significantly to ecosystem health and integrity (Wilcox and Meeker 1992, Poff et al. 1997). Lakeshore vegetation, beaches, shorelines, and associated plant and animal assemblages were established through cycles of high and low water levels and these attributes may be lost when natural water level fluctuation is prevented. Lake-level control constricts the margin or transition zone between water and land that is often rich in aquatic species diversity, provides high quality habitat for fish productivity, reptiles, amphibians and birds, and provides a buffer that protects the shoreline from extensive erosion during wind and wave events.

Operation of augmentation wells may lower regional groundwater tables, negatively affecting nearby wells and water bodies (streams, lakes, wetlands and springs) through reduction or complete loss of water supply or deteriorated water quality (Alley et al. 1999, Grannemann et al. 2000, MDEQ 2003c). A reduced flow or change in water chemistry can result in a loss of wildlife habitat (Lindorff et al. 1997). Environmental research on effects of groundwater pumping is limited; however, several case studies show effects such as diminished wetland area and streamflow and impaired water quality (Lindorff et al. 1997, Born et al. 2000).

Groundwater Hydrology in Terrestrial Systems

Hydrologic processes are very critical to the vegetative structure of several wetland and marginally upland natural communities (e.g., lakeplain prairie, prairie fen, floodplain forest, relict conifer swamp)

and the wildlife that depends on them (Albert and Kost 1998, Spieles et al. 1999, Kost 2001, Tepley et al. 2004). These communities tend to be disturbance dependent and experience seasonal/periodic flooding due to low topography and relatively high water tables. When groundwater flow is altered by agricultural and residential drains and wells, however, the underlying groundwater table is often lowered because of lack of recharge due to drained surface water and groundwater extraction. Prairie fens and relict conifer swamps also depend on a high water table to supply necessary permeation of calcareous groundwater (Spieles et al. 1999, Kost 2001).

Trees growing in anaerobic conditions associated with a high water table and muck and peat soils tend to be shallowly rooted and are therefore, especially prone to windthrow. Light gaps created by windthrow help to regenerate dominant tree species and maintain understory layers in forested systems. In addition, the coarse woody debris that results from windthrow also adds to the complex structures of these communities (Kost 2001). Lowered water tables in such systems can disrupt these natural processes.

Avoiding surface water inflows from drainage ditches and agricultural fields and protecting groundwater recharge areas by maintaining native vegetation types in the uplands around these communities are essential for their conservation. Healthy woodlands, savannas and prairies in uplands adjacent to wetlands allow infiltration of precipitation into groundwater, whereas lawns, agricultural fields, and impervious surfaces contribute warm, nutrient and sediment-laden surface runoff (Spieles et al. 1999).

Conservation Needs to Address Altered Hydrologic Regime Threats:

Land & Water Protection

- Protect springs and seeps from ground-disturbing activities

Land, Water & Species Management

- Restore areas where hydrologic regimes are significantly altered
- Protect areas where ecological conditions are particularly susceptible to hydrologic changes
- Protect the local hydrology in areas with high quality groundwater-dependent communities
- Implement best management practices that restore natural watershed processes while supporting human needs
- Require use of retention or detention basins in urban areas to reduce flashiness of stream flows
- Incorporate aquatic species passage into existing lake-level control structures
- Follow the recommendations of the International Joint Commission (1999) to "apply the precautionary principle with respect to removals and consumptive use of groundwater in the (Great Lakes) Basin"
- Create buffer strips around wells, lakes, streams, creeks and rivers

Law & Policy

- Consider downstream streamflow alterations during land-use planning and development of zoning regulations
- Discourage construction of lake-level controls and establishment of legal lake-levels
- Develop land-use recommendations to prevent hydrologic modifications and share these with local planning agencies
- Encourage green space development to promote water infiltration and on-site water retention

Research, Surveys & Monitoring

- Identify areas where hydrologic regimes are significantly altered

- Identify areas where ecological conditions are particularly susceptible to hydrologic changes
- Identify areas with high quality groundwater-dependent communities
- Develop and test best management practices that restore natural watershed processes while supporting human needs
- Develop and test best management practices, with respect to existing lake-level controls, that minimize disruption to annual or seasonal hydrological regimes, protect and maintain natural aquatic communities, protect downstream aquatic habitat, and maintain natural water temperatures
- Document or model historical hydrologic disturbance regimes and assess their potential for restoration
- Monitor streamflows for changes in natural range of variation
- Conduct research on effects of groundwater withdrawals
- Conduct research to identify the nature, extent and source of streamflow alterations
- Study groundwater recharge in landscape features that have the potential for high infiltration
- Conduct research to determine how changes in hydrologic regimes affect wildlife use of wetlands
- Conduct research to examine imperviousness in watersheds and develop tools, guidelines and methodologies to decrease it
- Develop hydrologic models and monitor hydrologic (e.g., groundwater, streamflow, dam operation) dynamics

Priority Threats: Modification of Natural Processes – Altered Fire Regime

Fires can alter and benefit landscapes in several ways: stand regeneration, successional maintenance, creation of landscape patterns, and increased primary and secondary plant productivity (Niemi and Probst 1990). The prairies of southern Michigan were dependent on fire as a periodic disturbance event that killed pioneering shrubs and trees and also promoted growth of forbs (dependent on timing of fire). Fires also maintained savannas and oak and jack pine barrens by killing shrubs and seedlings and subsequently providing an open understory, preferred by species such as eastern box turtle and Karner blue butterfly (Albert 1994).

Fire is an important mechanism for maintaining a mosaic of forest stands with varying age, size and shape characteristics (Haufler 1990). For instance, high intensity fires will kill large standing trees, providing standing woody debris for cavity-dependent wildlife, whereas less intense (cooler) fires will remove or suppress mid-level canopy structure and improve forb and grass stands, creating an open savanna-like structure. This open structure is critical for the regeneration and persistence of dry forest types dominated by shade-intolerant tree species, such as oaks.

When the natural fire regime has been greatly altered or suppressed due to human safety concerns, prescribed burning can be used as an effective management tool to mimic the role of wildfire. Shrublands can be invigorated and maintained with fire to benefit species such as Bluebird and Sharp-tailed Grouse. Burning old fields controls saplings and woody vegetation, and improves grasslands for use by nesting wildlife. Forest openings can be manipulated with burns to benefit more than 150 wildlife species. Upland nesting cover used by pheasants, waterfowl and songbirds will remain productive if periodically burned. Cattails and sedges are returned to vigor by an occasional burn. Lastly, fire will kill off less tolerant species such as maple and basswood, allowing oak to compete more successfully in a hardwood stand (Sargent and Carter 1999). Without fire, many of these species will be affected by loss of habitat.

Conservation Needs to Address Altered Fire Regime Threats:

Land, Water & Species Management

- Develop opportunities for use of prescribed burns on private lands
- Identify opportunities where prescribed burns can be implemented to restore the natural fire regime of landscape features
- Implement best management practices for conducting prescribed burns
- Implement management actions (e.g., mechanical removal, herbicides, timber sales) that best mimic the effects of fire on those lands where fire management may be restricted

Law & Policy

- Develop and pass 'right to burn' legislation

Education & Awareness

- Increase public awareness and knowledge of the value of prescribed burning as a management tool
- Incorporate fire management into local land-use planning efforts in landscapes where fire is an important component

Research, Surveys & Monitoring

- Document or model historic disturbance patterns of fire and assess their potential for restoration
- Continue research on the effects of prescribed burns on ecosystem processes
- Develop and test best management practices for conducting prescribed burns, especially in landscape features which were historically dependent on this disturbance, but where burning is currently seldom used
- Test alternative methods for their ability to mimic the benefits of fire

Priority Threats: Education - Lack of Scientific Knowledge

Scientific literature reviews conducted to associate SGCN with threats and landscape features found that a lack of thorough life-history information posed a high threat to more than 25% of the SGCN. No life-history information was available for several species. For others, such as the federally endangered Hungerford's crawling water beetle, distribution and habitat information is available, but much basic life-history information is lacking and relative severity of threats to the species is unknown. Without a thorough understanding of the needs of wildlife species and their responses to changes in ecological processes (e.g., fire and natural flow regimes), it is impossible to plan and implement conservation actions to aid them and the landscapes they use.

Many taxonomic groups have historically received little attention from scientists, researchers and managers due to a lack of resources. These groups tend to include smaller or less charismatic species, but many of these organisms perform critical ecosystem functions (Franklin 1993). For some of these species (e.g., non-sport fish, amphibians and reptiles, mussels, some terrestrial insects, and many small mammals, including bats), basic natural-history information is available, but knowledge about trends in their populations, their responses to threats, specifics of their life cycles, or their relationships with the landscape is lacking. For other groups (e.g., aquatic insects, land and aquatic snails, grasshoppers, crayfish, beetles, moths), limited information is available for specific members, but is lacking for most. And finally, information is so limited for some taxonomic groups (freshwater sponges, jellyfish, shrimp, roundworms, flatworms, spiders, bees, wasps, ants, and many more), that their consideration during action plan development was not possible. Many of these species will benefit greatly from conservation of the full diversity of landscape features and may not require any specific

efforts, but others may require individual attention. Ideally, all species should be conserved to assure the long-term health and functioning of Michigan's ecosystems.

Important relationships between species and the landscapes they use continue to be discovered, expanding our knowledge base and ability to make informed conservation decisions. For example, even though birds are a relatively well-studied taxonomic group, recent investigations have revealed a relationship between shoreline cedar swamps on the northern Lake Huron shoreline, midge hatches, and timing of bird migrations; in this region, midge hatches provide an important energy source for birds, while the cedar lowlands, not typically used by these species, provide cover (Ewert and Hamas 1995).

Where species are known to use a particular landscape feature, the functional utility of that feature to the persistence of the species is sometimes in question, particularly for heavily human-influenced or intensively managed features. Landscape features can sometimes act as population sinks, or areas where mortality exceeds recruitment (Pulliam 1988, Brawn and Robinson 1996). Inappropriate management decisions can result from a lack of understanding of the relative wildlife value of many landscape features.

Many of the ways disturbance regimes and other ecological processes influence ecological communities and species remain inadequately understood (Pess et al. 2003). This lack of understanding makes it difficult to identify management goals and conservation actions. Information on historic conditions and natural ranges of variation, which are also useful in determining management goals, are often incomplete or inadequate. Further uncertainty comes from recognition that as many ecological systems are spatially diverse. They are maintained by different ecological processes and influenced by different threats across a region (Ghazoul 2001, Pess et al. 2003). They also have different species assemblages that result in different biological interactions across a region. Therefore, understanding a particular system in one part of the State does not necessarily provide complete knowledge of the same type of system in another part of the State.

Conservation Needs to Address Lack of Scientific Knowledge Threats:

Land, Water & Species Management

- Incorporate added knowledge into management decisions

Law & Policy

- Incorporate added knowledge into species protection
- Identify funding sources and individuals with expertise to expand the knowledge base for species that are not well studied

Research, Surveys & Monitoring

- Develop a comprehensive summary of significant knowledge gaps for SGCN, landscape features and ecological processes and prioritize research, survey and monitoring needs to fill the gaps
- Implement research and survey actions to collect needed data
- Coordinate collection, storage and distribution of existing and new species information
- Diversify management actions and monitor outcomes to develop best management practices
- Test rare or indicator species responses to management practices
- Use landscape feature-level research efforts as an opportunity to collect additional information on SGCN
- Conduct research to determine whether human-created landscape features act as population

sinks

- Conduct research to determine whether human-created features (e.g., rights-of-way) act as effective surrogates when natural landscape features are lacking
- Conduct research to determine whether regenerating forests fill the same wildlife needs as shrublands
- Conduct research to examine which characteristics of landscape features (e.g., vegetation composition, disturbance patterns) determine their value to wildlife
- Conduct research to examine how timing and extent of disturbance in agricultural landscape features affect their use by wildlife
- Conduct research to determine how abundance, distribution and species of mast crops affect wildlife diversity and abundance
- Conduct basic inventories to catalog associations between landscape features and the species that depend on them

Priority Threats: Education - Social Attitudes

Public attitudes and perception of landscape features, species and certain land-management practices affect the ability to initiate conservation actions (Witter 1990). Information distribution is an important element in obtaining public support for conservation actions (Peyton 1990). Awareness and knowledge are two building blocks in establishing citizens' attitudes, values and patterns of action (Barro & Manfredo 1991). Several threats identified in this document relate directly to social attitudes about landscape features, species and management practices. See the Social & Economic Overview text in the State Overview chapter above for more information about basic attitudes about natural resources and natural resources management in Michigan and changes over time.

When asked to evaluate the importance of preserving habitat for rare and endangered species, nearly 90% of respondents to surveys, conducted over a three-year period in Michigan, indicated they either 'strongly agree' or 'mildly agree.' Yet, when respondents ranked the importance of endangered insect protection, 23% indicated it was 'not at all important.' This percentage was three times higher than that for any other taxonomic group, including plants (Koval & Mertig 2002). These results demonstrate a disconnect in the public's mind about relationships between species it considers important (mammals, birds, fish, reptiles and amphibians) and other species, and the importance of those relationships to ecological functions and persistence of all wildlife.

This survey result also illustrates the public's tendency to label wildlife species or groups based on perceived values ranging from bad to good. This tendency led to a campaign involving lethal control of wolves and many other predators, which spanned more than 100 years. Although education efforts have helped to change sentiments towards predators, negative attitudes still persist and can restrict management options. Snakes, as a group, are viewed negatively, and, therefore, human encounters often result in death of individual snakes.

Attitudes that impede conservation actions are usually due to misinformation, lack of information or lack of awareness. Misinformation has the potential to produce significant negative attitudes. For instance, use of fire as a management tool is a controversial issue. For nearly half a century, campaigns by government agencies (e.g., Smokey the Bear) informed the public about the dangers of forest fires, with little mention of their benefits. Over the years, research has shown that fire is an essential part of many natural systems. Land managers now recognize prescribed burns as a valuable tool, yet the stigma of uncontrolled wildfires and earlier information campaigns remains. Fortunately, sound information on ecological benefits can frequently alleviate concerns relating to the use of fire in habitat management (Courtner et al. 1984, Nielson and Buchanan 1986).

In some instances, individuals may be aware of certain issues, but possess only a small amount of information. In these cases, individuals may develop attitudes by making inferences or using unrelated information to fill in gaps. For example, people tend to discount or downgrade the importance of landscape components for which they possess little knowledge. A major barrier to sustaining or restoring early-successional communities, such as shrubland, is the perception that they are uninteresting or unappealing (Askins 2001), and, therefore, not valuable.

The most difficult hurdle to overcome is a lack of awareness. In certain instances, members of the public may view themselves as having no connection to the issue or resource. For example, wetlands are often labeled as 'wastelands,' with no acknowledgment of the many valuable roles they play. A property owner may know of an area in his/her woodlot that floods annually, but unless the owner obtains an awareness of the importance of ephemeral wetlands in ecological processes and to wildlife diversity, he/she may not be motivated to conserve the site. Urban residents who do not participate in activities directly involving natural resources may be less likely to see a connection between themselves, Michigan's landscapes, and the wildlife that inhabit them. Reaching these individuals will be challenging.

By increasing awareness and knowledge of the ecology of the Great Lakes region, citizens can be advocates for strategies that support long-term sustainability and management of natural resources for future generations. In addition, a deeper awareness helps guide individual behavior so citizens become more effective stewards of their homes, communities and neighborhoods. Wildlife will benefit when the common mind-set in which 'the human domain' is separate from 'the natural domain' shifts to one in which humans and our actions, constructs and consequences are viewed in the context of a global domain.

Conservation Needs to Address Social Attitude Threats:

Land, Water & Species Management

- Develop management actions that reflect results of public opinion assessments of emerging wildlife issues to increase public support

Education & Awareness

- Develop and distribute scientifically accurate information to raise awareness of Michigan's landscape features and species
- Respond proactively to misinformation, whether in the media or within specific user groups
- Encourage contact between the public and resource professionals and provide information through interpretive trails, planned tours, and facilities
- Provide or encourage existing volunteer opportunities for stewardship involvement at both species and landscape levels
- Provide information on management techniques, their use, and importance in stewardship of landscape features
- Develop and implement a statewide environmental education program focused on biological diversity
- Promote public participation in stewardship activities to improve the connection with and understanding of natural systems and processes
- Develop partnerships between zoos, agencies and other NGOs to provide more information about native species, biodiversity, native habitats, and habitat and species management at zoos

Capacity Building

- Distribute information to private landowners to explain their role in stewardship of landscapes in

Michigan, with management options for implementation

- Provide opportunities for meaningful public input into management actions and options

Research, Surveys & Monitoring

- Monitor the success of various education and awareness programs, projects and techniques
- Conduct periodic public opinion assessments to identify emerging wildlife issues
- Determine how and why cultural activities have fostered the retention of remnant natural landscape features in some locations

Other Priority Issues

Some of the following six topics are not specifically threats; therefore, they were not included within the threats framework outlined in the Methods chapter, nor were they evaluated for their importance by natural resource professionals, as were the threats. Other topics were included in the threats framework, but did not meet the criteria as statewide priority threats. All are issues of importance to the conservation of wildlife species and the landscapes they use and were repeatedly identified as such at meetings and workshops and through discussions with species experts and scientific literature reviews. However, due to the scale at which they need to be discussed, these issues are not adequately addressed, if at all, in the landscape feature and SGCN summaries.

Other Priority Issues: Landscape Mosaics

The Landscape Features & Conservation Needs section discusses conservation actions, research and monitoring needed to address threats to individual landscape features within specific regions. However, conserving any one landscape feature alone is not going to lead to the conservation of many species. Landscape features are components of the various landscapes that occur throughout Michigan; that is, landscape features occur intermixed on the landscape, creating a pattern or 'mosaic' of different features used by wildlife in daily, annual, or life cycles. These mosaics result from a multitude of variables, including differences in soils, topography, microclimate and disturbance regimes (e.g., Great Lakes fluctuations, seasonal flooding, beaver activities, fire, windthrow).

This dynamic mosaic influences associated plant and animal communities (Bormann and Likens 1979, Albert 1995). Adding to this complexity in terrestrial systems are the various vegetative communities associated with many landscape features and the continuum of successional stages that may be expressed, depending primarily on how recently and how extensively any disturbance events have occurred. Conserving all aspects of this mixture is important to conserving the full complex of native wildlife species (Haufler 1990). Additionally, understanding the role of landscape mosaics in wildlife distribution, abundance, movements and threats is vital, because without this knowledge, conservation actions cannot be properly defined.

The 'dry hardwood forest' landscape feature may include areas with very different dominant vegetation and, therefore, different wildlife compositions. Areas of more recent disturbance, dominated by cherry, trembling aspen and large-tooth aspen, are preferred by Prairie Warbler, Ruffed Grouse, snowshoe hare and woodland vole. In areas with less recent disturbance events, cherry and aspen may be replaced by white, red or black oak. Areas that remain undisturbed for long periods of time may eventually be dominated by shade-tolerant species such maple. These more mature dry hardwood forests are more likely to harbor species such as Red-headed Woodpecker, Yellow-billed Cuckoo, eastern box turtle, woodland jumping mouse and hoary bat (Kurta 1995, Hunter et al. 2001).

The combination of landscape features that define particular aquatic systems influences the species that will be present. A headwater stream will have a different and more diverse fish assemblage if it flows into a large river, than if it flowed into another small stream (Osborne and Wiley 1992). Stream

proximity to a lake or beaver pond will also result in a different fish assemblage (Schlosser 1995a, Schlosser 1995b, Snodgrass and Meffe 1998, Fausch et al. 2002). Similarly, lakes with higher connectivity to other waterbodies will be more diverse than isolated lakes (Tonn and Magnuson 1982, Radomski and Goeman 1995, Olden et al. 2001).

The juxtaposition of landscape features within a mosaic influences which species use a particular area. Bats use forested features during daylight hours for roosting, but also require grassland, wetland, or other semi-open features for foraging. Use of open features appears to be determined by nocturnal insect abundance. Massasauga rattlesnakes usually use wetland areas for winter hibernacula, but spend more time in adjacent upland areas during summer (Reinert and Kodrich 1982, Seigel 1986). Fish, both migratory and non-migratory, also tend to require different features for various parts of their annual cycles (e.g., reproduction, over-wintering, nursery). Distance and barriers between required landscape features will influence presence and abundance of wildlife in a mosaic.

Within wildlife species, animals of different genders and ages may be associated with different landscape features. Indiana bat maternal colonies have been located only in dead flooded timber; surveys have not detected similar site-use by males. Male Indiana bats have been identified using caves and upland forests (Kurta et al. 1993, Kurta 2004). Male American Woodcock generally select openings in shrubby sites as singing grounds (Gutzwiller and Wakeley 1980), but only shrub density and proximity to an edge appear to have any relation to nest site selection (Coon et al. 1980). As broods get older, males tend to select more mature, open stands (Dwyer et al. 1980). Also, location of sites with good soils and abundant earthworm populations may influence woodcock distribution, because earthworms are their primary food source (USGS 2005b). This multiplicity of feature use, both between and within species, requires maintenance of all landscape feature types.

The flow of organisms, material and other influences between landscape features can affect the characteristics of a feature itself (Meffe and Carroll 1994), not just the wildlife that occurs within it. For example, a bog in southern Michigan has different characteristics than those of bogs in the eastern Upper Peninsula due to differences in latitude, soil composition and chemistry, and differences in vegetative composition and structure of the surrounding area that influence the ongoing ecological processes. These various juxtapositions and interactions add to the overall biological diversity in Michigan, and should be considered during planning and implementation of conservation activities.

Conservation Needs to Address Landscape Mosaic Issues:

Land, Water & Species Management

- Develop management plans and actions that consider maintenance and restoration of multiple successional stages of landscape features
- Develop management plans and actions to maintain the necessary juxtaposition of landscape features for specific wildlife species

Education & Awareness

- Educate private landowners on how their property fits into the functioning of the larger landscape

Research, Surveys & Monitoring

- Continue to develop and improve habitat models to predict changes over time and responses to potential threats, and to identify appropriate metrics/indicators for monitoring
- Conduct research to identify relationships between specific landscape features
- Conduct research and develop models to identify the influence of feature juxtaposition on wildlife distributions and abundance

- Conduct research to examine how seasonal diversity in agricultural landscape features affect their use by wildlife
- Conduct research to determine whether agricultural landscape features act as buffers between natural and urban/suburban landscape features
- Conduct research to determine the relative value of temporal feature diversity to spatial feature diversity

Other Priority Issues: Ecosystem Representation and Networks

One the most widely accepted goals of conservation is ecosystem representation (i.e., the conservation of a representative set of high quality natural communities or ecosystems within a network of protected areas; Christensen et al. 1996). Ecosystem representation seeks to protect a broad diversity of habitats and ecological processes on which species depend; protecting this ecosystem diversity may be the most effective way to preserve biological diversity, including both rare and common species (Margules et al. 1988, Noss and Scott 1997, Groves and Valutis 1999). A hierarchical structure of representation should be considered for identification of protected areas or 'reserves,' from large functional landscapes at a coarse scale (to capture ecological processes and deflect larger-scale threats), through genetic variation in wildlife at the finest scale (Noss 1987, Noss 1990a, Groves and Valutis 1999, Margules and Pressey 2000, Poiani et al. 2000).

A reserve does not infer the absence of management or the maintenance of an unchanging system. In fact, to maintain representation of wildlife and vegetation diversity, management is imperative (Noss and Scott 1997) and change is inevitable, given that the ecological processes that are the subject of protection will ultimately cause change (Botkin 1990). Representing the full spectrum of species assemblages created by these processes and changes should be an ultimate goal of a reserve network.

Many agencies and organizations in Michigan have programs with goals of identifying and protecting areas that include important landscapes, features or species.

State Initiatives

The mission of the Natural Areas Program is "to identify, establish, maintain, and administer a system of high quality, representative, ecologically viable natural areas in Michigan" (Eagle and Herman 2000). The program has at its core a process to identify and legally protect (dedicate) natural areas on public and private lands. A broad spectrum of values is considered, but emphasis is on retained or restored natural characteristics. Currently, 26 natural areas are legally protected and an additional 52 are recognized through other programs, agreements, or inclusion in management plans. Approximately 130,000 acres of State land are currently recognized through the Natural Areas Program.

The Natural Rivers Program was developed to preserve, protect and enhance Michigan's finest river systems. Currently 2,091 miles of rivers and streams are protected. This program protects river corridors by using setbacks and restrictions for construction and management within a specified distance of the river.

The Biodiversity Conservation Planning Process has been proposed as a process to identify planning objectives and to develop plans to meet those objectives. Initially, the process will be used to identify areas on public and private lands with high quality natural communities, but will be expanded to also address various other high conservation value areas, considering both ecological and social values.

Federal Programs

The USFS's Research Natural Areas program recognizes high quality examples of various vegetative systems on Forest Service lands. In Michigan, these consist of five legally designated areas

encompassing approximately 5,000 acres. Most areas are small and do not fully represent the wildlife diversity of USFS lands (Noss 1990b). The larger Inventoried Roadless Areas program has reviewed and identified approximately 230,000 acres of relatively intact and unfragmented landscape patches in Michigan.

Two of the three major National Parks in Michigan (Sleeping Bear Dunes and Pictured Rocks) contain roughly 130,000 acres of land. The third park, Isle Royale, located in Lake Superior, consists of approximately 85 square miles. Although some portions of these parks have been developed for visitor interpretation and recreational use, the majority of each park is left undisturbed by human activities. Park Service land-management strategies include protection and restoration of natural features and wildlife species.

Federal Wilderness Areas are areas of undeveloped Federal land that have retained their primeval character and influence without permanent improvements or human habitation and are protected and managed to preserve their natural conditions. The 13 Federal Wilderness Areas in Michigan encompass approximately 92,000 acres, which include Nordhouse Dunes, Horseshoe Bay, Sturgeon River Gorge and Seney National Wildlife Refuge.

Wild and Scenic Rivers are selected rivers that, with their immediate environments, possess outstanding remarkable scenic, recreational, geologic, fish and wildlife, historic or cultural. They are preserved in a free-flowing condition to maintain those values. Sixteen stretches of water extending nearly 625 miles, including sections of the Pere Marquette, Au Sable, Tahquamenon and Presque Isle rivers, have been designated under this program in Michigan.

Non-governmental Initiatives

Non-governmental initiatives also contribute substantially to high quality land protection. Michigan Nature Association, Michigan Audubon Society and other organizations manage reserves throughout the State. The Nature Conservancy has established a number of reserves to protect rare systems in Michigan. The TNC reserves contain more than 13,000 acres and range from rare fen communities in southern Michigan to alvar sites in the Upper Peninsula. In addition, the DNR and TNC have entered into 27 cooperative agreements to protect rare species and systems through the TNC Natural Areas Registry Program. Numerous local and regional land conservancies have been established in Michigan and are working to protect important sites.

Beyond the Reserve

Although none of these programs alone will achieve the goal of protecting all representative landscapes, they collectively represent a core acreage scattered across the State that can be used to build larger-scale conservation efforts. Existing reserves tend to be small; in Michigan, these protected areas currently represent less than 1.5% of the state (Donovan et al. 2004) and this acreage is not likely to grow significantly. Therefore, to retain natural structure and function, the largest scales of representation must be captured as much as possible within a core protected area and then receive protection across the entire landscape through coordinated planning and conservation activities. For example, protection of a stretch of representative cold-water stream must address the ecological processes and water sources that maintain the lower temperature or it will fail to protect the system's diversity over the long term.

Donovan et al. (2004) found that only 3% of 214 bird species had at least 10% of their predicted distribution within identified reserves in Michigan. However, when other, primarily public, lands currently managed for natural resource values were included, the percentage of birds with at least 10% of their predicted distribution within the defined areas increased to 81% of species. These differences were similar for mammals (0% to 84%), amphibians (0 to 73%) and reptiles (0 to 60%). If even a small portion of the remaining, primarily private, lands were managed for similar values, the result would be a

significant step toward full ecosystem representation in Michigan. Cooperative efforts with private landowners will be a critical and effective means of protecting wildlife and ecological processes (Western and Wright 1994, Miller and Hobbs 2002).

The Nature Conservancy has made a step in this direction with its Ecoregional Conservation Planning efforts throughout North America (Groves et al. 2000). Large landscapes that possess and maintain important ecological communities or functions (e.g., a river watershed, a forest complex) are identified as priority areas. These areas generally reflect a variety of land ownership, leading TNC to develop partnerships with local communities in many areas. In Michigan, the identification of priority areas by TNC has been completed (TNC 2000, TNC and Nature Conservancy of Canada 2002, TNC 2003), and the formation of partnerships continues.

Conservation Needs to Address Ecosystem Representation and Network Issues:

Land & Water Protection

- Establish a cooperative system of protections, designations, or management that captures the full variety of landscape features and associated wildlife
- Identify, include and protect identified additional important lands in representative networks

Land, Water & Species Management

- Develop management plans for landscapes, regardless of ownership type, that include a network of protected sites and reflect landscape-scale ecological processes and management needs
- Identify and prioritize opportunities for restoration and conservation
- Develop management actions to preserve important ecological characteristics or processes for sites and landscapes

Education & Awareness

- Develop and implement an information and education program to provide interpretive materials for protected areas, their ecological processes, associated wildlife, and the interactions between them

Capacity Building

- Provide technical and financial assistance to private landowners to ensure ecosystem representation across all lands

Research, Surveys & Monitoring

- Conduct an inventory of the location, condition and extent of natural landscape features
- Identify important ecological characteristics or processes for sites and landscapes
- Complete an analysis of biodiversity elements (e.g., wildlife, plants, habitats) to identify areas of high biodiversity, regardless of ownership type
- Use GAP and other analyses to identify additional lands for inclusion in representative networks

Other Priority Issues: Bird Migration and Wintering

Most species identified as SGCN spend a significant portion of their life cycle in Michigan. A focus on these resident species would benefit a large proportion of Michigan's wildlife, but it would not address the needs of all wildlife found in the State over the course of a year.

Migration Routes and Stopover Sites
Migratory birds which pass through Michigan and the Great Lakes without breeding are largely overlooked in the set of SGCN, but they constitute a significant group of wildlife dependent on Michigan's landscape features for their continued survival. Important migratory pathways and habitat along Great Lakes shorelines have been identified at more than 60 sites (Scharf 1971). Table 8 identifies several recognized migratory paths and stopover sites with estimates of their use by birds. One site, Pointe Mouillee, has been designated part of the Western Hemisphere Shorebird Reserve Network.

Table 8. Partial list of stopover and migration sites in Michigan

Site	Survey year	Bird group	Count	Migration Period
Keweenaw Peninsula	1992	Raptors (migration)	16,000	Spring
Erie Metro Park	2004	Raptors (migration)	261,572	Fall
Baker Sanctuary	2003	Sandhill Cranes (staging)	5,328	Fall
Nayanquing Point		Tundra Swans	~5,000	Spring
Pointe Mouillee	2001	Shorebirds	15,428	Fall

Recent surveys have reconfirmed significant migratory bird use of Great Lakes islands. One-hundred eight different bird species were observed during spring migration on Beaver, Garden and Bois Blanc islands (Penskar et al. 2000). Islands may be important to migrants for three reasons: nocturnal migrants find themselves over open water and at dawn and seek the nearest land; islands act as northward extensions of mainland migration routes; and islands are the intended destination of migratory species that regularly nest on them (Scharf 1996). A recent study confirms that migrating birds do tend to congregate along Great Lakes shoreline areas because they provide the first opportunities to land upon daybreak (Diehl et al. 2003).

Migration accounts for the majority of annual adult mortality in land birds (Sillett and Holmes 2002). This biannual journey is the most energetically expensive process in a bird's life. Loss of stopover sites or modification of landscapes along important routes can have effects at a regional scale. One threat is the simple lack of knowledge of vital stopover sites and migratory pathways. Importance of these sites is not just defined by geographic locations, but also by their geologic and vegetative characteristics. A study using NEXRAD weather radar data to identify migratory routes and stopover sites found that important stopover habitat consists of sites with a diversity of vegetative types (Botner et al. 1992).

Migratory Obstructions
A potential mortality threat during migration is placement of obstructions along major migratory routes. Studies have identified collision with both tall buildings and communication towers as potentially significant causes of migratory bird mortality. An estimated 5,000 communication towers are constructed in the U.S. each year (Shire et al. 2000). In Michigan, 75% of species identified as Birds of Conservation Concern by the USFWS have been found dead under communication towers. Additionally, threats posed by wind farms may need to be considered if construction of these structures increases significantly in Michigan.

Wintering Sites
Although not readily apparent, Michigan is a wintering site for some northern nesting bird species. Regular winter residents include Snowy Owls, Great Gray Owls, Northern Shrikes and Oldsquaws which migrate from northern landscapes (Mcpeek and Adams 1994). Winter Bald Eagle surveys coordinated by the Michigan Department of Natural Resources have identified several wintering areas along the Great Lakes. These sites tend to be open water areas maintained by natural flow, warm

water discharge, or open water fissures in ice covering lakes. Occasionally, these sites have been reported to host more than a dozen eagles at any one time. Protection of features that support these species is important.

Conservation Needs to Address bird migration and wintering issues:

Land & Water Protection

- Initiate projects that protect known sites or ensure sites nearby are sustained
- Protect important migratory routes and stopover sites

Land, Water & Species Management

- Use best management practices for construction and management of human-made tall structures to help reduce mortality
- Assess value of management practices affecting migratory routes or stopovers
- Develop and implement management practices that ensure wintering bird habitat remains

Education & Awareness

- Provide information on important migration routes and stopover sites to land-planning agencies and organizations

Research, Surveys & Monitoring

- Identify characteristics and processes that make routes or stopovers attractive to migratory birds
- Develop and test best management practices for construction and management of human-made tall structures to help reduce mortality
- Conduct research to determine which management practices may affect migratory routes or stopovers
- Conduct research to determine relationships between winter resident birds and landscape features
- Identify important migratory routes and stopover sites and protect these areas
- Monitor migratory-bird use of Great Lakes features, both as stopover and as staging areas
- Conduct research to assess effects on wildlife populations due to mortality from collisions with fixed (e.g., communication towers, wind turbines) and mobile objects (e.g., airplanes)
- Conduct research to examine the effect of light pollution on wildlife movement patterns

Other Priority Issues: Hybridization

Closely related species sometimes hybridize in the wild where ranges and habitat niches intersect. For abundant species, this hybridization may have little effect. The genetic reservoir in the primary populations tends to overwhelm the crosses. For species that are rare or uncommon, however, hybridization with a more common species can pose a threat. Hybridization can be a particularly severe threat when it involves an invasive species, as is the case with the rusty crayfish, which has invaded the upper Great Lakes region and is hybridizing with native crayfish (Perry et al. 2001).

In Michigan, Black Ducks show little genetic differentiation from mallards, in part due to frequent hybridization (Ankney et al. 1986). Black Duck range and habitat selection is more restricted and the population is far smaller than that of mallards in the same range. Although the relationship between mallards and Black Ducks is still debated, hybridization is recognized as a threat to the latter species (Ankney et al. 1987). Hybridization between Golden-winged and Blue-winged warblers, both SGCN, has been made possible by human-caused changes to their environments (Levin 2002).

The smallmouth salamander reaches the northern edge of its range in southeastern Michigan. These salamanders are rare in Michigan, but can be locally abundant. Smallmouth salamanders hybridize with others in the *Ambystoma* genus (Harding 1997); in Michigan, this hybridization usually occurs with blue-spotted salamanders. Low abundance of this species in Michigan makes it susceptible to loss by hybridization.

Conservation Needs to Address Hybridization Issues:

Land, Water & Species Management

- Identify actions that can protect strong pure-strain population centers of species that readily hybridize
- Develop management strategies to prevent hybridization of native species with newly invading species

Research, Surveys & Monitoring

- Continue research into effects and potential threats of hybridization
- Identify strong pure-strain population centers of species that readily hybridize
- Conduct research to identify primary issues that make populations vulnerable to loss by hybridization
- Monitor newly invading species and identify potential hybridization threats to native species

Other Priority Issues: Rarity

Abundance of a few SGCN has always been low and conservation actions are not likely to increase population size to a secure level. Three characteristics on which rarity can be based are geographic range, habitat specificity, and local population size (Rabinowitz 1981). Rare species are much more likely to experience declines and have a higher potential for being extirpated in Michigan.

The Peregrine Falcon is an example of a species with a wide geographic distribution, narrow habitat specificity, and small local population size. Preferred habitat for Peregrine Falcons in Michigan was historically limited to rocky shorelines and rock outcrops in the Upper Peninsula. Current distribution reflects the ability of peregrines to adapt to human structures that mimic natural habitat. Eleven of the 16 identified areas currently used by peregrines are found either on buildings, bridges, or artificial platforms on smokestacks in southern Michigan. Due to the limited amount of habitat, peregrines will never be abundant in the State.

As an endemic species, Hungerford's crawling water beetle possesses a small geographic range (extending through parts of the northern Lower Peninsula and Ontario) and narrow habitat specificity (adults are generally found in portions of cooler stream segments that have riffles and stronger currents), and demonstrates a scattered, small local population. USFWS listed this species as federally endangered, in part, because of its rarity and threats associated with its habitat (USFWS 1994). Rare species are typically legally protected with either endangered or threatened species status.

Conservation Needs to Address Rarity Issues:

Land, Water & Species Management

- Develop management plans for rare species that ensure maintenance of viable population levels

Research, Surveys & Monitoring

- Identify historically rare species and develop habitat suitability models

- Determine population levels that will ensure viability and protect species in their habitats
- Develop monitoring protocols for rare species

Other Priority Issues: Urban, Municipal and Industrial Pollution

Even though rrban, municipal and industrial pollution as a threat did not meet the criteria as a statewide priority threat, resolution of this threat will require statewide, national and international efforts, as well as restoration efforts at specific contaminated sites. The severity of this threat is considered to be greater in the Lower Peninsula and Lake Erie and Huron basins than in the Upper Peninsula and Lake Michigan and Superior basins. See Appendix E for a graphic representation of the relative severity of threats between regions.

Effects of this threat on wildlife are expressed in many ways, including reduced reproductive rates of Bald Eagles along the Great Lakes coast; reduced rates or complete lack of reproduction in mammals near contaminated sites; threats to federally endangered species from contaminated areas; loss of freshwater mussel beds; and health advisories regarding consumption of fish. The most serious effects may still be unknown. The exact effects (direct or indirect) of many chemical pollutants on wildlife species are poorly understood; in many cases, knowledge is limited to the effects on game species alone. Through the years, pollution has been identified as one of most influential factors causing population declines and losses of species in the Great Lakes region. Environmental laws have helped reduce some contaminants, but the effects of pollution persist. Contaminants such as road salts, mercury, acid precipitation and increased sewage pose real questions and threats for the future of Michigan wildlife. See the Ecological Overview in the State Overview chapter above for more information about sources of aquatic contaminants and changes measured over time.

Five classes of contaminants may affect landscape features and wildlife (Gard et al. 1992). Three of these classes have their primary effect at the species level. Two, herbicides and acidic precipitation, may have effects at both the landscape feature level and directly on species.

Herbicides
These contaminants contain a number of compounds that have a variety of effects on vegetation, from defoliation to atrophy of plant roots. When used improperly, they can cause prolonged effects to vegetation used by wildlife species. Herbicides are also a valuable tool for conservation, including control of invasive plants. However, indiscriminant spraying of herbicides can kill rare or endangered plants. It can also kill plants with which many insects, including numerous SGCN, have obligate relationships, potentially eliminating entire colonies of rare insects (e.g., Cuthrell 2000, Rabe 2001).

Some concerns have arisen concerning use of certain herbicides and potential links to amphibian population declines (Hayes et al. 2002, Kiesecker 2002). Although Kiesecker et al. (2004) found that the direct cause of wood frog malformations in sampled ponds in Pennsylvania was a nematode parasite, they also found that frogs living in ponds with agricultural run-off developed abnormalities significantly more often than those in ponds without run-off. Amphibians tend to be more sensitive to environmental changes, but herbicides could also have long-term effects on other wildlife species. The nature of these potential effects are not yet understood.

Organochlorine Pesticides and Related Industrial Contaminants
This group of compounds includes chlorinated hydrocarbon insecticides (DDT, dieldrin, aldrin and mirex) and related industrial materials (PCBs, dioxins and furans). These compounds are persistent and fat soluble, characteristics that make bioaccumulation in animal tissue easier. Bioaccumulation of PCBs, DDT and metabolites in fish depends on factors such as growth rate, lipid content, and size, as well as environmental factors, including prey species, food chain length, and limnological factors.

DDT, PCBs and dieldrin have been documented as threats to Bald Eagle populations (Eisenreich

2002), through direct mortality (Elliott et al. 1996) and decreased productivity (Best et al. 1994). DDT, PCBs and metabolites were responsible for declines of Bald Eagles, Ospreys and Peregrine Falcons in Michigan. Although bans or restrictions on use of these compounds have significantly reduced sources, leaching and re-suspension allow continued mobilization in the water column of contaminants captured in sediment. Residual DDT also remains in upper soil layers and accumulates in many terrestrial animal species (DNR 2005b).

The Tittabawassee River demonstrates the long-term threat posed by contaminants trapped in sediments. The Tittabawassee River Aquatic Ecological Risk Assessment Report (MDEQ 2005) concluded the following: levels of dioxin and furan in ecological habitats downstream of Midland are high enough to potentially cause toxic effects to wildlife species; local carp, catfish, shad and bass have levels high enough to potentially cause serious reproductive impairment in fish-eating birds and mammals; similar risks exist in the Saginaw River and Saginaw Bay (MDEQ 2003b), which have important stopover areas for migrating birds.

Another example of an industrial contaminant is Trichloroethylene (TCE), an industrial cleaning solvent. Recent tests in southwestern Michigan have shown groundwater contamination with TCE leaching from a nearby industrial site. The related plume of TCE is expanding toward a federally listed Mitchell's satyr butterfly site. The potential effects of contamination on the satyrs themselves are currently unknown, but areas of extreme contamination upstream of one satyr population were found to be devoid of aquatic life (Hyde et al. 2003).

Organophosphorous and Carbamate Insecticides
Compounds in this group are acutely toxic and have been responsible for a number of wildlife die-offs (Grue et al. 1983); they work by blocking neurotransmitters. Poisonings of wildlife usually occur following exposure to recently treated areas. Although bioaccumulation is not a concern with these compounds, chronic exposure may be a threat. Diazinon intoxication in Canada Geese, Mallard Ducks and Wild Turkeys is the most common organophosphate poisoning seen in Michigan, but Parathion poisoning in Ring-billed Gulls and Sevin poisoning in bees have occurred as use of these compounds in agriculture has increased (DNR 2005b). There is some concern that declines in Black Ducks may be linked to use of insecticide treatments for spruce bud worm (Rusch et al. 1989). Although die-off incidents in the United States are sporadic and infrequent, unregulated use of these compounds in wintering areas of migratory birds remains a concern.

Metals
Due to their stability, metals persist for long periods and cycle slowly in the environment. Many metals have the ability to bioaccumulate through food chains, which is of special concern in aquatic systems. The metals of greatest concern include lead, mercury and selenium. High levels of mercury found concentrated in muscle tissues have been linked to reduced reproductive success in some wildlife species. Mercury has been reported to cause abnormal egg-laying behavior, impaired reproduction, slowed duckling growth, and altered duckling behavior in Mallard Ducks (DNR 2005b). Bioaccumulation poses threats to top predators, including Common Loons, Cormorants, Eagles, Ospreys, snapping turtles and mink (USEPA 2005b).

Direct ingestion of metal sources can also be a direct threat to wildlife. Lead poisoning has been recognized as a mortality factor in waterfowl since the late 1800s. Of 187 necropsies of Common Loons completed by the DNR since 1987, lead was found to be a causative mortality factor in 42 cases; the source was commonly spent lead shot and fishing tackle ingested during feeding activities. Ducks, geese, swans and loons are the most commonly affected wildlife; however, upland game birds, including Mourning Doves, Wild Turkeys, Ring-necked Pheasants and Northern Bobwhite Quail, are occasionally affected. Lead poisoning has also been noted in small mammals and raptors, presumably from the ingestion of lead-contaminated prey (DNR 2005b). The switch from lead to non-toxic shot has

significantly reduced the number of birds dying from lead poisoning in Michigan and the U.S.; however, the mortality directly due to lead ingestion may be secondary to the losses due to non-lethal effects of lead, such as reproductive problems, increased susceptibility to disease and infection, and increased predation due to anemia and weakened muscles (DNR 2005b).

Acidic Precipitation
Effects of acid precipitation occur primarily at the landscape feature level, especially in forest and inland lake landscape features. Acidic deposition affects terrestrial landscape features by altering soil chemistry and nutrient cycling. Although chemical changes have not been measured in Michigan's soils, such changes have been documented in forested systems to the south of the Great Lakes. On a regional basis, acid deposition is the second most important air pollutant affecting forested systems, behind only ozone (MDEQ 1999). Secondary effects may include reduced prey availability (Blancher 1991) and increased bioavailability of toxic metals, including mercury. Michigan acts as both a source and receptor for acid deposition (MDEQ 1999).

Other Contaminants
In addition to the contaminants listed above, other contaminants can affect wildlife and habitat. Road salts can affect vegetation and small vegetative communities. A small pocket of unique wetlands in southeastern Michigan that contains a relict forested bog is in jeopardy due to increased salinity from road runoff (MNFI 2005). It is not yet clear how road salts may affect other vegetative communities required by wildlife.

Any broad application of insecticides has the potential to effect non-target species. This is of particular concern when insecticides are applied in natural environments, as done with gypsy moth spraying. This activity has the potential to affect many non-target Lepidoptera species (Peacock et al. 1998), including numerous SGCN. Spraying for mosquitoes to control West Nile Virus may also affect many other wetland-dependent insect species, including numerous SGCN. Reductions in insect abundance due to large-scale spraying of insecticides may also affect other insectivorous species, such as bats and birds (USFWS 1999).

Conservation Needs to Address Urban, Municipal and Industrial Pollution Issues:

Land, Water & Species Management

- Develop action plans to prevent environmental contamination from identified sites and sources
- Implement best management practices that prevent secondary effects from regulated use of pesticides
- Form partnerships with conservation organizations to assist with contaminant issues in wintering areas of migratory birds
- Promote use of water retention sites for filtration of pollutants prior to entering local water bodies

Law and Policy

- Ensure existing environmental laws are properly enforced
- Recover costs of restoration from liable parties or compel them to perform the restoration work
- Collect penalties for natural resources damages, which can be used to fund restoration

Education & Awareness

- Implement programs to encourage anglers to voluntarily replace lead fishing tackle with less toxic alternatives
- Promote agricultural practices that reduce contaminants and run-off
- Promote practices that reduce private non-agricultural use of pesticides

- Encourage establishment of and participation in household hazardous waste collection

Research, Surveys & Monitoring

- Continue research on primary and potential secondary effects of contaminants on species
- Identify, quantify and monitor sites, sources and composition of significant contamination
- Conduct research to determine whether the effects of pollution vary by both physical and chemical characteristics of the pollution and the species of wildlife encountering it
- Conduct research to assess effects of both municipal sewage and residential septic systems
- Develop and test best management practices to prevent secondary effects from regulated use of pesticides

Research, Monitoring & Adaptive Management

To measure progress, success and failure of conservation actions, managers must have understanding of a variety of biological factors, such as baseline status and changes through time, and a concept of how natural systems function. Monitoring and research are critical assessment tools for obtaining this knowledge. For the purposes of this action plan, research and surveys refer to studies designed to test specific hypotheses regarding the status or cause(s) of particular observed ecological phenomena (Elzinga et al. 2001), and monitoring is defined as the collection and analysis of repeated observations or measurements of indicators to examine trends, evaluate changes in condition, or assess progress of conservation actions (Elzinga et al. 2001). Well-designed monitoring often functions as research when hypotheses are tested, and long-term research and survey projects may double as monitoring; both components, however, are requisites for effective conservation.

When done well, monitoring can improve a conservation program's success and value over time, by helping increase accuracy and efficiency. An effective monitoring program can help (from Noon 2003):

- determine whether resources are affected by a stressor;
- evaluate and contrast conservation actions;
- develop hypotheses regarding changes in the status of indicators;
- determine when and how management strategies should be altered; and
- warn of environmental decline.

Unfortunately, monitoring and research efforts are often inadequately designed or implemented to evaluate the effectiveness of conservation programs (Salafsky and Margoluis 1999, Parrish et al. 2003). Furthermore, research and monitoring are often poorly coordinated among agencies, organizations and academic institutions.

The overall approach of this action plan is to define threats and landscape features important to Michigan's wildlife, identify and quantify the many complex relationships between landscape features and SGCN, and recommend conservation actions that will abate threats to landscape features and SGCN. By extension, this action plan will also assist in conserving all wildlife species (by definition, both aquatic and terrestrial) in Michigan. Within this approach, the following activities must be completed at multiple scales.

- Identify and conduct specific research and surveys that will address gaps in knowledge related to threats, landscape features and species, and the relationships between them
- Assess the overall success of the program
- Monitor threats

- Monitor the spatial extent and condition of landscape features
- Monitor the status of rare, declining and indicator species
- Assess responses to specific conservation actions and use results to re-evaluate current conservation actions and recommend new ones (i.e., adaptive management)

Many questions must be considered prior to embarking upon a new monitoring or research project, regardless of whether the intent of the project is to address program effectiveness or ask questions about wildlife and its habitats. How will the data be used? What is the desired outcome? What is the desired accuracy? What level of accuracy would be acceptable? What scale must be considered? What level of funding is available? There are direct relationships between scale, accuracy and cost. A project that focuses on a small area will cost less than one that collects similar data at an ecoregion or statewide scale. A study based on qualitative (categorical) data will cost less than a more intensive one that collects quantitative data, but the quantitative study will produce results with greater power and accuracy. An effective monitoring or research project defines parameters such as scale, accuracy, cost and desired outcomes and incorporates them into the overall project design.

The following text defines areas of monitoring and research that must be undertaken, and identifies statewide priorities within these areas. Monitoring and research recommendations specific to individual landscape features within each ecoregion or lake basin are included within the landscape feature summaries in the Landscape Features & Conservation Needs section.

Research & Surveys

Throughout the process of developing, implementing, monitoring and evaluating conservation actions, needs for specific information to answer specific questions will arise. For instance, monitoring data collected while tracking a species assemblage might eventually indicate declines in one or more species. Resulting research priorities might include the identification of the threats contributing to the decline, investigation of species' life-history and requirements, or an experimental evaluation of habitat restoration techniques designed to reverse the decline. These specific research and survey activities would better direct management decisions by providing information that supplements long-term monitoring data.

Many monitoring needs that are identified below require baseline information that is currently not available. In particular, a statewide status assessment of wildlife distributions and abundance is necessary to identify baseline conditions for wildlife conservation, a need that is clearly identified as a priority in the SGCN Status & Species Specific Information section. Research to determine which species or communities will be most useful as indicators of overall condition will focus survey and monitoring efforts. Surveys to locate additional high quality natural communities identified by the Michigan Natural Features Inventory are also greatly needed, because spatial extent and condition of these communities may be valuable indicators of landscape feature condition.

Standards for Monitoring

Monitoring programs vary in their effectiveness, depending upon the standards used to develop, implement and integrate them. Monitoring programs can better direct management decisions when they include (from Noon 2003, Parrish et al. 2003):

- clearly defined conservation targets;
- a firm foundation in ecological theory and empiricism;
- a clear, logical basis for selection of indicators;
- an obvious linkage to cause–effect interpretation of monitoring signals;
- specified indicator values for triggering management response;

- a firm connection between results of monitoring and decision making; and
- adequate and consistent funding.

Incorporating these elements requires planning to develop clear goals and to identify key ecological relationships (Noon 2003).

Monitoring efforts are useful only when commitments are made to evaluate monitoring data and subsequently use results to develop priorities and direct management decisions. Effectiveness of conservation efforts can be further improved when monitoring results are shared among conservation partners, increasing the common knowledge base and avoiding unnecessary duplication.

Program Assessment

The most basic step in measuring success for a program is to compare actions implemented to those identified during strategic planning. Although this task is often overlooked, systematically revisiting actions and determining why they were or were not implemented can be vital to a program. This evaluation will lead to more effective future planning efforts. Another key aspect of program assessment is determining whether partnerships were formed and what contributions were made by each partner. Initial steps required to assess the success of the WAP are identified in the Review & Revision text above.

Threat Monitoring

Use of threat status as a tool to assess condition of natural resources and as a measure of success for conservation actions can be a cheaper and simpler approach than direct measures of biological resources (Salafsky and Margoluis 1999). However, establishing direct links between threats and the condition of ecological resources can be difficult (Salafsky and Margoluis 1999, Parrish et al. 2003). The extent of the difficulty is reflected in the landscape feature and SGCN summaries, which frequently identify the need for more information on the effects of threats on species, ecological communities and ecosystems. Therefore, monitoring of threat status should be done in conjunction with direct ecological research.

Data and information are already collected for some threats, often for other purposes. These data need to be examined and evaluated for their utility for wildlife conservation. Information on habitat loss, population growth, development patterns, social attitudes, recreation, and invasive species introduction and establishment rates are already collected by various public agencies and NGOs and may be suitable for monitoring of threats or natural processes. For instance, spatial analysis of remotely sensed land-cover data, such as those collected for the DNR's IFMAP system, can be used to assess extent of landscape fragmentation, and streamflow data, such as that collected by the USGS, can be used to assess hydrologic alteration.

Some threats are more difficult to measure directly and may be more easily quantified by using biological indicators (e.g., indicator species or community metrics). Measuring success in threat abatement through biological indicators or in combination with them can help to resolve problems associated with linking threats to biological resources.

Threat monitoring must be implemented at multiple scales in a coordinated manner. For some threats, existing data will be appropriate for statewide or regional assessments of change, but local-level assessments may require additional data collection. Assessments of local changes in habitat using currently available land-coverage data may be inappropriate even though the same approach is suitable for regional analyses (Donovan et al. 2004). Monitoring of invasive species requires efforts at statewide levels in conjunction with local efforts to ensure that species are identified immediately after they are introduced or become established, because this is the most effective and efficient time to

implement conservation actions to control them.

The highest priorities for threat monitoring at a statewide scale include those threats identified above as statewide priority threats. The most severe threats to individual landscape features within ecoregions and lake basins have also been identified in the Landscape Features & Conservation Needs section. Efforts should be made to ensure that these threats are monitored at appropriate scales.

Landscape Feature Condition Monitoring

Compared to monitoring of individual species, monitoring condition of landscape features and associated natural communities provides a more comprehensive understanding of natural resource health and changes over time (MacNally et al. 2002). Assessments of landscape feature condition include quantifying the spatial extent (numbers or acreage) and configuration of representative occurrences, as well as measuring the ecological integrity of existing occurrences. Baseline data, including historic condition (potential condition), current condition, and natural range of variation, are needed to develop and evaluate conservation goals.

Periodic assessments of the spatial extent of all occurrences (e.g., acres of prairie), representative natural community occurrences and high quality occurrences (e.g., miles of high quality coldwater headwater stream reaches) of landscape features should be completed as an indicator of the condition of the landscape feature as a whole across the landscape. These measures can be performed more easily over a large area using data generated by remote sensing than with on-the-ground monitoring projects. Some species assemblages correlate well to these gross measures, but others may not be sufficiently assessed (MacNally et al. 2002). Currently, coarse spatial data are available for some landscape features (e.g., forest features), but are entirely lacking for others (e.g., savanna, prairie; Donovan et al. 2004).

Determining the ecological integrity of landscape features is generally more difficult than obtaining simple measures of spatial extent. However, the critical components determining condition can usually be reduced to a few key ecological indicators (Parrish et al. 2003). These indicators should reflect an ecosystem's ability to support community structure and functional attributes comparable to those of natural habitats within a region and within the historic natural range of variability (Karr and Dudley 1981, Parrish et al. 2003). Ecological indicators include direct measures of important functional components (e.g., number of vertical vegetation layers, bed and bank erosion) and community metrics (e.g., index of biotic integrity, floristic quality assessment), as well as species indicators. Because landscape features are coarse units, they may contain substantial diversity (e.g., many MNFI natural communities, multiple successional stages), and key ecological indicators may only apply to specific sites or structures within a landscape feature. Various classification systems may need to developed or improved to help determine which of the diverse components of landscape features are indicative of condition.

Landscape feature-specific indicators should be used to monitor changes in condition over time. Research to identify these metrics, as well as associated benchmarks to incrementally assess changes in condition or to trigger specific management actions, is a high priority to enable efficient and useful monitoring. Specific measures of condition have been identified for many landscape features in the Landscape Features & Conservation Needs section.

The following research, survey and monitoring efforts, drawn from the Landscape Features & Conservation Needs section, were each identified for multiple landscape features as necessary for assessing condition of those features and determining the most effective conservation actions to address significant threats.

- inventories and mapping to identify the number of occurrences and size of landscape features
- monitoring of changes in the number and size of occurrences of landscape features

- inventories and mapping to identify the extent and severity of threats within landscape features
- monitoring of changes in extent and severity of threats within landscape features
- inventories to identify species or community associations with landscape features
- monitoring of changes in the community composition of landscape features
- monitoring of changes in land-use
- development of hydrologic models
- monitoring of changes in hydrologic (e.g., groundwater, streamflow, dam operation) dynamics
- research to examine and evaluate responses to management techniques
- identification of historic condition of landscape features and communities (including natural ranges of variation)

The highest monitoring priorities include those landscape features that are associated with imperiled natural communities or wildlife species (globally or regionally rare), are at a high threat risk, or are used by a significant number of SGCN. Any area that is a high quality representative of any landscape feature (e.g., natural communities, designated natural rivers or natural areas) should also be considered a monitoring priority to determine whether its high quality status is being maintained. Measures of condition at restoration sites should also be priorities, to allow evaluation of restoration success and techniques. However, well-coordinated monitoring of conditions of any landscape feature will help to assess status, trends, and conservation efforts. Initial efforts for many landscape features need to include scientific assessments to collect baseline data on spatial extent and ecological integrity.

Species Monitoring

Although targeting macrohabitats, such as landscape features, for conservation actions and monitoring is an efficient approach to conservation (Noss 1987, Franklin 1993, Scott et al. 1993), obtaining a desired ecosystem condition may not result in the desired response from all species (Herkert 1994, Swengel and Swengel 1997) or even entire species assemblages (MacNally et al. 2002). Many species respond to very specific aspects of a landscape feature and are therefore not necessarily protected by feature-level actions. Because of these specific responses, species can be good indicators of specific changes within ecosystems that might otherwise be overlooked. Further, some species are not limited primarily by habitat and are threatened or otherwise influenced by forces independent of landscape feature conditions. Collecting, storing and assessing information on individual species will always be necessary to prevent extinction and to evaluate the condition of more-specific ecosystem components.

More rigorous monitoring of individual species should focus on species that are:

- highly imperiled;
- known indicators of ecological integrity;
- known to have specific requirements that are not assessed by landscape feature monitoring (e.g., area limited (size), resource limited (e.g., Karner blue butterfly and lupine), dispersal limited (distance between habitat patches), or process limited (fire regimes); or
- otherwise of considerable interest (e.g., socially or economically important species, keystone species).

General tracking of endangered, threatened and special concern species is already conducted by many entities who contribute data to MNFI's Biotics database. Identification of ways to collect, store and share information for SGCN that are not tracked in Biotics is also needed. By monitoring species assemblages (e.g., frog and toad survey, breeding bird survey, fish surveys), trend information on specific species can be assessed. In addition, broad tracking of species trends should be

supplemented with specific, well-reasoned research efforts to validate trends and determine causes. Research to collect baseline data for poorly understood species should be a priority, as identified within the discussion of the 'Lack of scientific knowledge' threat in the Statewide Conservation chapter above.

Rigorous monitoring is not feasible for all SGCN across the entire State. Therefore conservation tools, including predictive models, can be useful for drawing broad-scale conclusions on distribution and abundance based on assessments made at smaller scales. These models can greatly increase the utility of information from monitoring programs.

Specific monitoring and research needs for individual species are noted in the SGCN Status & Species Specific Information section. Priorities for species monitoring conducted in the future should include determining the influence of landscape features and threats on population parameters.

Existing Monitoring & Research Efforts

Many monitoring and research efforts within the State and Great Lakes region already assess the status and condition of Michigan's ecosystems, natural communities and wildlife populations. Whenever possible, these efforts should be used to address the needs identified in this action plan. For example, the DNR, often in partnership with other agencies and organizations, already:

- conducts surveys, research and monitoring on the status and distribution of threatened, endangered and otherwise imperiled species;
- assesses the status and trends of aquatic communities in Great Lakes, inland lakes, and rivers;
- assesses land habitat coverage at multiple scales;
- assesses changes in forest health; and
- conducts aquatic and terrestrial GAP assessments.

A set of recommended environmental indicators for Michigan, the majority of which are already monitored, was developed as part of a recent statewide review (Premo et al. 2001; Appendix I). The DNR is currently developing monitoring guidelines at a statewide level for Forest Certification. Regionally, interdivisional Eco-Teams are identifying comprehensive lists of ecological indicators (see Appendix J for draft Eastern Upper Peninsula ecological indicators). In addition, statewide indicators and metrics for rivers and lakes are currently being developed by the DNR Fisheries Division.

Many conservation partners also collect valuable information on the status and trends of natural resources within the State. These partners include academic institutions, other public agencies, NGOs and private entities. For example, the MDEQ collects information on water quality and aquatic macroinvertebrate community composition in streams across the State. The USGS collects data on stream flows, water quality and groundwater. The National Oceanic and Atmospheric Administration collects information on physical, ecological and biological conditions in the Great Lakes, including the spread of aquatic invasive species. Other long-term monitoring data are available for breeding bird distributions and abundance, contaminant levels in fish and Bald Eagles, and wetland community conditions.

One of the most important factors in implementing a useful and cost-effective monitoring program is to ensure that monitoring efforts are coordinated. Without coordination, efforts may be duplicated, data may not be comparable, and priority needs may remain unaddressed. The monitoring efforts recommended by the WAP integrate and reflect, to the extent possible, the research, monitoring and programs currently ongoing throughout the state and Great Lakes region.

Adaptive Management

Successful ecosystem management allows conservation approaches to change appropriately based on new information. Conservation actions must be evaluated so that relative success can be documented and subsequent actions can be adapted for greater effectiveness.

Adaptive management can be successful, when management goals and objectives are clearly stated so that monitoring benchmarks can be developed accordingly (Noon 2003). Objectives should be quantifiable and should address the conservation target, the geographic area, the desired action, a measurable state or degree of change desired, and a time frame (Elzinga et al. 2001). Sampling designs for evaluating conservation actions should be robust, and the ability to adequately assess outcomes based on monitoring data must be analyzed (i.e., power analysis) to avoid the possibility of declaring an action unsuccessful when it was actually working or vice versa. There must be a commitment of time and money for implementation of monitoring and for data analysis and evaluation. Finally, managers must commit to accepting monitoring results and to changing conservation actions accordingly.

Adaptive management also requires a willingness to modify assumptions, goals and actions based on new information gained through monitoring efforts. It necessitates extensive documentation of hypotheses, action designs and results.

Research is also a critical component of the adaptive management approach. Many conservation actions necessarily proceed with limited ecological information and without knowledge of whether the conservation action is the best approach. Research is needed to better understand ecological relationships and to test new and existing approaches. A diversity of actions to address specific threats or needs should be designed, implemented and monitored to help determine best practices.

Priority Conservation Needs

All conservation needs identified as statewide priorities should be considered by conservation partners as they assess their own conservation priorities, goals, and resources available for implementing conservation actions, research, surveys and monitoring. Some conservation needs are already being addressed.

Conservation Needs to Address Priority Threats & Issues

Conservation actions, research and monitoring identified in the preceding discussions of 'Priority Threats' and 'Other Priority Issues,' have already received some degree of prioritization over conservation needs identified in the landscape feature summaries, because they address threats and issues that are considered priorities statewide. All of the statewide priority threats and issues are important, and it is difficult to justify further prioritization of associated conservation needs.

Any conservation action, research or monitoring identified to address the highest priority threats, invasive species and fragmentation, should be considered a statewide priority conservation need, regardless of where it fits in the discussion that follows.

In an effort to provide some index of importance, very similar conservation needs were grouped into categories, regardless of which statewide priority threat or issue they address. The number of conservation needs in each category was then counted. Successful implementation of conservation actions, research and monitoring to fulfill needs in categories with the greatest totals will have the widest influence on wildlife conservation statewide, because those conservation needs were repeatedly identified to address multiple threats and issues. This summary analysis is somewhat flawed in that it may be influenced either by threats and issues that had a large number of similar conservation needs identified or by the individual who completed the grouping and identification of categories to be totaled.

However, it provides a starting point for discussion and a way for conservation partners to begin considering where they can best direct their efforts.

The 'Threats & Issues Addressed' identified below for each category include only the 14 statewide priority threats and six statewide conservation issues discussed above. When the associated conservation needs are fulfilled, many other threats that were not identified as statewide priorities will likely also be addressed.

The following categories (no order implied) have the greatest number of associated conservation needs, which should be considered statewide priorities.

- Identification and conservation of representative areas, high quality areas, and other areas of high ecological significance (includes development of site conservation plans and any formal protection determined to be necessary)
    - → *Threats & Issues Addressed:* fragmentation, wetland modifications, non-consumptive recreation, ecosystem representation and networks, bird migration and wintering, hybridization
- Identification and conservation of areas with urgent conservation needs (e.g., invasive species, lack of disturbance regime, contamination)
    - → *Threats & Issues Addressed:* invasive species, wetland modifications, non-consumptive recreation, altered sediment loads, altered hydrologic regimes, altered fire regime, urban, municipal and industrial pollution
- Development and use of best management practices, recommended strategies, or recommended plans for conservation and management in specific situations
    - → *Threats & Issues Addressed:* invasive species, fragmentation, wetland modifications, dredging, channelization, riparian modifications, non-consumptive recreation, altered sediment loads, altered hydrologic regimes, altered fire regime, bird migration and wintering, urban, municipal and industrial pollution
- Identification and elimination of significant information gaps for SGCN, landscape features and ecological processes, including responses to threats
    - → *Threats & Issues Addressed:* invasive species, disease and pathogens, altered hydrologic regimes, altered fire regime, lack of scientific knowledge, landscape mosaics, bird migration and wintering, hybridization, rarity, urban, municipal and industrial pollution
- Assistance to private landowners and creation of partnerships between conservation organizations/agencies and private landowners for conservation of wildlife and landscape features
    - → *Threats & Issues Addressed:* invasive species, fragmentation, wetland modifications, dredging, riparian modifications, altered sediment loads, altered fire regime, social attitudes, landscape mosaics, ecosystem representation and networks

Although the following categories (again, no order implied) have slightly fewer associated conservation needs, those needs should also be considered statewide priorities.

- Development of new regulations/legislation to protect SGCN and landscape features
    - → *Threats & Issues Addressed:* invasive species, disease and pathogens, altered fire regime

- Development of artificial techniques and engineering of new structures that mimic natural processes

→ *Threats & Issues Addressed:* fragmentation, channelization, dams, altered sediment loads, altered hydrologic regimes, urban, municipal and industrial pollution

- Education of the public on primary threats to wildlife and landscape features, biodiversity and essential ecological processes
  → *Threats & Issues Addressed:* invasive species, fragmentation, non-consumptive recreation, altered sediment loads

- Development of survey, monitoring and response protocols to identify and address new disease, pathogens, and invasive species
  → *Threats & Issues Addressed:* invasive species, disease and pathogens

A group of representatives from conservation organizations that attended the WAP 'Kick-off' Workshop (see Table 7) were asked to evaluate the same categories of conservation needs and provide opinions on importance and urgency of the needs associated with each category. The results of this evaluation were similar to the summary analysis above, with a small number of notable differences.

Workshop participants felt strongly that additional categories, not identified as priorities through the analysis above, were also very important and urgently needed for wildlife conservation in Michigan.

- Development of conservation plans for landscapes (e.g., mosaics, networks, adjacent land ownerships)
  → *Threats & Issues Addressed:* landscape mosaics, ecosystem representation and networks

- Identification and protection of corridors between large areas and isolated habitat patches
  → *Threats & Issues Addressed:* fragmentation

- Monitoring of natural resource metrics for changes in historical/natural range of variation and development of plans/actions to restore the historical/natural range of variation
  → *Threats & Issues Addressed:* altered hydrologic regimes, landscape mosaics

Workshop participants also indicated that they did not find the following categories, identified in the analysis above as priorities, to be as important or as urgently needed as some of the others.

- Development and use of best management practices, recommended strategies, or recommended plans for conservation and management in specific situations
- Development of artificial techniques and engineering of new structures that mimic natural processes (This result may reflect the composition of participants: most were terrestrially oriented, whereas the conservation needs in this category were primarily related to aquatic threats and issues.)

And finally, workshop participants added one additional category of conservation needs that they felt was very important and urgently needed, even though associated needs were not specifically identified to address any of the statewide priority threats or issues: development of explicit measurable goals for landscape features and SGCN. This conservation need is identified within the discussion of Research, Monitoring & Adaptive Management above.

Research and Monitoring Needs

The following is a summary of research and monitoring needs at a statewide scale that were identified

as priorities during Regional Technical Workshops, from scientific literature review, and in discussions with natural resource professionals. Because research and monitoring efforts required to fulfill these needs will address multiple threats, issues, landscape features and species, they have the potential for the widest influence on wildlife conservation statewide.

- Monitor status and trends of the priority threats in the State and region at multiple scales and use the data to evaluate conservation actions
- Develop quantitative linkages between wildlife and primary threats
- Improve classification systems as needed to ensure that they reflect the current state of knowledge (including MNFI's Natural Communities and aquatic systems such as stream/river, lake and wetland)
- Resolve problems with landscape feature spatial data, so that spatial extent can be sufficiently determined for status and trend assessments
- Develop criteria for identifying high quality representative occurrences of landscape features
- Conduct Inventories to ground-truth and refine spatial mapping of landscape features and high quality representative occurrences and to collect baseline data
- Periodically map the spatial extent of landscape features and assess all occurrences and high quality occurrences to determine loss or gain (number of occurrences and/or acreage)
- Monitor high quality representatives of landscape features to assess whether ecological integrity is being maintained
- Develop explicit measurable goals for landscape features and SGCN
- Develop science-based indicators and benchmarks for measuring the condition of each landscape feature
- Complete research to determine the historic condition of landscape features and natural communities (including natural ranges of variation)
- Monitor indicators of landscape feature condition over time to assess trends and evaluate conservation actions
- Inventory community composition across landscape features to develop baseline data
- Monitor changes in community composition across landscape features
- Complete a statewide baseline assessment of wildlife distribution and abundance
- Identify species assemblages associated with specific landscape features and specific feature components
- Assess species status and trends using MNFI's Biotics database, DNR Fisheries status and trends databases, and other species-assemblage monitoring data
- Identify ways to collect, store and share information on the SGCN that are not tracked in the Biotics database
- Develop and refine tools that enable assessments of wildlife through limited sampling (i.e., using predictive models)
- Conduct more specific and strategic monitoring for individual species that are imperiled, known indicators of ecological integrity, or known to have specific requirements that are not assessed by landscape feature monitoring
- Conduct surveys and status assessments for taxonomic groups that are poorly understood or undocumented
- Determine habitat use by and threats to SGCN for which basic life-history information is unavailable
- Complete research and monitoring to evaluate effectiveness of conservation actions

LITERATURE CITED

Albert, D.A. 1994. Michigan's Landscape in D.C. Evers (ed.) Endangered and Threatened Wildlife of Michigan. University of Michigan Press, Ann Arbor, MI.

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working classification (Fourth Revision: July 1994). North Central Forest Exp. Station. Forest Service—U.S. Dept. of Ag. General Technical Report NC-178. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/1998/rlandscp/rlandscp.htm (Version 03JUN98).

Albert, D.A. and M.A. Kost. 1998. Natural community abstract for lakeplain wet prairie. Michigan Natural Features Inventory, Lansing, MI. 4pp.

Albert, D.A., S.R. Denton, and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. University of Michigan, School of Natural Resources, Ann Arbor, MI. 32 pp. & map.

Alexander, G. R. and E. A. Hansen. 1982. Sand sediments in a Michigan trout stream part II. Effects of reducing sand bedload on a trout population. Michigan Department of Natural Resources, Fisheries Research Report No. 1902. Ann Arbor, MI.

Alley, W. M., T. E. Reilly, and O. L. Franke. 1999. Sustainability of ground-water resources. US Geological Survey, Circular 1186, Denver, CO.

American Rivers, Friends of the Earth, and Trout Unlimited. 1999. Dam removal success stories: restoring rivers through selective removal of dams that don't make sense.

Ankney, C.D., D.G. Dennis, and R.C. Bailey. 1987. Increasing mallards, decreasing black duck cause and effect? Journal of Wildlife Management 51:523-529.

Ankney, C.D., D.G. Dennis, L.N. Wishard, and J.E. Seeb. 1986. Low genetic variation between black ducks and mallards. Auk 103:701-709.

Annear, T., I. Chisholm, H. Beecher, A. Locke and 12 other authors. 2004. Instream flow for riverine resource stewardship, revised edition. Instream Flow Council, Cheyenne, WY.

Armantrout, N.B. compiler. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, MD.

Askins, R.A. 2001. Sustaining biological diversity in early successional communities: the challenge of managing unpopular habitats. Wildlife Society Bulletin 29(2): 407-412.

Bailey, R.G, P. Avers, T. King, W.H. McNab. 1980. Ecoregions and subregions of the United States. U.S. Forest Service, ECOMAP Team. 1 map (1:7,500,000), Washington, D.C.

Bain, M. B., J. T. Finn, and H. E. Booke. 1988. Streamflow regulation and fish community structure. Ecology 69(2):382-392.

Barro, S. and M. J. Manfredo. 1991. Understanding publics: The relationship between what they say and what they do. Paper presented at the SAF national convention. August 4-7, San Francisco, CA.

Belden and Russonello Research and Communications. 1996. Human values and nature's future: American's attitudes on biological diversity; an analysis of findings from a national survey. Washington DC: Belden and Ressonello Research and Communications.

Belden, Russonello and Stewart Research and Communitications. 2002. Americans and biodiversity: new perspectives in 2002. National Survey on Biodiversity prepared for the Biodiversity Project, Washington, D.C.

Belyea, G.Y. and J.M. Lerg. 1976. Public Use of Southern Michigan Game and Recreation Areas. Wildlife Division Report 2754. Michigan Department of Natural Resources, Lansing, MI.

Benke, A. C. 1990. A perspective on America's vanishing streams. Journal of the North American Benthological Society 9(1):77-88.

Best, D.A., W.W. Bowerman, T.J. Kubiak, S.R. Winterstein, S. Postupalsky, M.C. Shieldcastle, and J.P. Giesy. 1994. Reproductive impairment of bald eagles *Haliaeetus leucocephalus* along the Great Lakes shorelines of Micxhgian and Ohio. Pages 697-701 in Raptor conservation Today (eds.) Meyburg, B.U. and R.D. Chancellor. World Working Group on Birds of Prey/The Pica Press, New York.

Blancher, P.J. 1991. Acidification: implications for wildlife. Transactions of the North American Wildlife and Natural Resources Conference 56: 195-204.

Bormann, F.H. and G.E. Likens. 1979. Pattern and process in a forested ecosystem. Srpinger-Verlag, New York.

Born, S., M. Leffler, T, Reese, R. Veltman, A. Wieben, and K. Zeiler. 2000. Modernizing Wisconsin groundwater management: reforming the high capacity well laws. University of Wisconsin: Madison/Extension Report Series, 2000-1.

Botkin, D.B. 1990. Discordant harmonies: an ecological model. Oxford University Press.

Botner, D., S.A. Gauthreaux, and T.M. Donovan. 1992. Are migratory birds selecting stopover sites based on landscape characteristics? Remote Sensing with WSR-88D (NEXRAD) Radar in the Great Lakes Basin. An published report submitted to: The Nature Conservancy Great Lakes Basin. 40pp.

Bovee, K.D., T.J. Newcomb, T.G. Coon. 1994. Relations between habitat variability and population dynamics of bass in the Huron river, Michigan. Biological Report 21. U.S. Department of the Interior. Washington, D.C.

Brawn, J.D. and S.K. Robinson. 1996. Source-sink population dynamics may complicate the interpretation of long-term census data. Ecology 77:3-12.

Breck, J.E. 2004. Compilation of databases on Michigan lakes. Michigan Department of Natural Resources, Fisheries Division, Technical Report 2004-2. Ann Arbor, Michigan.

Callicott, J.B. 1986. On the intrinsic value of nonhuman species. In B.G. Norten (ed.), The preservation of species: the Value of biological diversity, pp138-172. Princeton University Press, Princeton, NJ.

Chick, J.H., R.J. Maher, and B.M. Burr. 2003. First black carp captured in U.S. Science 300:1876-1877.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, M.G. Turner, R.G. Woodmansee. 1996. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. Originally published in Ecological Applications 6(3): 665-691.

Comer, P.J., D.A. Albert, H.A. Wells, B.L. Hart, J.B. Raab, D.L. Price, D.M. Kashian, R.A. Corner, and D.W. Schuen. 1995. Michigan's presettlement vegetation, as interpreted from the General Land Office Surveys 1816-1856. Michigan Natural Features Inventory, Lansing, MI. Digital Map.

Convention on Biological Diversity. 2004. Indicators for assessing progress towards the 2010 target: connectivity/fragmentation of ecosystems. Notes from the Tenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice. Bangkok, 7-11 February 2005. 9 pp. Available: http://www.biodiv.org/doc/meetings/sbstta/sbstta-10/information/sbstta-10-inf-20-en.pdf

Coon, R.A., B.K. Williams, J.S. Lindzey, and J.L. George. 1980. Examination of woodcock nest sites in central Pennsylvannia. In Woodcock Ecology and Management T.J. Dwyer and G.L. Storm (Tech. Coord.): Woodcock Symposium (7th: 1980: Pennsylvannia State University. U.S. Fish and Wildife, Wildlife Research Report 14.

Copp, G.H. 1989. The habitat diversity and fish reproductive function of floodplain ecosystems. Environmental Biology of Fish 26:1-27.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387:252-259. Available: http://www.uvm.edu/giee/publications/Nature_Paper.pdf

Courtner, H.J., M.J. Zwolinski, E.H. Carpenter, and J.G. Taylor. 1984. Public support for fire management policies. Journal of Forestry 82:359-361.

Cushman, R. M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management 5:330-339.

Cuthrell, D.L. 2000. Special animal abstract for *Papaipema silphii* (silphium borer moth). Michigan Natural Features Inventory, Lansing, MI. 3pp.

Cwikiel, W. 2003. Michigan wetlands, yours to protect: a citizen's guide to wetland protection. Tip of the Mitt Watershed Council. 278pp.

DePhilip, Michele. 2001. Aquatic ecoregional planning in the U.S. portion of the Great Lakes watershed. The Nature Conservancy, Great Lakes Program. Chicago, Illinois.

Detroit Zoological Institute, Belle Isle Aquarium. Accessed: 2005. Mussel Database. Detroit, Michigan.

Diehl, R.H., R.P. Larkin, J.E. Black. 2003. Radar observations of bird migration over the Great Lakes. The Auk 120:278-290.

(DNR) Michigan Department of Natural Resources. 1990. Michigan trapper education manual. Michigan Department of Natural Resources, Wildlife Division. Lansing, MI. 46 pages.

(DNR) Michigan Department of Natural Resources. 1992. Michigan's environment and relative risk. A report to Govenor John Engler prepared by the Michigan Environmental Science Board.

(DNR) Michigan Department of Natural Resources. 2003a. Integrated forest monitoring assessment and prescription (IFMAP) / GAP Lower Peninsula land cover. Remote sensing image. Time period of content 1997 – 2001. Available: http://www.mcgi.state.mi.us/mgdl/?rel=thext&action=thmname&cid=5&cat=Land+Cover+2001

(DNR) Michigan Department of Natural Resources. 2003b. Integrated forest monitoring assessment and prescription (IFMAP) / GAP Upper Peninsula land cover. Remote sensing image. Time period of content 1997 – 2001. Available: http://www.mcgi.state.mi.us/mgdl/?rel=thext&action=thmname&cid=5&cat=Land+Cover+2001

(DNR) Michigan Department of Natural Resources, Institute for Fisheries Research. 2004a July 29. Institute for Fisheries Research GIS Working Group, Ann Arbor, MI. Accessed: 2005. URL: http://ifrgis.snre.umich.edu/

(DNR) Michigan Department of Natural Resources. 2004b. Snowmobile program 2002-2003 season report. An unpublished report prepared by the Michigan Department of Natural Resources, Law Enforcement Division.

(DNR) Michigan Department of Natural Resources. 2004c. Michigan 2004 forest health highlights. Prepared by Forest, Mineral & Fire Management Division. 8 pp. Available: http://www.michigan.gov/documents/2004ForestHealthHighlights3_116430_7.pdf

(DNR) Michigan Department of Natural Resources. Accessed 2005a. Fisheries Division Boundaries. Lansing, Michigan.

(DNR) Michigan Department of Natural Resources. 2005b. Michigan wildlife disease manual. Available: http://www.michigan.gov/dnr/0,1607,7-153-10370_12150_12220---,00.html

Donovan, M.L., G.M. Nesslage, J.J. Skillen, and B.A. Maurer. 2004. The Michigan Gap Analysis Project final report. Wildlife Division, Michigan Department of Natural Resources, Lansing, MI.

Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. Entering the watershed: a new approach to save America's river ecosystems. Island Press, Washington, D.C.

Duda, M.D. and K.C. Young. 1994. Americans and wildlife diversity: public opinion, attitudes, interest and participation in wildlife viewing and wildlife diversity programs. Prepared for The Wildlife Diversity and Watchable Wildlife Committee of the International Association of Fish and Wildlife Agencies. 155pp.

Dwyer, T.J., E.L. Derleth, and D.G. McAuley. 1980. Woodcock brood ecology in maine. In Woodcock ecology and management T.J. Dwyer and G.L. Storm (Tech. Coord.): Woodcock Symposium (7th: 1980: Pennsylvannia State University. U.S. Fish and Wildlife, Wildlife Research Report 14.

Eagle, A.C. and K. Herman. 2000. Natural areas program strategic plan. Michigan Department of Natural Resources, Lansing, MI.

Edsall, T.A. 1998. Great Lakes. Pp. 219-226 in Mac, M. J., P. A. Opler, C. E. Puckett Haecker, and P. D. Doran (eds.). Status and trends of the nation's biological resources. Vol. 2. U.S. Department of the Interior, U.S. Geological Survey, Reston, VA. 436 pp.

Edwards, R.J. 1978. The effect of hypolimnion reservoir releases on fish distribution and species diversity. Transactions of the American Fisheries Society 107:71-77.

Eisenreich, K.M. 2002. Factors influencing the recovery and productivity of the bald eagle (Haliaeetus leucocephalus) in Michigan. A thesis presented to the Graduate School of Clemson University in partial fulfillment of the requirements for the degree of Master of Science, Environmental Toxicology. 104 pp.

Elliot, J.E., R.J. Norstrom, A. Lorenzen, L.E. Hart, and H. Philibert. 1996. Biological effects of polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls in Bald eagle (Haliaeetus leucocephalus) chicks. Environmental Toxicology and Chemistry 15:782-793.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby, and J.P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell, Malden, MA.

(ESRI) Environmental Systems Research Institute, Inc. 2000. Great lakes shoreline (Gl_lakes_esri_100K). Environmental Systems Research Institute, Inc. Redlands, California.

Ewert, David. 1999. Great Lakes bird ecoregional planning: a final report. The Great Lakes Program of The Nature Conservancy, Chicago, IL.

Ewert. D.N. and M.J. Hamas. 1995. Ecology of terrestrial migratory birds during migration in the Midwest. Pages 200-208 in F. R. Thompson, III, ed. Management of Midwestern landscapes for the conservation of Neotropical migratory birds. U.S. Forest Service, Gen. Tech. Rep. NC-187. North Central For. Exp. Sta., St. Paul, MN.

Faaborg J., M. Brittingham, T. Donovan, and J. Black, 1993. Habitat fragmentation in the temperate zone: a perspective for managers. Pp. 331-338 in D.M. Finch and P.W. Stangel (eds.). Status and management of Neotropical migratory birds. USDA Forest Service, General Technical Report RM-229.

Farrand, W.R. 1988. The glacial lakes around Michigan. Michigan Department of Natural Resources, Geological Survey Division, Bulletin 4. Lansing, MI.

Fausch, K.D., C.E. Torgensen, C.V. Baxter, H.W. Li. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fish. Bioscience 52:483-498.

Franklin, J. F. 1993. Preserving biodiversity: species, ecosystems or landscapes? Ecological Applications 3(2):202-205.

Freeman, M.C., Z.H. Bowen, K.D. Bovee, and E.R. Irwin. 2001. Flow and habitat effects on juvenile fish abundance in natural and altered flow regimes. Ecological Applications 11:179-190.

Gard, N.W., M.J. Hooper, and R.S. Bennett. 1992. Effects of pesticides and contaminants on neotropical migratory birds. in D.M.Finch, and P.W. Stangel, eds. 1993. Status and Management of Neotropical Migratory Birds; 1992 September 21-28, Estes Park, CO. Gen. Tech. Rep. RM-229. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Pp 310-314.

Garling, D., S. Dann, T. Edsall., T. Grischke, S. Miller, and L. Ramseyer. 1995. Status and potential of Michigan natural resources: fisheries. A special report prepared by the Michigan Agricultural Experiment Station, Michigan State University. Special Report 74. 39pp.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59:871-883.

Ghazoul, J. 2001. Barriers to biodiversity conservation in forest certification. Conservation Biology 15:315-317.

Gilman, C. 1982. Where two worlds meet: the great lakes fur trade. Minnesota Historical Society, Museum Exhibit Series #2. St. Paul, MN.

Gislason, J.C. 1985. Aquatic insect abundance in a regulated stream under fluctuation and stable diel flow patterns. North American Journal of Fisheries Management 5:39-46.

Goforth, R.R. D. Stagliano, Y. Lee, J. Cohen, and M. Penskar. 2002. Biodiversity analysis of selected riparian ecosystems within a fragmented landscape. Michigan Natural Features Inventory Report (2002-26) prepared for Michigan Great Lakes Protection Fund and Michigan Department of Environmental Quality, Office of the Great Lakes.

Grannemann, N.G., R.J. Hunt, J.R. Nichols, T.E. Reilly, and T.C. Winter. 2000. The importance of ground water in the great lakes region. U.S. Geological Survey, Water-Resources Investigations Report 00-4008, Lansing, Michigan.

Great Lakes Commission. 1999. Dredging and the Great Lakes. Great Lakes Commission, Great Lakes Dredging Team, Ann Arbor, Michigan. 15pp.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones: focus on links between land and water. Bioscience, 41(8):540-549.

Groves, C. and L. Valutis. 1999. Guidelines for representing ecological communities in ecoregional conservation plans. The Nature Conservancy, Arlington, VA.

Groves, C., L. Valutis, D. Vostick, B. Neely, K. Wheaton, J. Touval, and B. Runnels. 2000. Designing a geography of hope: a practitioner's handbook for ecoregional conservation planning. The Nature Conservancy, Arlington, VA.

Grue, C.E., W.J. Fleming, D.G. Busby, and E.F. Hill. 1983. Assessing hazards of organophosphate pesticides to wildlife. Transactions of North American Wildlife and Natural Resources Conference 48: 200- 220.

Gutzwiller, K.J. and J.S. Wakeley, 1980. Differential use of woodcock singing grounds in relation to habitat characteristics. In Woodcock ecology and management, T.J. Dwyer and G.L. Storm (Tech. Coord.): Woodcock Symposium (7th: 1980: Pennsylvannia State University. U.S. Fish and Wildife, Wildlife Research Report 14.

Harding, J.H. 1997. Amphibians and reptiles of the Great Lakes region. The University of Michigan Press, Ann Arbor, MI.

Harrison, K. G. (editor). 2003. State of Michigan's environment 2003, second biennial report, December 2003. Special Projects, Michigan Department of Environmental Quality. Lansing, MI. 84 pages.

Haufler, J.B. 1990. Static management of forest ecosystems. in J.M Sweeney (ed.) Management of dynamic ecosystems. Proc. Of a Symposium. 51st Midwest Fish and Wildl. Conf., Springfield, Illinois. 5 Dec 1989 180pp.

Hayes, B. N. 1964. An ecological study of wet prairie on Harsons Island, Michigan. The Michigan Botanist 3: 71-82.

Hayes, T.B., A. Collins, M. Lee, M. Mendoza, N. Noriega, A.A. Stuart, and A. Vonk. 2002. Hermaproditic, demasculinized frogs after exposure to the herbicide atrazine at low ecologically relevant doses. Proceedings of the National Academy of Science 99(8): 5476-5408.

Herkert, J.R. 1994. Breeding bird communities of Midwestern prairie fragments: the effects of prescribed burning and habitat-area. Natural Areas Journal 14: 128-135.

Herman, K.D., L.A. Masters, M.R. Penskar, A.A. Reznicek, G.S. Wilhelm, W.W. Brodovich, and K.P. Gardiner. 2001. Floristic Quality Assessment with Wetland Categories and Examples of Computer Applications for the State of Michigan – Revised, 2nd Edition. Michigan Department of Natural Resources, Wildlife, Natural Heritage Program. Lansing, MI. 19pp. + Appendices.

Hoagman, W. J. 1998. Great Lakes Wetlands. Michigan Sea Grant Publications. Ann Arbor, Michigan.

Holden, P.B. 1979. Ecology of riverine fish in regulated stream systems with emphasis on the Colorado River, p. 57-74. In: The ecology of regulated streams. J.V. Ward and J.A. Stanford (eds). Plenum Press, New York.

Hunter, W.C., D.A. Buehler, R.A. Canterbury, J.L. Confer, and P.B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29(2):440-455.

Hyde, D., J. Paskus, N. Fuller, and J. Simoes. 2003. Conservation site plan for Mitchell's satyr butterfly. A report prepared by Michigan Natural Features Inventory and Southwest Michigan Land Conservancy for the Michigan Department of Natural Resources. MNFI Report No. 2003-9.

Hynes, H.B.N. 1970. The ecology of running waters. University of Toronto Press, Toronto.

International Joint Commission. 1999. Protection of the waters of the Great Lakes. Interim Report to the Governments of Canada and the United States.

(IUCN) International Union for Conservation of Nature and Natural Resources. 2003 IUCN red list of threatened species. Available: http://www.redlist.org.

Kalff, J. 2002. Limnology. Prentice Hall, Inc. NJ. 592 pp.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68.

Karr, JR, and I.J. Schlosser. 1978. Water resources and the land-water interface. Science 201:229-234.

Kiesecker, J.M. 2002. Synergism between trematode infection and pesticide exposure: A link to amphibian limb deformities in nature? Proceedings of the National Academy of Science 99(15): 9900-9904.

Kiesecker, J.M., L.K. Belden, K. Shea, and M.J. Rubbo. 2004. Amphibian decline and emerging disease. American Scientist 92:138-147.

Kingsbury B., J. Manning, and J. Stage. 2004. Massasauga ecology in Michigan an update on research prepared for the Michigan Department of Natural Resources, Wildlife Division. 180pp.

Kingsbury, B. and J. Gibson. 2002. Habitat management guidelines for amphibians and reptiles of the midwest. Partners in Amphibian and Reptile Conservation. 57p

Koel, T.M., K.S. Irons, and E. Ratcliff. 2000. Asian carp invasion of the upper Mississippi River System. Project Status Report 2000-05. USGS Upper Midwest Environmental Sciences Center.

Kohler, C. C. and W. Hubert, editors. 1993. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Kolar, C.S. and D.M. Lodge. 2002. Ecological Predictions and Risk Assessment for Alien Fish in North America. Science 298: 1233-1236.

Kost, M.A. 2001. Natural community abstract for relict conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 6pp.

Koval, M.H. and A.G. Mertig. 2002. Attitudes towards natural resources and their management: a report on the "2001 resource attitudes in Michigan survey." A report to the Michigan Department of Natural Resources, Wildlife Division. PR project W-127-R-16. 166p.

Kurta, A., D. King, J.A. Teramino, J.M. Stribley, and K.J. Williams. 1993. Summer roosts of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. American Midland Naturalist 129:132-138.

Kurta, A. 2004. Habitat requirements of the endangered Indiana bat in southern Michigan: 2004 progress report. Submitted to Michigan Department of Natural Resources, Wildlife Division. 14pp.

Kurta, A. 1995. Mammals of the Great Lakes region (rev. ed.). University of Michigan. Ann Arbor, MI.

Levin, D.A. 2002. Hybridization and extinction. American Scientist 90: 254-261.

Ligon, F. K., W. E. Dietrich, and W. J. Trush. 1995. Downstream ecological effects of dams. BioScience 45(3):183-192.

Lindorff, D., J. Helmuth, D. Johnson, and S. Karklins, editors. 1997. Status of groundwater quantity in Wisconsin. WDNR Publication No. PUBL-DG-043-97, Madison, Wisconsin

MacNally, R., A.F. Bennett, G.W. Brown, L.F. Lumsden, A. Yen, S. Hinkley, P. Lillywhite, and D. Ward. 2002. How well do ecosystem-based planning units represent different components of biodiversity? Ecological Applications 12:900-912.

Madenjian, C.P., G.L. Fahnenstiel, T.H. Johengen, T.F. Nalepa, H.A. Vanderploeg, G.W. Fleischer, P.J. Schneeberger, D.M. Benjamin, E.B. Smith, J.R. Bence, E.S. Rutherford, D.S. Lavis, D.M. Roberson, D.J. Jude, and M.P. Ebener. 2002. Dynamics of the Lake Michigan food web, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences 59:736-753.

Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. Nature 405:234-253.

Margules, C.R., A.O. Nicholls, and R.L. Pressey. 1988. Selecting networks of reserves to maximize biological diversity. Biological Conservation 43:63-76.

Maxwell, J.R., C.J. Edwards, M.E. Jensen, S.J. Paustian, H. Parrott, and D.M. Hill. 1995. A hierarchical framework of aquatic ecological units in North America (Nearctic zone). United States Department of Agriculture, Forest Service, North Central Forest Experiment Station. General Technical Report NC-176. St. Paul Minnesota.

McPeek, G.A. and R.J. Adams (eds.). 1994. The Birds of Michigan. Indiana University Press, Bloomington & Indianapolis, IN.

(MDEQ) Michigan Department of Environmental Quality. 1999. Michigan's relative risk task force report on air quality issues. Prepared by Air Quality Task Force, G. Wolff (chair).

(MDEQ) Michigan Department of Environmental Quality. 2003a. Beach maintenance and removal of vegetation on great lakes bottomlands in Michigan. Available: http://www.deq.state.mi.us/documents/deq-glm-water-greatlakes-InformationSheet.pdf

(MDEQ) Michigan Department of Environmental Quality. 2003b. Fish contaminant monitoring program: review and recommendations. Unpublished report prepared for Michigan Department of Environmental Quality by Exponent®

(MDEQ) Michigan Department of Environmental Quality. 2003c. Ground water withdrawal disputes. Fact Sheet, MDEQ Water Division Groundwater Section, Lansing, Michigan.

(MDEQ) Michigan Department of Environmental Quality. 2005. Tittabawassee River aquatic ecological risk assessment report. Unpublished report prepared for Michigan Department of Environmental Quality by Galbraith Environmental Sciences, LLC.

Meffe, G.K., C.R. Carroll, (eds.). 1994. Principles of Conservation Biology. Sinauer Associates, Inc. Sunderland, MA. pp 242-243.

Menzel B.W. 1983. Agricultural management practices and the integrity of instream biological habitat. In Schaller FW, Bailey GW, editors. Agricultural management and water quality. Iowa State University Press, Ames, Iowa, USA; 305-329.

Michigan Department of Labor and Economic Growth. 2005. Industry employment forecasts 2000 – 2010. Available: http://www.michlmi.org/LMI/ind_proj/sic_02.htm

Michigan Economic Development Corporation. 2005. Economic overview: a widely diversified economy. Available: http://medc.michigan.org

Michigan Land Use Leadership Council. 2003. Michigan's land, Michigan's future. Final report of the Michigan Land Use Leadership Council, submitted to Governor Jennifer Granholm and the Michigan legislature. Lansing, MI. 89 pages.

Michigan Sea Grant. 2002. Great Lakes coastal wetlands [Online]. Michigan Sea Grant. Available: http://www.miseagrant.org/wetlands/

Miller, J.R. and R.J. Hobbs. 2002. Conservation where people live and work. Conservation Biology 16: 330-337.

Mills, E.L., J.H. Leach, J.T. Carlton, and C.L. Secor. 1994. Exotic species and the integrity of the Great Lakes. Bioscience 44:666-676.

(MNFI) Michigan Natural Features Inventory. 2002. Michigan's Special Animals. Available: http://web4.msue.msu.edu/mnfi/data/animal_list.pdf

(MNFI) Michigan Natural Features Inventory). 2003. Michigan's natural communities: draft list and descriptions. Michigan Natural Features Inventory, Lansing, MI. 36 pp. Available: http://www.msue.edu/mnfi/lists/natural_community_types.pdf

(MNFI) Michigan Natural Features Inventory. Accessed 2005. Statewide Biotics 4 database. Lansing, MI.

Mitsch, W. J. and J. G. Gosselink. 1993. Wetlands, 2nd edition. Van Nostrand Reinhold, NewYork.

Morrison, M.L., B.G. Marcot, and R.W. Mannan. 1998. Wildlife-habitat relationships: concepts & applications, 2nd edition. The University of Wisconsin Press, Madison, WI.

National Biological Information Infrastructure. 2005. NBII wildlife disease information node factsheet. Available: http://www.nbii.gov/about/pubs/factsheet/pdf/WDIN.pdf

National Environmental Education & Training Foundation and Roper Starch Worldwide. 1998. 1998 NEETF/Roper Survey: Main street America's view of the environment. 61 pp.

National Invasive Species Council. 2001. Meeting the invasive species challenge. A report to Congress. Available: http//www.invasivespecies.gov/council/nmptoc.shtml

NatureServe. 2004. NatureServe Explorer: An online encyclopedia of life [web application]. Version 3.1. NatureServe, Arlington, Virginia. Available: http://www.natureserve.org/explorer

Nielson, C., and T. Buchanan. 1986. A comparison of the effectiveness of two interpretive programs regarding fire ecology and fire management. Journal of Interpretation, 1: 1–10.

Niemi, G. J., and J. R. Probst. 1990. Wildlife and fire in the upper midwest. In Management of dynamic ecosystems, J. M. Sweeney, ed., 31-46. West Lafayette, Indiana: The Wildlife Society.

(NOAA) National Ocean and Atmospheric Administration. 2004 July 6. U.S. Department of Commerce's NOAA, National Geophysical Data Center's Marine Geology and Geophysics Division and NOAA, Great Lakes Environmental Research Laboratory. <http://www.noaa.gov/>. Accessed: 2005.

Noon, B.R. 2003. Conceptual issues in monitoring ecological resources. Pages 27-71 in DE Busch and JC Trexler (eds) Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives. Island Press, Wash. DC.

Norris, P.E., and J. Soulé. 2003. Managing land use change and Michigan's future. in Michigan's opportunities and challenges, Michigan State University faculty perspectives. (Online Cited 1/17/05) Available: http://www.msue.msu.edu/msue/iac/transition/papers/index.htm

Noss, R.F. 1987. From plant communities to landscapes in conservation inventories: a look at The Nature Conservancy (USA). Biological Conservation 41:11-37.

Noss, R.F. 1990a. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

Noss, R.F. 1990b. What can wilderness do for biodiversity? In P. Reed (eds.) Preparing to manage wilderness in the 21st century. General Technical Report SE-66. USDA Forest Service, Southeastern Forest Experiment Station, Asheville, NC.

Noss, R.F. and A.Y. Cooperrider. 1994. Saving nature's legacy: protecting and restoring biodiversity. Island Press, Washington D.C.

Noss, R.F. and J.M. Scott. 1997. Ecosystem protection and restoration: the core of ecosystem management. Pp. 239-264 in Boyce, M.S. and A. Haney (eds.). Ecosystem management: applications for sustainable forest and wildlife resources. Yale University Press, New Haven, CT.

Olden, J.D., D.A. Jackson, and P.R. Peres-Neto. 2001. Spatial isolation and fish communities in drainage lakes. Oecologia 127:572-585.

Osborne, L.L., and D. A. Kovacic. 1993. The influence of riparian vegetation on nutrient losses in a Midwestern stream watershed. Freshwater Biology 29:243-258.

Osborne, L.L. and M.J. Wiley. 1992. Influence of tributary spatial position on the structure of warmwater fish communities. Canadian Journal of Fisheries and Aquatic Sciences 49:671-681.

Parrish, J.D., D.P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. Bioscience 53:851-860.

Peacock, John W., Schweitzer, Dale F., Carter, Jane L. and Dubois, Normand R. 1998. Laboratory Assessment of the effects of *Bacillus thuringiensis* on native Lepidoptera. Environmental Entomology 27(2): 450-457.

Pegg, M.A., A.M. Lemke, J.A. Stoeckel. 2002. Establishment of bighead carp in an Illinois River floodplain lake: a potential source population for the Illinois River. Journal of Freshwater Ecology 17: 161-163.

Penskar, M.R., D.A. Hyde, J.A. Olsen, M.A. Kost, P.J. Higman, J.J. Paskus, R.L. Boehm, and M.T. Fashoway. 2000. Biological inventory for conservation of great lakes islands: year 1999 report. Prepared for Michigan Coastal Management Program, Land and Water Management Division, Michigan Department of Environmental Quality. Report No. 2000-11.

Perry, W.L., J.L. Feder, and D.M. Lodge. 2001. Hybridization and introgression between introduced and resident *Orconectes* crayfish; Implications for conservation. Conservation Biology 15:1656-1666.

Pess, G.R., T. J. Beechie, J. E. Williams, D. R. Whitall, J. I. Lange, and J. R. Klochak. 2003. Watershed Assessment Techniques and the Success of Aquatic Restoration Activities. Pages 185-201 in Wissmar, R. C., and P. A. Bisson, editors. 2003. Strategies for restoring river ecosystems: sources of variability and uncertainty in natural and managed systems. American Fisheries Society, Bethesda, Maryland.

Petersen, E.T. 1979. Hunters' heritage: a history of hunting in Michigan. Michigan United Conservation Clubs. Lansing, MI. 55p.

Peyton, R.B. 1990. Institutional and public constraints on dynamic management of fish and wildlife resources. in J.M Sweeney (ed.), Management of dynamic ecosystems. Proc. Of a Symposium. 51st Midwest Fish and Wildl. Conf., Springfield, Illinois. 5 Dec 1989 180pp.

Pimentel D., L. Lach, R. Zuniga, and D. Morrison. 1999. Environmental and economic costs associated with non-indigenous species in the united states. College of Ag & Life Sci., Cornell Univ. unpublished, Available: http//www.news.cornell.edu/releases/Jan99/species_costs.html

Pinkham, R. 2000. Daylighting: new life for buried streams. Rocky Mountain Institute.

Poff, N.L. and J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46:1805-1818.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. Bioscience 47:769-784.

Poiani, K.A., B.D. Richter, M.G. Anderson, and H.E. Richter. 2000. Biodiversity conservation at multiple scales: functional sites, landscapes, and networks. Bioscience 50: 133-146.

Premo, B.J., D.T. Long, R.J. Huggett, D. Premo, W.W. Taylor, G.T. Wolff, and K.G. Harrison. 2001. Recommended environmental indicators program for the state of Michigan, July 2001. Michigan Environmental Science Board, Lansing. x +88pp.

Pringle, C.M. 1997. Exploring how disturbance is transmitted upstream: going against the flow. Journal of the North American Benthological Society 16:425-438.

Public Sector Consultants. 2001. Michigan land resource project. Prepared for the Frey Foundation and W.K. Kellogg Foundation on behalf of the Michigan Economic and Environmental Roundtable. Lansing, Mich.: PSC.

Public Sector Consultants. 2002. Land use and sustainability. In: Michigan in brief. Prepared for the Michigan Nonprofit Organization and the Council of Michigan Foundations. http://www.michiganinbrief.org/edition07/Chapter5/LandUse.htm

Pullium, H.R. 1988. Sources, sinks and population regulation. The American Naturalist 132:652-661.

Rabe, M.L. 2001. Special animal abstract for *Lycaeides Melissa samuelis* (Karner blue). Michigan Natural Features Inventory. Lansing, MI. 6pp.

Rabinowitz, D. 1981. Seven forms of rarity. in The biological aspects of rare plant conservation. H. Synge (ed.). John Wiley & Sons Inc. pp 205-217.

Radomski, P.J. and T.J. Goeman. 1995. The homogenizing of Minnesota fish assemblages. Fisheries 20:20-23.

Raibley, P.T., D. Blodgett, and R.E. Sparks. 1995. Evidence of grass carp (Ctenopharyngodon idella) reproduction in the Illinois and upper Mississippi Rivers. Journal of Freshwater Ecology 10:65-74.

Reinert, H.K. and W.R. Kodrich. 1982. Movements and habitat utilization by the massasauga, *Sistrurus catenatus catenatus*. Journal of Herpetology 16(2):162-171.

Resh, V.H., A.V. Brown, A.P. Covich, M.E. Gurtz, H.W. Li, G.W. Minshall, S.R. Reice, A.L. Sheldon, J.B. Wallace, R.C. Wissmar. 1988. The role of disturbance in stream ecology. Journal of the North American Benthological Society 7:433-455.

Rhymer, J.M. and D. Simberloff. 1996. Extinction by hybridization and introgression. Annual Review of Ecology and Systematics 27:83-109.

Ricciardi, A. 2001. Facilitative interactions among aquatic invaders: is an "invasional meltdown" occurring in the Great Lakes? Canadian Journal of Fisheries and Aquatic Sciences 58:2513-2525.

Richards, R.P. 1990. Measures of flow variability and a new flow-based classification of Great Lakes tributaries. Journal of Great Lakes Research 16:53-70.

Richter, B.D., D.P. Braun, M. A. Mendelson, and L.L. Master. 1997a. Threats to imperiled freshwater fauna. Conservation Biology 11:1081-1093.

Robbins, C., D. Dawson, and B. Dowell. 1989. Habitat area requirements of breeding forest birds of the Middle Atlantic States. Wildlife Monographs 103:1-34.

Roberts, T. M., T. Robson, and P. J. Catling. 1977. Factors maintaining a disjunct community of *Liatris spicata* and other prairie species in Ontario, Canada. Canadian Journal of Botany 55: 593-605

Robinson, S.K., J.A. Grzybowski, S.I. Rothstein, M.C. Brittingham, L.J. Petit, and F.R. Thompson. 1993. Management implications of cowbird parasitism on Neotropical migrant songbirds. in D.M. Finch and P.W. Stangel (eds.). Status and management of Neotropical migratory birds. USDA Forest Service, General Technical Report RM-229, pp. 93-102

Rocky Mountain Bird Observatory. 2002. Partners in flight: species assessment database [web application]. Rocky Mountain Bird Observatory, Brighton, Colorado. Available: http://www.rmbo.org/pif/pifdb.html.

Rosenberg, K.V., R.W. Rohrbaugh, S.E. Barker, J.D. Lowe, R.S. Hames, and A.A. Dhondt. 1999. A land mangers guide to improving habitat for Scarlet Tanagers and other forest-interior birds. The Cornell Lab of Ornithology. Ithaca, NY.

Rosenburg, K.V., R.S. Hames, R.W. Rohrbaugh, Jr., S. Barker Swarthout, J.D. Lowe, and A.A. Dhoundt. 2003. A land manager's guide to improving habitat for forest thrushes. The Cornell Lab of Ornithology.

Rosgen, D. 1996. Applied river morphology, second edition. Wildland Hydrology, Pagosa Springs, CO.

Rusch, D.H., C.D. Ankney, H. Boyd, J.R. Longcore, F. Montalbano III, J.K. Ringelman, and V.D. Stotts. 1989. Population ecology and harvest of the American Black Duck: a review. Wildlife Society Bulletin 17(4):379–406

Salafsky, N. and R. Margoluis. 1999. Threat reduction assessment: a practical and cost-effective approach to evaluating conservation and development projects. Conservation Biology 13:830-841.

Salafsky, N., D. Salzer, J. Ervin, T. Boucher, and W. Otlie. 2003. Conventions for defining, naming, measuring, combining, and mapping threats to conservation: an initial proposal for a standard system, December 2003 Draft. Bethesda, MD.

Sargent, M.S and Carter, K.S., ed. 1999. Managing Michigan's Wildlife: A Landowners Guide. Michigan United Conservation Clubs, East Lansing, MI. 297pp.

Salzer, D. and N. Salafsky. 2004. Proposed Taxonomy of Conservation Actions, November 2004 Draft. Methesda, MD.

Scharf, W.C. 1971. Critical nesting and migration areas survey. Unpublished report prepared for the Shoreline Study of the Great Lakes Basin Shoreline Survey. Great Lakes Basin Commistion.

Scharf, W.C. 1996. The importance of Great Lakes islands to neartic-neotropical migrant birds. in K.E. Vigmostad (ed.) State of the Great Lakes Islands Report: Proceedings from the August 18-22, 1996 workshop, Roscommon, MI pp 42-26.

Schloesser, D.W., W.P. Kovalak, G.D. Longton, K.L. Ohnesorg, and R.D. Smithee. 1998. Impact of zebra and quagga mussels (Dreissena spp.) on freshwater unionids (Bivalvia: Unionidae) in the Detroit River of the Great Lakes. American Midland Naturalist 140:229-313.

Schlosser, D.W., W.P. Kovalak, G.D. Longton, K.L. Ohnesorg, and R.D. Smithee. 1998. Impact of zebra and quagga mussels (Dreissena spp.) on freshwater unionids (Bivalvia: Unionidae) in the Detroit River of the Great Lakes. American Midland Naturalist 140:299-313.

Schlosser, I.J. 1993. From local habitat patches to landscapes in stream fish ecology. in Hamilton, S.W., E.W. Chester, and A.F. Scott (eds), Proceedings of the fifth annual symposium on the natural-history of lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State University, Clarksville, Tennessee. pp. 17-30

Schlosser, I.J. 1995a. Critical landscape attributes that influence fish population dynamics in headwater streams. Hydrobiologia 303:71-81.

Schlosser, I.J. 1995b. Dispersal, boundary processes, and trophic-level interactions in streams adjacent to beaver ponds. Ecology 76:908-925.

Schwab, G.O., D.D. Fangmeier, W. J. Elliot, and R. K. Frevert. 1993. Soil and Water Conservation Engineering. John Wiley & Sons, Inc., New York.

Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.C. Edwards, Jr., J. Ulliman, and G. Wright. 1993. Gap analysis: A geographic approach to protection of biological diversity. Wildlife Monographs 123.

Seelbach, P.W., M.J. Wiley, J.C. Kotanchik, and M.E. Baker. 1997. A landscape-based ecological classification system for river valley segments in lower Michigan (MI-VSEC version 1.0). Michigan Department of Natural Resources, Fisheries Research Report 2036, Ann Arbor.

Seigel, R.A. 1986. Ecology and conservation of an endangered rattlesnake, *Sistrurus catenatus*, in Missouri, USA. Biological Conservation 35:333-346.

Shire, G., K. Brown, and G. Winegrad. 2000. Communications towers: a deadly hazard to birds. American Bird Conservancy, Washington D.C.

Shuman, J.R. 1995. Environmental considerations for assessing dam removal alternatives for river restoration. Regulated Rivers: Research & Management 11:249-261.

Sillett, T.S. and R. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71:296-308.

Smyth, P. 1995. Patterns on the land: our choices, our future. Prepared for the Planning and Zoning Center on behalf of the Michigan Society of Planning Officials. Rochester, MI.

Snodgrass, J.W. and G.K. Meffe. 1998. Influence of beavers on streamfish assemblages: effects of pond age and watershed position. Ecology 79:928-942.

Sparks, R.E. 1995. Need for ecosystem management of large rivers and their floodplains. Bioscience 45:168-182.

Spieles, J.B., P.J. Comer, D.A. Albert, and M.A. Kost. 1999. Natural community abstract for prairie fen. Michigan Natural Features Inventory, Lansing, MI. 4pp.

Strong, D.R. and R.W. Pemberton. 2000. Biological control of invading species—risk and reform. Science 288:1969-1970.

Swengel, A.B. and S.R. Swengel. 1997. Co-occurrence of prairie and barrens butterflies: applications to ecosystem management. Journal of Insect Conservation 1:131-144.

Tepley, A.J., J.G. Cohen, and L. Huberty. 2004. Natural community abstract for southern floodplain forest. Michigan Natural Features Inventory, Lansing, MI. 14pp.

(TNC) The Nature Conservancy. 1999. Great Lakes ecoregional plan: a first iteration. Great Lakes Ecoregional Planning Team, Great Lakes Program, Chicago, IL. 85pp.

(TNC) The Nature Conservancy. 2000. Toward a new conservation vision for the Great Lakes Region: A second iteration. The Nature Conservancy. Chicago, IL.

(TNC) The Nature Conservancy. 2003. The North Central Tillplain Ecoregion: a conservation plan. The Nature Conservancy.

(TNC) The Nature Conservancy and Nature Conservancy of Canada. 2002. The Superior Mixed Forest Ecoregion: a conservation plan. The Nature Conservancy.

Tonn, W.M. and J.J. Magnuson. 1982. Patterns in the species composition and richness of fish assemblages in northern Wisconsin Lakes. Ecology 63:1149-1166.

U.S. Census Bureau. 2005. Michigan quick facts (Online Cited 1/15/05) Available: http://quickfacts.census.gov

U.S. Department of Commerce. 2005. Regional Economic Accounts. Bureau of Economic Analysis Web site. Available: http://www.bea.gov/

(USDA) U.S. Department of Agriculture. 1997. Census of agriculture—state-level data. National Agricultural Statistics Services, Available: http://www.nass.usda.gov/census/census97/volume1/mi-22/toc97.htm

(USDA) U.S. Department of Agriculture. 2002. Census of agriculture—state-level data. National Agricultural Statistics Services, Available: http://www.nass.usda.gov/census/census92/volume1/mi-22/92_mi.htm

(USDA) U.S. Department of Agriculture. 2003. Emerald ash borer: Michigan eradication strategy. Available: http://www.emeraldashborer.info

(USEPA) U.S. Environmental Protection Agency. 2005a. Wetlands website. Available: http://www.epa.gov/owow/wetlands/types/marsh.html

(USEPA) U.S. Environmental Protection Agency. 2005b. Mercury in the environment website. Available: http://www.epa.gov/grtlakes/seahome/mercury

(USFWS) U.S. Fish and Wildlife Service. 1985. Kirtlands warbler recovery plan (updated 1985). An unpublished report prepared by the United States Fish and Wildlife Service.

(USFWS) U.S. Fish and Wildlife Service. 1994. Determination of endangered status for Hungerford's crawling water beetle. Federal Register 59(44) 10580-10584.

(USFWS) U.S. Fish and Wildlife Service. 1999. Agency Draft Indiana Bat (*Myotis sodalis*) revised recovery plan. Fort Snelling, Minnesota. 53pp.

(USFWS) U.S. Fish & Wildlife Service, National Wetlands Inventory. Accessed 2005. National Wetlands Inventory Data 1979-1994. St. Petersburg, Florida.

(USFWS) U.S. Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau. 2001. 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. 46pp.

(USFS) U.S. Forest Service. 2004. Forest Service website – sensitive species info for MI National Forests. http://www.fs.fed.us/biology/resources/pubs/tes/fs_ss_1dec04.pdf

(USGS) U.S. Geological Survey, National Water Quality Assessment Program. 2005a. Accessed: 2005 April 14. U.S. Department of the Interior Geological Survey. URL: http://water.usgs.gov/nawqa/

(USGS) U.S. Geological Survey. 2005b. American woodcock. Information provided on the National Biological Survey website. Available: http://biology.usgs.gov

University of Michigan. 2003. Michigan Odonata survey master database [web application]. Museum of Zoology, University of Michigan, Ann Arbor, Michigan. Available: http://insects.ummz.lsa.umich.edu/MICHODO/MOS.html.

University of Michigan, Museum of Zoology, Division of Reptiles and Amphibians. Acessed:2005. Amphibian and reptile database. Ann Arbor, Michigan.

Ward, J.V. and J.A. Stanford. 1989. Riverine ecosystems: the influence of man on catchment dynamics and fish ecology. Pages 56-64 in D. P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7.

Watters, G.T. 1996. Small dams as barriers to freshwater mussels (Bivalvia, Unionoida) and their hosts. Biological Conservation 75:79-85.

Western, D., and R. M. Wright. 1994. Natural connections: perspectives in community-based conservation. Island Press, Washington, DC, USA.

Wetzel, R.G. 2001. Limnology: Lake and river ecosystems. Third edition. Academic Press. 1006 pages.

Whitcomb, R.F., C.S. Robbins, J.F. Lynch, B.L. Whitcomb, M.K. klimkiewica, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pp. 125-206 in: R.L. Burgess and D.M. Sharpe, eds. Forest island dynamics in man dominated landscapes. Springer-Verlag, New York.

Wilcox, D. A. and J. E. Meeker. 1992. Implications for faunal habitat related to altered macrophyte structure in regulated lakes in northern Minnesota.

Wiley, M.J., S.L. Kohler, and P.W. Seelbach. 1997. Reconciling landscape and local views of aquatic communities: lessons from Michigan trout streams. Freshwater Biology 37:133-148.

Williams, J.D. and G.K. Meffe. 1998. Nonindigenous Species. pp. 117-129 in Mac, M. J., P. A. Opler, C. E. Puckett Haecker, and P. D. Doran (eds.). Status and trends of the nation's biological resources. Vol. 1. U.S. Department of the Interior, U.S. Geological Survey, Reston, Va.

Witter, D.J. 1990. Wildlife management and public sentiment. in J.M Sweeney (ed.) Management of dynamic ecosystems. Proc. Of a Symposium. 51st Midwest Fish and Wildl. Conf., Springfield, Illinois. 5 Dec 1989 180pp.

Zorn, T.G., P.W. Seelbach, and M.J. Wiley. 1998. Patterns in the distributions of stream fish in Michigan's lower peninsula. Michigan Department of Natural Resources Fisheries Research Report No. 2035. Lansing, Michigan.