Biodiversity Assessment of Michigan
Technical Report

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Introduction

Michigan is approximately 37 million acres in size, and contains over 43,000 miles of rivers and streams, nearly 11,000 inland lakes, as well as over 4,500 miles of Great Lakes shoreline. Its diverse glaciated terrain contains a variety of forest, wetland, and grassland communities that provide habitat to over 15,000 native species of insects, 1,815 native species of vascular plants, and 691 native species of animals (Evers 1994). Several of these species, such as Michigan monkey flower and dwarf lake iris are only found in the Great Lakes region.

Michigan's landscape, however, has undergone major changes over the last century and the pace of this change is rapidly increasing. Between 1982 and 1997, acreage of developed land in Michigan grew by over 30 percent. If current trends continue, projections indicate that the built areas of Michigan will increase by 178% between 1980 and 2040 (Public Sector Consultants 2001). In addition to direct habitat destruction, sprawling development patterns are continuing to fragment Michigan's remaining forests, grasslands, and wetlands, as well as alter hydrologic routing and increase levels of stormwater.

As a result of these and other changes to the landscape that have occurred since the early 1800's, 665 species of the state's plants, birds, mammals, reptiles, amphibians, fish, insects, and mollusks are listed as threatened, endangered, and special concern. In addition, 46 plants and 10 animals are currently extinct or extirpated in Michigan (Michigan Natural Features Inventory 2006). The major factor contributing to this loss of biological diversity or biodiversity is loss of habitat. Since the mid 1800's, Michigan has lost over 99 percent of its prairies, oak savannas, and oak and oak-pine barrens. What remains of these communities tend to be small, isolated patches. Michigan has also lost approximately 35 percent of its wetlands through conversion to urban and agricultural land uses, with most of these losses occurring in the southern portion of the Lower Peninsula. In some counties, over 75 percent of the wetlands have been lost. In addition, Michigan has lost approximately 50% of its forest cover, with the majority of that loss occurring in the southern Lower Peninsula.

One of the first steps towards conserving Michigan's natural heritage is knowing what is left on the landscape. With limited resources it is especially important to be able to identify and prioritize the best places to conserve biodiversity. Before too many resources have been allocated, and before too much of our precious natural heritage is lost, a focused effort to assess Michigan's biodiversity needs to be conducted. This technical report was born out of the MDNR's Wildlife Action Plan (WAP), which was officially approved by the Natural Resource Council in November, 2005 (Eagle et al. 2005). Of the fourteen threats identified in the WAP, fragmentation was listed as one of the two most important threats to the future of Michigan's wildlife and landscape features. Conservation needs identified in the WAP to address fragmentation include: 1) identifying large tracts and systems to target for protection, 2) identifying areas of biological significance, 3) identifying lands that serve as important linkages between isolated patches of priority landscape features, and 4) completing an analysis of biodiversity elements to identify areas of high biodiversity regardless of ownership type. In addition, another key issue identified in the plan focuses on ecosystem representation and networks. Conservation needs to address this issue include: 1) establishing a cooperative system that captures the full variety of landscape features and associated wildlife and 2) identifying and protecting additional important lands in representative networks (Eagle et al. 2005).

To address the conservation needs stated in the WAP the following key questions need to be answered:

1. How do we go about conducting a biodiversity assessment for the state of Michigan?

2. What type of framework should be used to organize the landscape and conduct a statewide analysis?
3. What parts of biodiversity should we focus on for conservation?
4. Where are the best places to conserve these elements of biodiversity?

Goals

Ultimately, Michigan's biodiversity needs to be protected by maintaining and restoring all natural community and aquatic ecosystem types, as well as viable populations of all native species in natural patterns of abundance and distribution. The primary goal of this initial effort was to gather, develop, and assess a series of data layers for both terrestrial and aquatic natural features that could be used for future conservation planning efforts at multiple scales. Ultimately, we hope this project provides a foundation for end users to target potentially important terrestrial and aquatic biodiversity areas across the state for biological surveys, and eventually strategic conservation at a variety of scales.

This work will inform one of the most important conservation strategies identified in the WAP; the development of a cooperative, voluntary based, statewide, conservation network by providing information and data layers focused on: 1) large, intact natural landscapes, 2) rare species hotspots, 3) representative natural areas and high quality natural communities, 4) functional watersheds, and 5) rare and high quality stream segments and lakes.

One of the key decisions made early on in this project was to provide end users with a series of data layers, that can be mixed and matched depending on the end users needs and preferences, to construct a conservation network or help set priorities for inventory. One of the shortcomings with providing a statewide conservation network is that watershed councils, township planning commissions, and park managers all have different conservation values, as well as different needs to help them assess important conservation areas. Providing access to multiple data layers allows the end user to determine their own methods of analysis for identifying important conservation areas for whatever jurisdiction or region that may be of interest. Likewise, it was also decided that at least one possible conservation network alternative would be provided from a scientific point of view. This gives end users the option of utilizing an existing, defensible product, or at the very least an alternative that can be modified to best suit their needs.

Major Steps

The four major steps of this project were to: 1) review other state biodiversity projects; 2) enhance the natural heritage database; 3) develop an approach and methodology for a GIS biodiversity assessment; and 4) conduct the GIS analysis and develop a technical product.

Review Other State Biodiversity Projects

Before initiating a biodiversity project in Michigan, we explored and summarized other state level biodiversity conservation efforts from around the country. We expected that only a few such projects existed. In fact, we found that 24 states were involved in some sort of statewide terrestrial biodiversity project since the early 1990's, however, only three state projects involved aquatic biodiversity (Florida, Massachusetts, and Missouri). Only a few of these projects were completed as of December 2002, most were a work in progress, and some were just getting under way. In total, 35 different projects from 24 states were reviewed. We used these previous efforts to inform the approach we developed to ensure we captured the best components.

Enhance the Natural Heritage Database

The natural heritage database is a critical component of the biodiversity assessment. In fact it is probably the heart of the assessment. When this project was initiated, the Michigan Natural Features

Inventory (MNFI) had a high volume of data backlog to review in each of the field science disciplines, particularly zoology and botany. In addition, many of our existing Element Occurrences' (EOs) were missing relevant pieces of information such as EO rank, or required a comprehensive review due to revised EO specifications or other issues. During the course of this project, over 2,500 element occurrence records were added to the MNFI database. In addition, all plant, animal, and natural community records were quality checked for element occurrence rank and spatial location accuracy. For the terrestrial natural communities, a new procedure was developed to improve the standardization of natural community ranks, provide consistent identification of natural community observations, and provide consistent specifications for each type of natural community.

Develop an Approach and Methodology

As stated previously, Michigan's biodiversity comes from both terrestrial and aquatic ecosystems. These ecosystems and associated species have evolved, function, and are classified very differently. Terrestrial ecosystems are primarily influenced by climate, landforms, soils, and vegetation and are described in terms of biomes, ecoregions, landscapes, and vegetation types. Whereas aquatic ecosystems are also influenced by these variables, they are further defined by how water flows over the landscape and are described in terms of basins, watersheds, and water body types. As a result, species distributions and migrations for most aquatic species tend to be restricted to watersheds. Terrestrial species on the other hand tend to be much less restricted, and many terrestrial animal species use both terrestrial and aquatic habitats to complete their life cycle or to exploit resources.

Another complication is the discrepancy in available classification frameworks. A solid framework and classification system had already existed and has been tracked in the MNFI database for terrestrial systems in Michigan for several decades. On the other hand, frameworks and classifications for aquatic systems have only recently been described, are still under development and have not been tracked by MNFI. In Michigan, it is critical that both terrestrial and aquatic elements are taken into account, in order to sufficiently address biodiversity. As a result of the functional and practical differences, the terrestrial and aquatic analyses were generally conducted separately. By having both, it also makes it possible to combine data layers and identify places that are important for both terrestrial and aquatic biodiversity.

We outlined a methodology and conducted preliminary analyses for conducting a statewide assessment for terrestrial and aquatic biodiversity. We used a fine and coarse filter approach with prioritization to represent biodiversity at a variety of levels; this approach has been frequently used and advocated for (Angermeir and Schlosser 1995, Grossman et al. 1998, Abel et al. 2000, Noss 2004). More information will be given on the fine and coarse filter approach in the approach section of this document. This methodology brings together existing and newly created data to begin assessing Michigan's biodiversity statewide and regionally as well as identifying weaknesses or information gaps needed to create a more robust assessment.

Develop Technical Product

The primary purpose of this effort was to produce a technical report detailing a methodology for conducting a statewide assessment for biodiversity in Michigan. This report brings together existing GIS data layers and produces new data layers with associated metadata relevant to the assessment. This information can be used to begin answering key conservation questions, and to address some of the most important conservation needs outlined in Michigan's WAP. As a follow up to this project, it is our intention to utilize the information resulting from this project along with additional input, information, and analyses to create a user-friendly publication, such as Massachusetts' BioMap and Living Waters or Oregon's Living Landscape, for the state of Michigan.

Brief Summary of Michigan's Biological Diversity

What exactly are we trying to conserve? Most conservation references today focus on the conservation of an area's biological diversity or biodiversity. Biodiversity is most simply defined as the variety of life on earth and its processes. More specifically, it is the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting (Noss and Cooperrider 1994). It is typically measured at several levels of organization: genes, species, natural communities, and landscape ecosystems.

The principles of biological protection and restoration are based on several assumptions: 1) biodiversity depends on functioning ecosystems, 2) biodiversity, at all levels, is integral to ecosystem function, 3) priority should be given to keystone species, 4) ecological redundancy is important to the long-term persistence of ecosystems, and 5) natural processes and disturbances are critical to the health and evolutionary pathways of native ecosystems and their associated biota (Armstrong, 1993). In addition, it is important to realize that native ecosystems are complex systems that we still do not fully understand.

The MNFI database tracks a total of 665 different plant and animal species (Table 1, Appendix A, B, C, and D). The majority, 417 (62%) are plants, and the next largest category is insects with 94 (14%) (figure 1). The five species that have gone extinct include: one bird (passenger pigeon), three fish (deepwater cisco, blackfin cisco, and bluepike), and one snail (acorn ramshorn). Of the 665 species tracked, 94 or 14% have a global rank of G1-G3 as assigned by NatureServe (Figure 2). G1 refers to species that are considered critically imperiled on a global scale; G2 means that a species is considered globally imperiled, and G3 means that a species is either very rare throughout its range or found locally in a restricted range. Although plants have the highest number of G1-G3 species, 58% of the mussels tracked by MNFI have a global rank of G1- G3. This represents approximately 20% of all native mussels found in Michigan. In addition, 40% of the reptiles and 32% of the insects tracked in the MNFI database have a global rank of G1 – G3. For more information about global and state ranks, please refer to Appendix E.

Table 1. Aquatic and terrestrial species summary (MNFI 2006)

Major Taxon	Total Native	Extinct	State X	State E	State T	State SC	Total Tracked	# of EOs	*G1-G3	% G1-G3
plants	1,815		46	52	210	109	417	5,923	32	8%
mammals	68			4	2	4	10	79	1	10%
breeding birds	238	1	1	8	13	21	43	3,056	3	7%
reptiles	28			2	2	6	10	1,211	4	40%
amphibians	23			1	1	2	4	149	0	0%
fish	136	3	6	8	7	11	35	761	7	20%
insects	15-20,000			8	11	75	94	1,061	30	32%
snails	180	1		2	2	29	33	207	7	21%
mussels	46			8	2	8	19	700	11	58%
Totals		5	53	94	250	265	665	13,147	95	14%

Figure 1. Percent of species tracked by major taxon

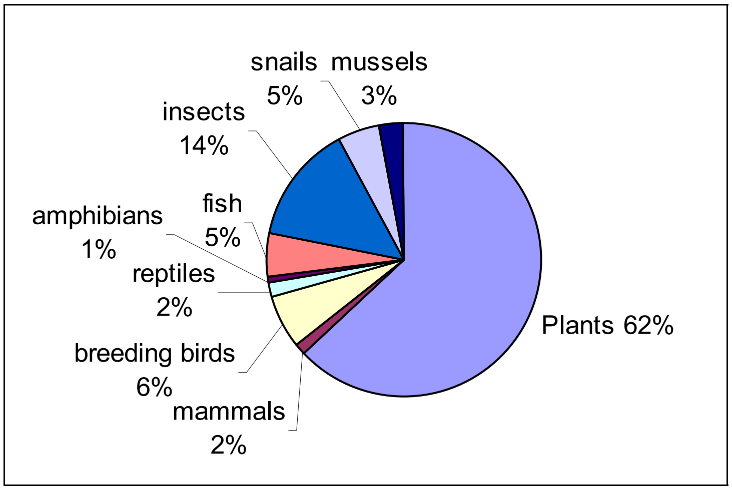
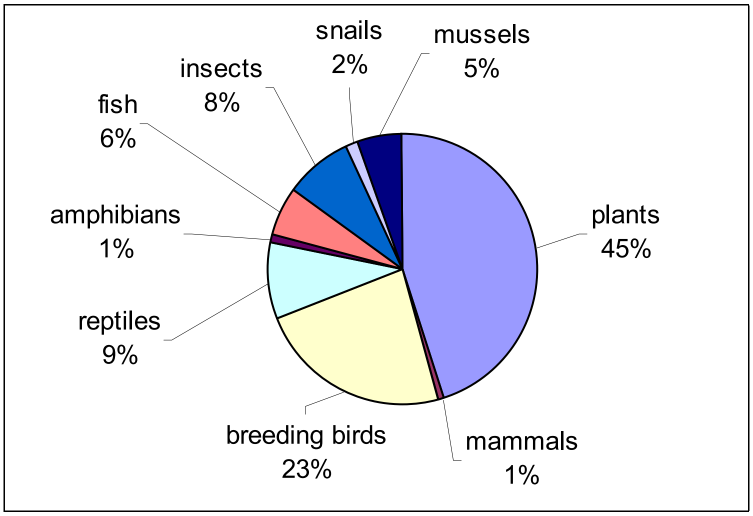


Figure 2. Percent of element occurrences by major taxon



There were a total of 1,371 natural community element occurrences in the MNFI database with the most recent last observed date of September 28, 2006 (Table 2). This represented about 9 % of the total MNFI database (plants, animals, and natural communities). Of the 1,371 natural community element occurrences in the MNFI database, 68 % (932) of these occurrences had an element occurrence rank of BC or higher (A, AB, B, BC). These ranks were interpreted to mean that these occurrences are high quality and viable over a long period of time. The spatial extent of natural communities with a BC rank or higher totaled 390,919 acres; approximately 1 % of the landscape. Of the 74 different types of natural communities tracked by MNFI, 56 % are considered to be critically imperiled or imperiled in Michigan (SX - S2) (Figure 3). Incredibly, 90 % of Michigan's natural communities are considered to be at least rare or uncommon in Michigan (SX - S3), and 64 % are considered to be at least very rare or local throughout their range (G1-G3) (Figure 4). All prairies and savannahs (grassland dominated systems) in Michigan have a state rank of SX – S3 and a global rank of G1 - G3. Bur oak plains, a type of savannah historically found in the interlobate region of the

Table 2. Summary of Natural Communities tracked by MNFI

Major Natural Community Groupings	# of MNFI types	# of EOs	Acres	SX	S1	S2	S3	S4	S5	G1	G2	G3	G4	G5	GNR	GU
Upland Forest	7	255	105,277				7					2	4			1
Lowland Forest	7	184	42,890				6	1				3	4			
Non-forested wetlands	**24**	**598**	**135,643**		5	5	8	4	2	3	6	6	3		1	5
Prairie	5	47	884		3	2				1	1	3				
Savanna/barrens	8	75	13,209	1	4	3				2	2	3				1
Other (mostly Great Lakes shoreline)	**23**	**212**	**134,061**		4	**15**	4				1	**15**	5		1	1
Totals	74	1,371	431,964	1	16	**25**	**25**	5	2	6	10	**32**	16	0	2	8

Figure 3. Percentage of natural communities by state rank

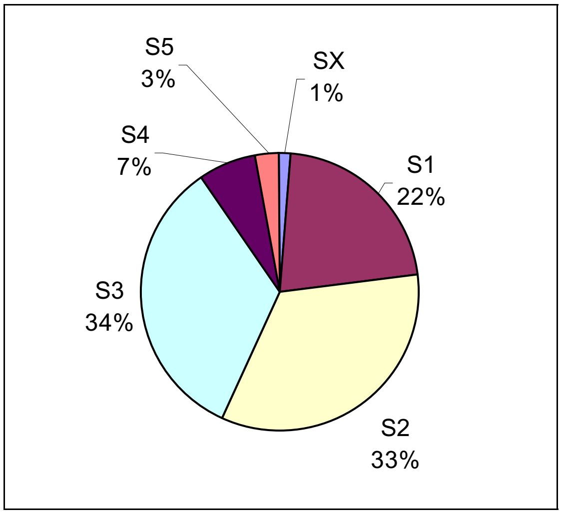
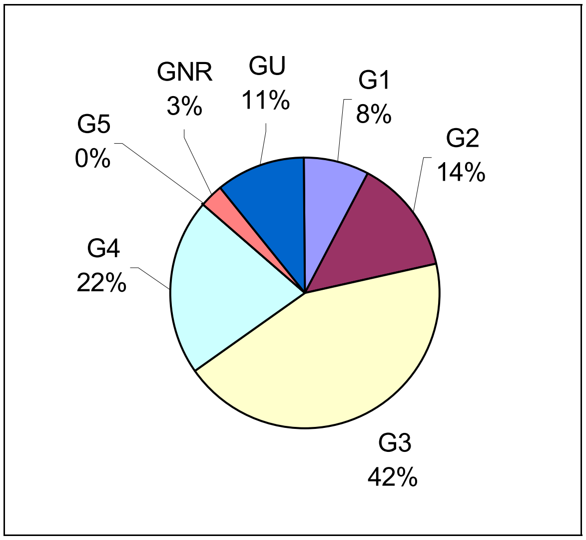


Figure 4. Percentage of natural communities by global rank



southern Lower Peninsula, is the only natural community considered extirpated from Michigan. In terms of the 6 major categories of natural communities identified in table 2, the non-forested wetlands category contains the most natural community types tracked by MNFI with 24 (32 %). The non-forested wetlands category also has the highest number of element occurrences at 598, which represents approximately 44 % of all natural community EO's in Michigan (For a list natural communities tracked by MNFI, please see Appendix F).

Approach

Different Types of Approaches

To help the inform assessment of Michigan's biological diversity, we reviewed and summarized other state level biodiversity conservation efforts from around the country. We expected only a few such projects existed. In fact, we found that 24 states were involved in some sort of statewide terrestrial biodiversity project since the early 1990's, and only three states had conducted aquatic biodiversity projects. Few of these projects were completed (as of 2002), the majority were still a work in progress, and some were just getting under way. In total, there were 35 different projects to review (several states had multiple projects), and only 16 projects developed a repeatable methodology.

The approaches taken by these 16 projects were categorized into four different types: status, fine filter, coarse filter, and prioritization. Status refers to the current status and trends of biodiversity in the state without identifying conservation priorities or specific sites on the landscape. Fine filter focuses on species that slip through the cracks such as rare, focal, or restricted species. Coarse filter focuses on natural communities, ecological hubs, core areas, connecting corridors, enduring features (e.g., land type associations), and large blocks of undeveloped land. The main idea behind the coarse filter is that these larger features, such as natural communities, capture the majority of common species associated with that feature. Prioritization involves ranking the final set of sites based on some sort of value system. For a species or natural community, this could be based on its global or state rarity rank, and/or element occurrence rank, i.e. its viability.

Of the 16 projects that developed assessment methodology, states either conducted: 1) a status assessment, or employed: 2) a coarse filter approach, 3) a combination of a fine and coarse filter approach, 4) a combination of a coarse filter and prioritization approach, or 5) a combination of a fine filter, coarse filter, and prioritization approach. Maine was the only state to conduct strictly a status assessment. Five projects (Florida: ecological network project, Illinois, Indiana, Missouri: aquatic integrity areas, and Wisconsin) employed the coarse filter approach, while six projects (Delaware, Florida: closing the gaps, Massachusetts: biomap and living waters, Oregon, and Vermont) used a combination of fine filter and coarse filter. Maryland was the only state to use a coarse filter-prioritization approach, while New Jersey, Florida (Florida Forever conservation needs assessment), and Missouri (GAP) were the only projects to use a combination of fine filter, coarse filter, and prioritization.

In our opinion, the best assessment methodologies were developed by the states of Florida, Missouri, and New Jersey. These states used a fine and coarse filter approach with prioritization. It should be noted that Florida was motivated by legislation to acquire land based on a scientific approach, and Missouri has been working on their assessment since 1997. Other commendable assessments were developed by Massachusetts (and used by Delaware), Oregon, Maryland, and Vermont. All four of these states used both a fine and coarse filter approach but decided not to prioritize the final selection of sites based on ecological significance. Below is a brief summary of the Florida, New Jersey, and Missouri assessments.

Florida Forever Conservation Needs Assessment

The Florida Forever Conservation Needs Assessment was prepared by the Florida Natural Areas Inventory in 2000. It was funded by the Florida Department of Environmental Protection, Division of State Lands and was initiated by the Florida Forever Act, a 10 year, $3-billion land and water conservation program. The act specifically states that acquisition should be based on a comprehensive assessment of Florida’s natural resources and planned so as to protect the integrity of ecosystems. The goal of the project was to develop and compile statewide resource data to evaluate the protection status of these resources and guide decisions about future conservation efforts.

Three overlay models were developed for the report: 1) a biodiversity model, 2) a water resources model, and 3) an integrated conservation priorities model. The biodiversity model overlayed the Strategic Habitat Conservation Areas (SHCA), Florida Natural Areas Inventory (FNAI) element occurrence records, Habitat Conservation Priorities (HCP), ecological greenways and under-represented natural community data layers. Overlap was addressed by halving the weighting factor for individual species habitats in the FNAI data layer that were common to both FNAI and SHCA. Areas of the natural community data layer that overlapped with SHCAs were removed from the natural community data layer. The water resources model combined the floodplain, surface water, wetlands, and aquifer recharge data layers. The floodplain data layer was scored significantly less to reduce double counting. The integrated model combined the biodiversity model, water resources model, and two additional layers – coastal resources and recreation. Scores for each model were lumped into five priority classes.

A GAP Analysis For Riverine Ecosystems Of Missouri

The GAP Analysis for Riverine Ecosystems of Missouri (Sowa et al. 2005, 2007), prepared by the Missouri Resource Assessment Partnership (MoRAP), was started in 1997 and completed in 2005. It was funded by the U.S. Geological Survey’s National Water Quality Assessment Program, the U.S. Department of Defense-Legacy Program, and the Missouri Department of Conservation.

This project is a bit different from the other state efforts in that it is a GAP analysis. The GAP project set out to identify riverine ecosystems, habitats, and species that are not adequately represented within existing conservation lands. To accomplish this they created a hierarchical riverine ecosystem classification using GIS. This classification scheme incorporated and nested ecological drainage units, aquatic ecological system types, and valley segment types. They also predicted species distributions based on available data and the create classification. By using this data in conjunction with public ownership and stewardship lands, and a human-threat index, a conservation plan for Missouri was developed.

New Jersey Landscape Project

The New Jersey Landscape Project (2001) was prepared by the Endangered and Nongame Species Program, New Jersey Division of Fish, and Wildlife and Rutgers University. The goal of the project was to protect New Jersey’s biological diversity by maintaining and enhancing rare wildlife populations within healthy, functioning ecosystems.

To achieve this goal, the project set out to identify and map areas of critical habitat for rare species within each of the five major landscape regions. Continuous patches for each habitat type are delineated and then intersected with endangered and threatened species location data. Patches were classified based on conservation status of species present (i.e., patches with federally listed species were given a higher ranking than patches with state listed species). Only seconds precision records with a last observation date of 1970 or greater were used. The project also identified critical area maps for species dependent on forests, forested wetlands, emergent wetlands, grasslands, and dunes. Highest rank was assigned to patches with federally listed species, followed by state endangered, state threatened, non-listed state priority species, and finally patches that met the minimum size requirement (different for each habitat type). In addition, each patch was coded with the number of listed species present as well as the total number of species records within the patch.

Our Approach

There are essentially five basic concepts that form the foundation of the Michigan statewide biodiversity assessment: 1) representation, 2) regionalization, 3) quality (viability), 4) core ecological areas, and 5) supporting natural landscapes. Each of these concepts can be applied to both the terrestrial and aquatic analysis.

Representation

To truly conserve biodiversity, The Nature Conservancy (TNC) recommends that there be a sufficient number, distribution, and quality of each native species and ecosystem to ensure their long term persistence within an ecoregion (1996). Capturing multiple examples is necessary to capture variability and to ensure persistence in the face of natural and human disturbances. However, it is an impossible task to track all native species of biota. The native biota of an area includes innumerable species unknown or at best poorly known to science, embedded in numerous ecosystems whose webs of biotic and abiotic interactions are only poorly understood (Parrish et al. 2003). Ideally, conservation decisions would be based on definitive knowledge of the distribution and viability of native species within an ecosystem. However, it is impossible to track all native species and their biotic and abiotic interactions.

Coarse Filter - Fine Filter Approach:

One solution to this problem is to identify conservation targets. TNC defines conservation targets as a limited number of species, natural communities or ecosystems chosen to represent the biodiversity of a given area. Due to the limitations of using individual species as filters for other species, it is recommended to initially select ecological communities or ecosystems as coarse filter targets (Noss et al. 1994). Ecological communities or ecosystems are often defined as the sum of the assemblages of populations of plants, animal, bacteria, and fungi and their environment (Groves 2003). If ecological communities are to work as coarse filters for all associated plants and animals they must (Anderson et al. 1999):

1) be conserved as often as possible at a size and scale that they naturally occurred prior to major human impacts;
2) be conserved as part of dynamic, intact, landscape mosaics;
3) maintain some level of connectivity between communities; and
4) contain a full complement of their associated flora and fauna in so far as it is known.

In addition, TNC also recommends that smaller and rarer natural community types (lakeplain prairie, prairie fen, coastal plain marsh, bog) should be represented at a higher number in the landscape than larger and more common community types such as mesic southern forest.

The coarse filter approach should then be followed by the selection of species with unique ecological requirements that cannot be met through the conservation of natural communities or ecosystems. Wide ranging, rare, extremely localized or keystone species are all likely to need fine filter strategies (Abell et al. 2002). Furthermore, the spatial scale at which organisms use the environment differs tremendously among species and depends on body size, food habits, mobility, and other factors. Hence, no coarse filter will be a complete assessment of biodiversity protection status and needs. However, species that are not addressed using the coarse filter, such as narrow endemics and wide-ranging mammals or fish, can be captured by the safety net of the fine filter. Community-level (coarse-filter) protection is a complement to, not a substitute for, protection of individual rare species (Donovan et al. 2004).

One approach is to identify a set of species typical of or restricted to a particular community in the ecoregion and then use available information on their space, resource, and breeding habitat needs to determine minimum area requirements for the community type (Anderson et. al. 1999). Building on this concept, Lambeck (1997) recommends the use of a suite of focal species to define different spatial and compositional attributes that must be present in a landscape and their appropriate management regimes. All species considered at risk are grouped according to the processes that threaten their persistence. Within each group, the species most sensitive to the threat is used to define the minimum acceptable level at which that threat can occur. Species are categorized as either area-limited, resource-limited, dispersal-limited, and/or process-limited (Lambeck 1997). Combined, this has commonly been referred to as the coarse filter-fine filter approach to biological conservation.

Representative Outliers:
High quality and/or rare occurrences of species may not be located in high biodiversity value areas or large functional sites. As mentioned earlier, to truly conserve biodiversity, there needs to be a sufficient number, distribution, and quality of each native species to ensure their long term persistence within an ecoregion. Since it is impossible to track all species and their occurrences in Michigan, only species tracked by the MNFI database were considered (endangered, threatened, and special concern). It is important to ensure that a sufficient number of occurrences for each rare and declining species in Michigan are identified for protection regardless of landscape context and integrity and possibly even viability. These outlier occurrences may actually be more important than populations that are located in more contiguous settings because they may contain unique genomes.

Regionalization

To adequately ensure representation, species and ecosystems need to be distributed across their range. A critical step to ensuring representation is determining a regionalization framework. For the terrestrial analysis, we used Albert's (1995) regional landscape ecosystems of Michigan. Albert's approach to classifying landscapes in the upper Midwest can be characterized as multifactor and multilevel in orientation. Landscape units are delineated based on multiple abiotic factors (bedrock geology, glacial landforms, soils, hydrology, and climate). This approach provides a basis for understanding patterns of species distribution, natural disturbance regimes, and natural processes. The classification is also hierarchical; the landscape is viewed as a series of various sized ecosystems nested within one another. The three hierarchical levels are section, subsection, and sub-subsection. There are 4 sections, 22 subsections, and 38 sub-subsections in Michigan (Albert 1995). Section boundaries were used for the coarse scale terrestrial analysis. Due to the relative intactness of the vegetation in the Upper Peninsula, the western and eastern Upper Peninsula sections were combined for this study. Related to this, the boundary between the northern and southern Lower Peninsula was modified slightly in order to minimize false fragmentation of vegetation patches that fell along the section boundary. Subsection and sub-subsection boundaries were used as a surrogate to capture potential genetic diversity for the species representation analysis (Figure 5). All levels were used to identify high quality natural communities.

For the aquatic assessment, we used Ecological Drainage Units (EDU's) of the Great Lakes as the regionalization framework (TNC 2001, Higgins et al. 2005). EDU's are aggregates of watersheds based on hydrologic units that share similar ecological characteristics such as climate, hydrologic regime, physiography, and zoogeographic history. EDU's and ecoregions do share similar characteristics but EDU's are based on watersheds which provide a more effective framework for aquatic ecosystems and species distributions. EDU's have been shown to be effective in landscape-based classification efforts for both riverine and lake ecosystems (Higgins et al. 2005, Cheruveilil in prep) and have been used in other biodiversity planning efforts (Sowa et al. 2005, 2007). This regionalization will allow us to break the state up into meaningful units to ensure representation of aquatic ecosystems and populations. There are a total of nine Ecological Drainage Units in Michigan

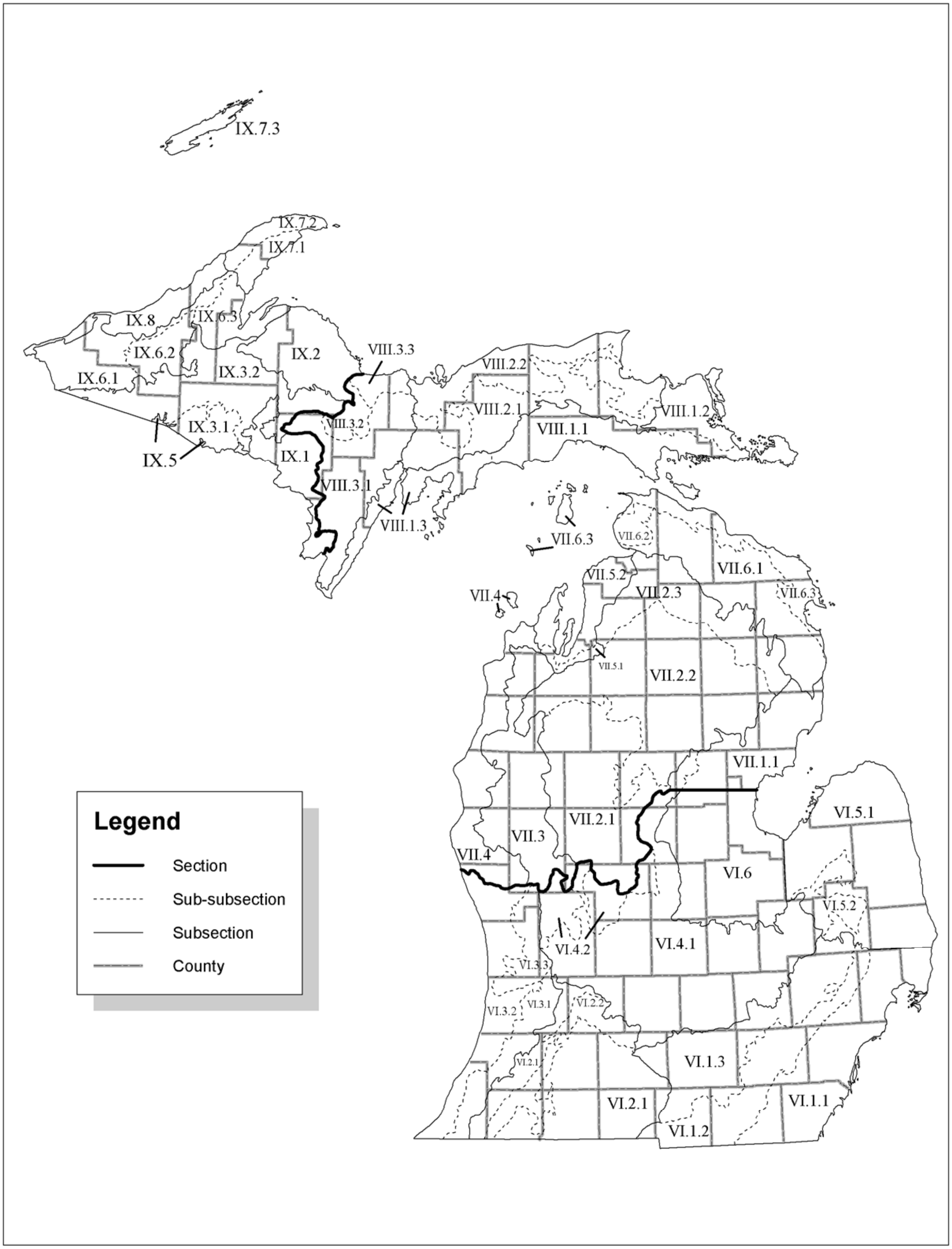


Figure 5. Regional landscapes of Michigan.

(Figure 6). We combined the Bayfield Peninsula and Uplands (12) EDU with the Western Upper Pennisula and Keweenaw Penninsula (6) EDU and the Western Lake Erie (2) EDU with the Southeast Michigan Interlobate and Lake Plain (16) EDU together for a total of 7 EDUs for this analysis. For a detailed description of each EDU see Appendix G.

Quality (viability)

TNC defines ecological integrity as the ability of an ecological system to support and maintain a community of organisms that has species composition, diversity, and functional organization comparable to those of natural habitats within a region (reference sites). An ecosystem or species has integrity or is viable when its dominant ecological characteristics - composition, structure, function, and processes - occur within their natural ranges of variation and can withstand and recover from most disturbances. In other words, ecosystems and populations of plants and animals should be self-sustaining. Integrity expresses itself in the characteristics of resistance and resilience. TNC recommends using three criteria to assess integrity: 1) size, 2) current condition, and 3) landscape context.

Size:
Stability and resilience of a terrestrial natural community tend to increase with the size of the patch. For a natural community occurrence to persist over long time frames, it much be large enough to sustain, absorb, and buffer disturbances. For rivers, size is thought of more as longitudinal intactness, although there is little research to suggest optimal stream lengths for the preservation of natural processes. However, research is working towards identifying minimal units for river conservation (Fausch et al. 2002, Allen 2004). On the other hand, the persistence of small patch natural communities however, such as depressional wetlands or lakes, is largely dependent on the surrounding landscape context rather than size. Evidence also suggests that species loss is strongly correlated with the size and landscape context of the area (Newmark 1987).

For species, size is a quantitative measure of the area and/or abundance of an occurrence. Components of this factor are:
a) area of occupancy;
b) population abundance;
c) population density; and
d) population fluctuation (NatureServe 2003)

Current Condition:
Current condition refers to the viability of the occurrence. For a natural community or ecosystem, condition refers to native species diversity, threats, presence of exotic species, and is affected by: 1) anthropogenic impacts (exp. fragmentation, pollution) and 2) biological legacies. TNC defines biological legacies as critical features that take hundreds to thousands of years to develop. In forests these might include: presence of fallen logs and rotting wood, a well developed moss and herbaceous understory, structural complexity in the canopy and understory layers, a reservoir of soil organic matter for nutrient storage, seed banks, and evidence of intact nutrient cycles. For rivers these might include: channel sinuosity, riffle – pool – run composition, and available substrates.

For species, condition refers to demographics, reproductive success, degree of threats, and extent and quality of critical habitat. For many animals, condition is very difficult to determine due to the intensity and duration of sampling required to get scientifically defensible data. As a result, the majority of animal occurrences in the MNFI database (64%) are given an element occurrence rank of E for

Figure 6. Ecological Drainage Units (EDUs) of the Great Lakes.

extant. In other words, if an individual or several individuals are found within a given area, their presence alone does not allow scientists to comment on the long-term viability of the population.

Landscape Context:
Landscape context for terrestrial ecosystems refers to the size of the surrounding natural vegetation patch or block, proximity and extent of incompatible land uses, and the potential for ecological processes to occur at natural rates and scales. Surrounding landscape functionality (context) is an issue for all communities, but particularly for patch types that depend on easily disrupted processes occurring at scales larger than those of the individual community. Examples of key threats to consider in the surrounding landscape include: fire suppression, diversion of groundwater, coastal revetments, impervious surface, and agricultural runoff.

For aquatic ecosystems, landscape context must be viewed at different spatial scales. Ecological processes (i.e. hydrologic, geomorphic) function at the catchment (or watershed) scale for each reach of a stream or the catchment of a lake. Additionally, adjacent and upstream riparian areas can have a strong influence on the functionality of a stream reach and the availability of habitat. Landscape context in aquatic ecosystems refers to the proximity and extent of incompatible land uses, the potential for ecological processes to occur at natural rates and scales, and the amount of natural land cover within the catchment and the riparian area. Examples of key threats to consider in the surrounding landscape include: dams, impervious surface, erosion, diversion of groundwater, agricultural runoff, and road crossings.

Core Ecological Areas

Large Functional Landscapes:
These are the best areas to conserve terrestrial biodiversity over the long term, maintain essential ecological processes and services and provide habitat for common species. These areas also provide the best opportunity for supporting viable populations of rare species and high quality natural communities. Landscape integrity is critical to maintaining the long-term viability of species and natural communities. Landscape integrity addresses the health of the larger ecosystem, as well as large scale stresses impacting individual components across the landscape. Without landscape integrity, maintaining fragmented patches of habitat and isolated populations of flora and fauna becomes akin to keeping a patient alive on a respirator in the hopes that a cure will be discovered in the future. Fragmentation is one of the greatest threats to biodiversity. Large functional landscapes provide the best chances for mitigating the effects of roads, invasive species, pollution, development, and other threats to biodiversity, and allow natural processes to occur at more natural rates and scales. Natural disturbances such as flooding, wildfires, tornadoes, ice storms, insect outbreaks, and disease alter the landscape and ultimately help create the variety of ecosystems needed to provide habitat for Michigan’s native species.

Functional Watersheds:
Aquatic species conservation is a very difficult task given the interconnected nature of rivers and the high vulnerability of both lake and river ecosystems to human disturbance. Parallel to the large functional terrestrial landscapes, functional watersheds provide the best opportunity to conserve biodiversity over the long-term, maintain essential ecological processes and services and provide habitat for common species. By identifying watersheds that have a relatively high degree of integrity, we can focus conservation efforts on those watersheds that can have the greatest long-term impact on aquatic conservation, including rare species. Functional watersheds are areas that can be characterized as having: 1) high percentage of natural land cover, 2) low imperviousness, 3) intact riparian buffers, and 4) minimal road/stream crossings, dams, point source pollution sites, and nearby mining operations.

Biological Rarity Hotspots (biological rarity score):
This concept has often been referred to as biological hotspots. The general idea is to prioritize spatially defined areas on the landscape that contain a large number of rare or declining species and natural communities. These areas may not coincide with the conditions of the other concepts (representation, quality, functional watersheds, and large functional landscapes), but in general areas that contain concentrations of globally imperiled species and/or occurrences of rare species or natural communities with high viability should receive higher priority over areas with concentrations of element occurrences with low viability and/or more secure species.

Supporting Natural Landscape

This concept was borrowed from the Massachusetts BioMap project (2000), however our interpretation of the supporting natural landscape is much narrower. We define the supporting natural landscape as natural lands not included as part of the large functional landscapes described in the previous section. Although these lands do not contain known occurrences of rare species or natural communities, or are not part of a large, high quality, undeveloped roadless area, these lands provide potential ecological services or functions. They provide the potential for connectivity between important wildlife habitat areas, buffering large intact patches from incompatible land uses, and allowing natural processes such as flooding to occur at more natural rates and scales. These lands may be smaller fragments, degraded due to human activity, or intensively managed for natural resources such as timber, game species, or other recreational pursuits. The important point here is that these areas have potential natural resource value that should be evaluated by the local or regional community or land manager. Primary evaluation should be based on the ecological value these lands could provide to nearby or adjacent terrestrial and aquatic core ecological areas and representative plant, animal, and natural community occurrences.

Products

One of the things we noticed from the other state biodiversity projects was the tendency to develop only one solution. However, we realized up front that different end users have different needs and values. The very concept of conservation is inherently based on values. A group or an individual conserves things in the natural environment based on what they think is important. Potential criteria for conservation may include: function, aesthetics, services, goods, recreation, jobs, and/or the needs of future generations.

Another very important point to consider is that there will always be uncertainty in the data used in the analysis, and new information will have the tendency to change outcomes, sometimes significantly. Some of the data sets available for this statewide analysis are outdated, incomplete, and/or have a level of accuracy that may be appropriate at the statewide or regional scale but may not be appropriate to use at a smaller scale. A local unit of government for example, may have a more recent and/or more accurate land cover data set than the statewide IFMAP land cover data set used in this analysis. By providing only one composite product, we eliminate the opportunity for end users to incorporate better data sets. To address these challenges, we decided to focus on flexibility instead of the creation of one solution that somehow fits every end user's needs. The primary goal of this initial effort was to gather, develop, and assess a series of data layers for both terrestrial and aquatic natural features that could be used for future conservation planning efforts. We addressed this by creating a wide-ranging series of data layers with associated documentation, as well as creating several composite maps to show end users different ways the various data layers can be integrated to develop various conservation network designs at multiple scales.

Terrestrial Biodiversity Assessment Methodology

Introduction

The analysis used in the assessment of Michigan's terrestrial biodiversity was based on two major categories of data: land cover and element occurrences of natural features. The two land cover datasets used were developed from two different projects: the Michigan GAP Analysis project developed by the Michigan Department of Natural Resources (MDNR), and the circa 1800 vegetation of Michigan project developed by the Michigan Natural Features Inventory (MNFI). The element occurrence dataset is a continuously updated database developed and maintained by the Michigan Natural Features Inventory (MNFI). From the land cover datasets we developed a large number of new data layers that can be used to identify and prioritize core vegetation areas, potentially unchanged vegetation, large functional landscapes, important patches of different vegetation cover types, and large supporting landscapes. The MNFI element occurrence database identifies places on the land that contain unique elements of biodiversity – rare species and high quality natural communities, which MNFI refers to as element occurrences. The database, which is updated periodically throughout the year, contains a wealth of detailed information that was used to identify and prioritize areas based on frequency, likelihood of persistence, viability, and/or rarity of EOs. Both land cover and EOs of natural features are discussed in more detail below.

Categories of land cover based datasets developed by this project:

1. Natural vegetation core areas - by ecoregional section
2. Potentially unchanged natural vegetation core areas - by ecoregional section
3. Natural vegetation types - statewide
4. Large functional landscapes – statewide

Categories of MNFI EO based datasets developed by this project:

1. EO frequency count
2. EO likelihood
3. Bio-rarity score
4. Best two occurrences of each terrestrial species by sub-subsection
5. High quality natural communities (≥ B/C rank)
6. Best three occurrences of each natural community (statewide, section, subsection, and sub-subsection)

A table summarizing the EO based datasets can be found in Appendix L.

Coarse Filter: Land Cover Data

The following paragraph was primarily borrowed from the Michigan GAP Analysis Project Final Report (Donovan et al. 2004).Vegetation patterns are an integrated reflection of the physical and chemical factors that shape the environment of a given land area (Whittaker 1965). They also are determinants for overall biodiversity patterns (Franklin 1993, Levin 1981, Noss 1990), and they can be used as a currency for habitat types in conservation evaluations (Specht 1975, Austin 1991). The central concept is that the physiognomic and floristic characteristics of vegetation (and, in the absence of vegetation, other physical structures) across the land surface can be used to define biologically meaningful biogeographic patterns.

IFMAP land cover

Description:
A major component of the Michigan GAP Analysis Project was the development of a statewide digital land coverage called the Integrated Forest Monitoring Assessment and Prescription (IFMAP) land cover (Figure 7). IFMAP was developed to assess the distribution and protection status of terrestrial vertebrate species in Michigan, and to assist with forest inventory on state lands (Donovan et al. 2004). We decided to use the IFMAP land coverage for this assessment because it is currently the most up-to-date, statewide, digital land coverage for Michigan. The IFMAP land coverage was derived from classification of Landsat Thematic Mapper (TM) imagery taken between 1999 and 2001. The data is stored in a raster format with a cell resolution of 30 meters. Both supervised and unsupervised classication techniques were used in conjunction with multiple ancillary data sources to produce 32 categories of land cover ranging from high density residential to lowland deciduous forest (Table 3).

Table 3. IFMAP land cover classification.

Class Name	Value
Low Intensity Urban	1
High Intensity Urban	2
Airports	3
Roads / Paved	4
Non-vegetated Farmland	5
Row Crops	6
Forage Crops / Non-tilled herbaceous	7
Orchards / Vineyards / Nursery	9
Herbaceous Openland	10
Upland Shrub / Low-density trees	12
Parks / Golf Courses	13
Northern Hardwood Association	14
Oak Association	15
Aspen Association	16
Other Upland Deciduous	17
Mixed Upland Deciduous	18
Pines	19
Other Upland Conifers	20
Mixed Upland Conifers	21
Upland Mixed Forest	22
Water	23
Lowland Deciduous Forest	24
Lowland Coniferous Forest	25
Lowland Mixed Forest	26
Floating Aquatic	27
Lowland Shrub	28
Emergent Wetland	29
Mixed Non-Forest Wetland	30
Sand / Soil	31
Exposed Rock	32
Mud Flats	33
Other Bare / Sparsely Vegetated	35

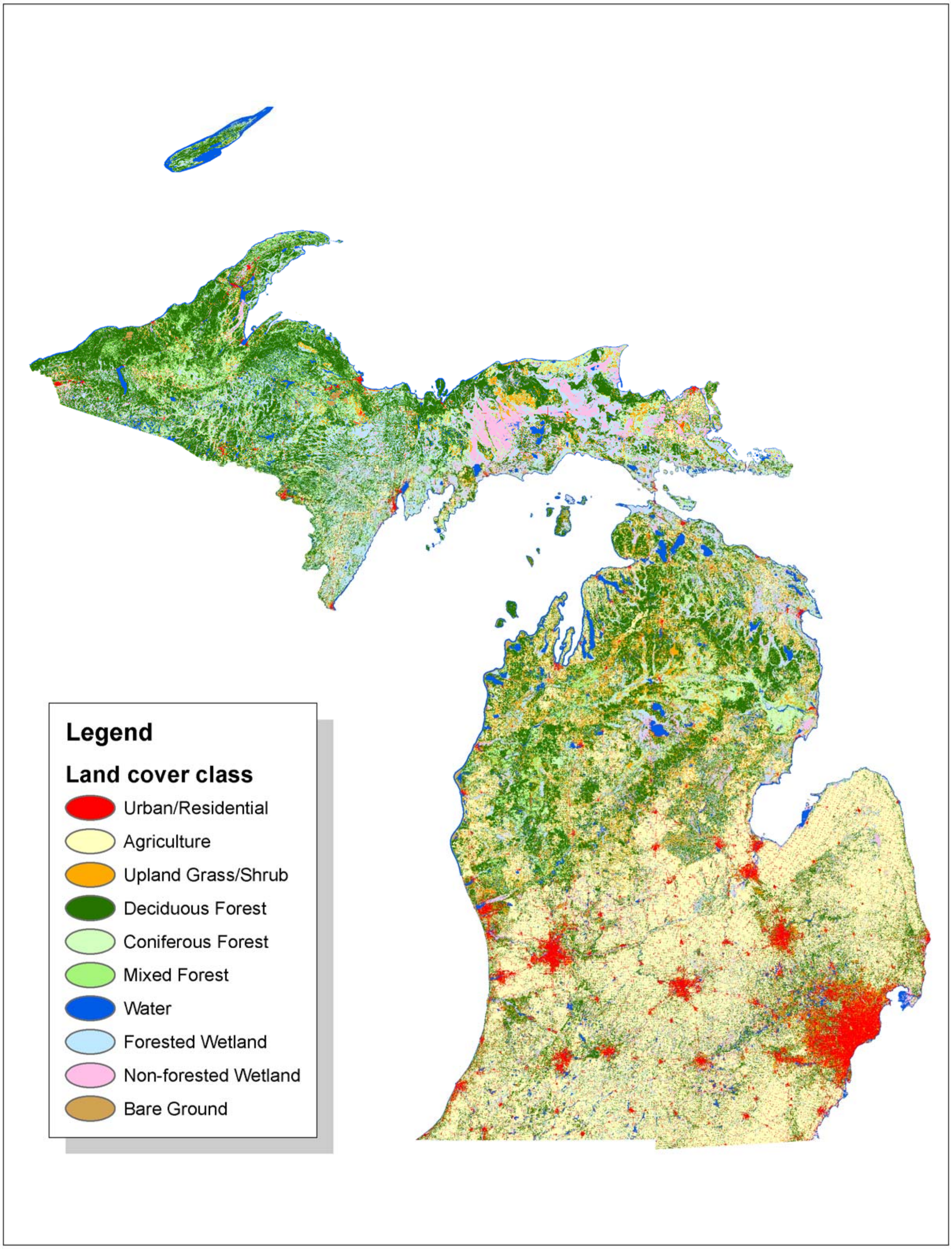


Figure 7. IFMAP landcover classification, 2000.

Limitations:
IFMAP data products and assessments represent a snapshot in time generally representing the date of the satellite imagery (1999-2001). Users of the data must be aware of the static nature of the products. IFMAP data are derived from remote sensing and modeling. Any decisions based on the data must be supported by ground-verification and more detailed analyses. An accuracy assessment of the final land cover layer determined it to be 87 percent accurate at level 2 in the hierarchical classication scheme. At the next level of classification detail (level 3), class accuracies range from 36 to 87 percent. Overall accuracy was 80.7 percent for the non-forested types and 67.9 percent for forested types (Donovan et al. 2004). Please see the Space Imaging Report "Review of Remote Sensing Technologies used in the IFMAP Project" (Space Imaging 2004) for a complete discussion of the accuracy assessment and associated tables.

MNFI Circa 1800 Vegetation of Michigan

Description:
Between 1816 and 1855 Government Land Office Surveyors mapped a one-mile grid across the entire surface of Michigan, starting in the southeast near Lake Erie and finishing along the Wisconsin border along Lake Superior. The Land Office Surveyors were not only creating a grid for land sales, they were also recording information about the land and its vegetation, describing the fertility of the soil, mapping bedrock exposures, and recording the size and species of the trees. As they measured out the boundaries of townships and sections, surveyors made notes on the topography, soils, and vegetation they encountered along each one mile section line. Surveyors were instructed to note the exact location of wetlands, lakes and streams, comment on the agricultural potential of soils, and note the quantity and quality of timber resources as they were encountered along each section line (White 1984, Caldwell 1990).

With this information plotted over topography maps, ecologists interpreted cover type boundaries primarily using the locations of dominant tree species and associated landforms. Wetland boundaries were interpolated between section lines by using associated elevation lines as they were depicted on the topographic maps. Ecologists consulted surface geology maps, soils maps, and earlier vegetation maps throughout the process of interpretation. Once cover type boundaries were interpreted and assigned codes, the maps were proofed and then digitized (Figure 8, Table 4) (Comer et al. 1995).

Limitations:
Given that these surveys were not undertaken as a scientific sample of vegetation, they should not be considered as such. It is important to place the circa 1800 vegetation map within the context of the times when the surveys were conducted. Aspects of long-term climatic cycles, Native American activities, and the European fur trade, all had the potential to influence natural patterns on the landscape traversed by surveyors in the nineteenth century. The interpolated boundary line between each section line should be considered an approximation that could differ on the ground depending on local variation not apparent on topographic maps. Upland and wetland boundaries in interior sections should be most accurate where topography is abrupt. Given the scale of survey data, much of the small-scale variation one normally encounters in natural environments was not well represented. One should assume that wetlands which naturally occur as relatively small, complex shapes, totaling less than 50 acres in area, are highly under-represented in this data layer (Comer et al. 1995).

Table 4. Summary of Circa 1800 Vegetation Classification.

Cover Type	Acres
Aspen-birch forest	292,266
Beech-sugar maple forest	5,845,677
Beech-sugar maple-hemlock forest	6,346,662
black ash swamp	280,705
Black oak barren	719,043
Cedar swamp	1,254,093
Exposed bedrock	9,209
Grassland	73,088
Hemlock-white pine forest	1,962,192
Hemlock-yellow birch forest	295,314
Jack pine-red pine forest	1,112,655
Lake/river	799,203
Mixed conifer swamp	4,290,553
Mixed hardwood swamp	1,421,462
Mixed oak forest	418,363
Mixed oak savannah	1,061,564
Mixed pine-oak forest	106,331
Muskeg/bog	287,610
Oak-hickory forest	1,888,010
Oak/pine barrens	112,051
Pine barrens	270,330
Sand dune	18,365
Shrub swamp/emergent marsh	608,044
Spruce-fir-cedar forest	954,169
Sugar maple-basswood forest	213,036
Sugar maple-hemlock forest	2,321,507
Sugar maple-yellow birch forest	948,608
Wet prairie	382,029
White pine-mixed hardwood forest	1,185,681
White pine-red pine forest	1,272,127
White pine-white oak forest	437,231
Total	37,187,178

Coarse Filter: Land Cover Analysis

Introduction

The primary purpose of the land cover analysis was to identify the most important natural vegetation areas in the state. Ideally, condition would be one of the primary variables to prioritize or rank one patch over another. Other relevant variables include size, core area, shape, proximity, connectivity, and landscape context. Due to the large area of analysis, high degree of variation from one part of the state to another, and the high number of pixels that needed to be processed, we decided to minimize the number of variables, and focus primarily on: 1) total size, 2) core area, and 3) condition. Using these three variables, five different types of land cover analyses were conducted for the whole state.

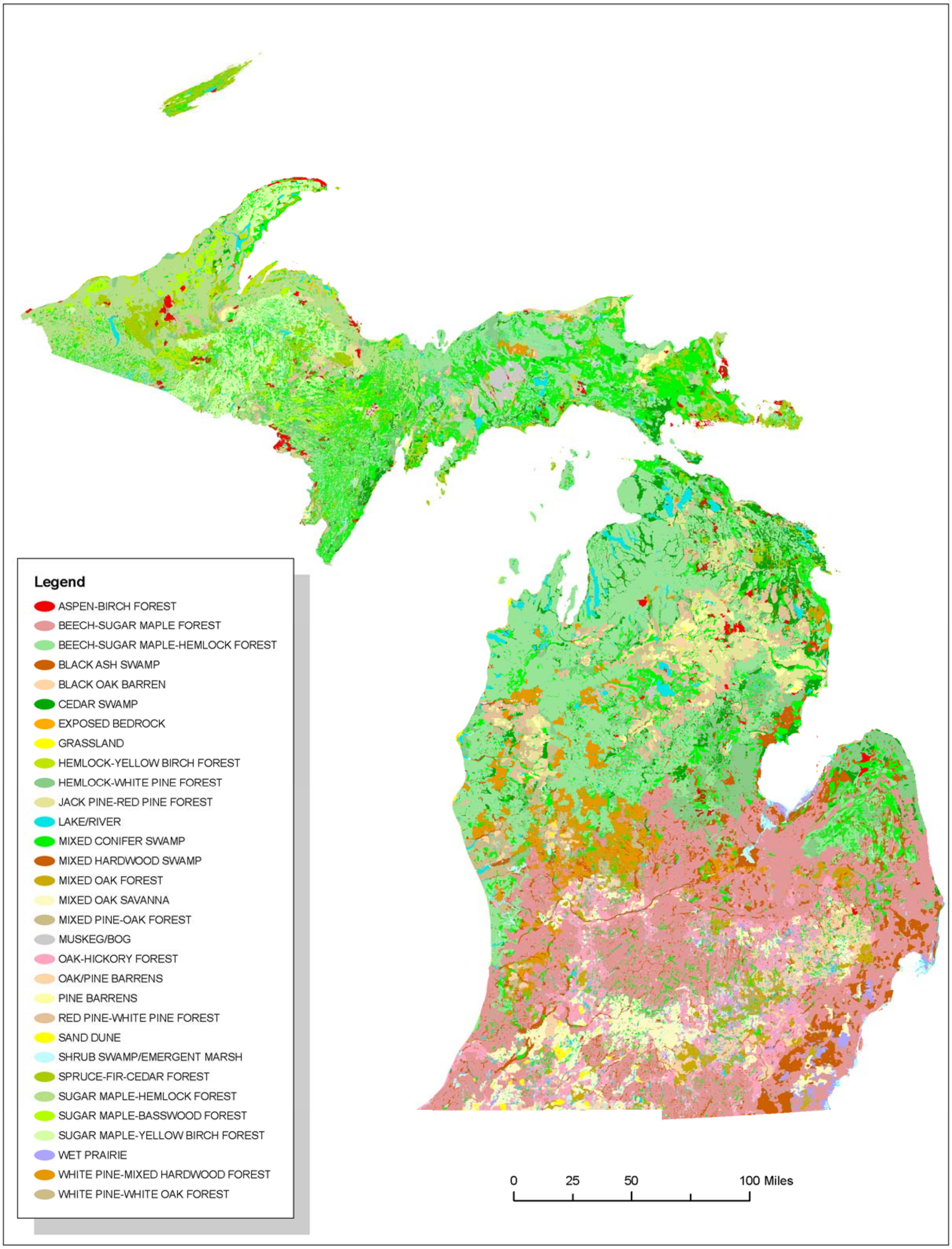


Figure 8. Circa 1800 vegetation map.

Land cover analyses

1. Natural vegetation core areas - by ecoregional section
2. Potentially unchanged natural vegetation core areas - by ecoregional section
3. Natural vegetation types - statewide
4. Large functional landscapes – statewide

All four analyses are based on the 2001 IFMAP land coverage, and one includes the MNFI circa 1800 vegetation data layer. Two analyses provide information on an ecoregional section basis, and the other two analyze natural vegetation patches from a statewide perspective. As stated earlier, the boundaries of Albert's (1995) four ecoregional sections were modified to minimize problems associated with artificially fragmenting natural vegetation patches that fell along the section boundaries. The western and eastern Upper Peninsula were combined, and the boundary between the Northern Lower Peninsula and Southern Lower Peninsula were slightly modified to follow existing breaks in the vegetation. A brief discussion of how these data layers can be used in combination with other data layers is provided at the end of this chapter, as well as the chapter entitled: Looking for Patterns: Bringing the Data Layers Together.

IFMAP Reclassification

A modified version of the IFMAP land cover classes was created to help minimize inaccuracies and to simplify a land cover analysis of the whole state. For example the aspen, oak, and maple layers were combined together to form an upland deciduous forest type layer, rather than treating each forest type individually. In total, eight different natural land cover types were identified for this project: 1) upland deciduous forest, 2) upland mixed forest, 3) upland conifer forest, 4) lowland deciduous forest, 5) lowland mixed forest, 6) lowland conifer forest, 7) grassland, and 8) non-forested wetlands (table 5).

Roads

Three different road data layers were used in the analysis to distinguish between patches of vegetation. The first data layer did not include any roads, the second data layer used only major roads to differentiate between patches, while the third data layer used all roads to identify vegetation patches. The road data layer used in the analysis is the Michigan Geographic Framework Statewide All Roads Layer Version 5a. All road arcs identified in the Framework were converted to a 30 meter raster dataset.

Roads were used to differentiate and define vegetation patches due to their widespread yet uneven distribution across the landscape, combined with their potential impact on wildlife and ecological processes. According to Diamondback (1990), the construction and maintenance of roads is among the most widespread form of modification in the United States during the past century. Road construction kills sessile and slow moving organisms in the path of or areas influenced by the road. Existing roads: 1) cause mortality of both vertebrates and invertebrates from collision with vehicles, 2) modify animal behavior (such as altered home range, altered movements, altered reproductive success and altered escape patterns), and 3) increase the spread of exotic species (Trombulak and Frissell 2000).

Species prone to road kill include moose, white-tailed deer, raccoon, opossum, wolf, barn owl, eastern screech owl, American kestrel, frogs, turtles, amphibians, and flying invertebrates such as butterflies. Research has shown that many different types of animal species are impacted by roads. Black bear in North Carolina shift their home range away from areas with high road densities (Brody and Pelton 1989), and several species of rodents, such as white footed mice and prairie voles, will not cross

Table 5. Modified IFMAP land cover classes.

IFMAP Class Name	Value	IFMAP_Code	Natural Vegetation	New Class Name
Low Intensity Urban	1	110		
High Intensity Urban	2	123		
Airports	3	121		
Roads / Paved	4	122		
Non-vegetated Farmland	5	2111		
Row Crops	6	2112		
Forage Crops / Non-tilled herbaceous	7	2113		
Orchards / Vineyards / Nursery	9	222		
Herbaceous Openland	10	310	X	Filtered grassland
Upland Shrub / Low-density trees	12	320	X	Filtered grassland
Parks / Golf Courses	13	350		
Northern Hardwood Association	14	411	X	Upland decidious forest
Oak Association	15	412	X	Upland decidious forest
Aspen Association	16	413	X	Upland decidious forest
Other Upland Deciduous	17	414	X	Upland decidious forest
Mixed Upland Deciduous	18	419	X	Upland mixed forest
Pines	19	421	X	Upland conifer forest
Other Upland Conifers	20	423	X	Upland conifer forest
Mixed Upland Conifers	21	429	X	Upland conifer forest
Upland Mixed Forest	22	431	X	Upland mixed forest
Water	23	500	X	Water
Lowland Deciduous Forest	24	611	X	Lowland decidious forest
Lowland Coniferous Forest	25	612	X	Lowland conifer forest
Lowland Mixed Forest	26	613	X	Lowland mixed forest
Floating Aquatic	27	621	X	Non-forested wetland
Lowland Shrub	28	622	X	Non-forested wetland
Emergent Wetland	29	623	X	Non-forested wetland
Mixed Non-Forest Wetland	30	629	X	Non-forested wetland
Sand / Soil	31	710		
Exposed Rock	32	720		
Mud Flats	33	730		
Other Bare / Sparsely Vegetated	35	790		

roads as narrow as 3 meters (Swihart and Slade, 1984). Productivity of bald eagles in Oregon and Illinois declined with proximity to roads (Anthony and Issacs 1989, Paruk 1987), and they preferentially nested away from roads. Sandhill cranes also avoid nesting near paved and gravel roads (Norling et al. 1992). In Ontario, it was discovered that the local abundance of toads and frogs was inversely related to traffic density on adjacent roads. Despite the lower populations adjacent to highly trafficked roads, roadkill relative to abundance was higher on highly traveled roads (Fahrig et al. 1995). More recently, a study conducted in upstate New York found that turtle populations in high road density areas had a much higher proportion of males than populations found in low road density areas. The study suggests that more female turtles are killed on roads presumably during nesting migration (Gibbs and Steen 2005).

Grassland and forest interior birds also appear to be affected by roads. The population density of the most sensitive forest interior species (cuckoo) in a recent study was significantly reduced within a distance of 650 meters from the road (Forman and Deblinger 1999). Similarly, in a Netherlands study, the most sensitive grassland species (black tailed godwit) was significantly reduced in density within a distance of 930 meters from the road (Reijen et al. 1996).

Buffers

In addition to roads, three different buffers were applied to roads and non-natural landcover classes to represent the potential impact of incompatible edges on wildlife and natural processes: 90 meters, 210 meters, and 300 meters. Initially we intended to use 100 meter increments; however, the IFMAP raster land cover data layer consists of 30 meter pixels. As a result we chose to substitute 90 meters for 100 meters, and 210 meters for 200 meters. These distances were chosen based on a literature review of buffers. Rodgers et al. (1997) found that flushing distances of waterbirds extended to 100 meters, and a 100 meter buffer around forests was found to be sufficient for a relatively sensitive guild of bird species (Sandilands and Hounsell 1994). Bolger et al. (1997) found that the abundance of interior habitat bird species was reduced within 200 meters of an edge, and Sandilands and Hounsell (1994) found that a 200 meter buffer around a forest was sufficient for a second more sensitive guild of bird species. Lastly, Brittingham and Temple (1983) found that nest parasitism by brown headed cowbirds decreased with distance away from forest edge, but extended greater than 300 meters into the forest, and Environment Canada (2004) recommended that natural lands should be buffered up to 300 meters to avoid the negative effects of edges on wildlife.

Natural vegetation types - statewide

Description:

This analysis focused on the different natural vegetation communities found in Michigan. Each patch of natural vegetation was buffered from roads and non-natural land cover using several different buffer widths, and then either selected or removed based on the large patch, small patch, matrix size criteria developed by The Nature Conservancy (Anderson et al. 1999). A matrix community is defined as a large, regional sized cover type that ranges in size from 2,000 to 100,000 hectares. They typically encompass a variety of large and small patch communities. Examples of matrix communities include: northern hardwood forests, deserts, mangrove swamps, tallgrass prairies, and tundra. For Michigan, only upland deciduous forests were categorized as a matrix community type. Large patch communities are communities that are relatively easy to define spatially, and range in size from 20 to 2,000 hectares. In Michigan, large patch communities include: forested wetlands, coastal wetlands, barrens and savannas, and upland conifer forests. Small patch communities were defined as communities with a very limited, highly defined spatial extent that are typically embedded with larger community types. Sizes typically range from .1 hectares to 20 hectares. Examples of small patch communities in Michigan include: fen, coastal plain marsh, emergent marsh, dry sand prairie, and bog. The 11 different vegetation categories used in the analysis were: 1) forest, 2) upland forest, 3) upland deciduous forest, 4) upland mixed forest, 5) upland coniferous forest, 6) lowland forest, 7) lowland deciduous forest, 8) lowland mixed forest, 9) lowland coniferous forest, 10) filtered grassland, and 11) non-forested wetland (Table 6). Due to the large amount of anthropogenic grasslands in Michigan, a process was used to identify existing grasslands that were also historically grasslands; these patches are referred to as filtered grassland.

Twelve different data layers were developed for each of the 11 vegetation type categories mentioned above, for a total of 132 data layers. The 12 data layers are: 1) no roads – no buffer, 2) no roads - 90 m buffer, 3) no roads – 210 m buffer, 4) no roads – 300 m buffer, 5) major roads – no buffer, 6) major roads – 90 m buffer, 7) major roads – 210 m buffer, 8) major roads – 300 m buffer, 9) all roads – no buffer, 10) all roads – 90 m buffer, 11) all roads – 210 m buffer, and 12) all roads – 300 m buffer.

Table 6. Natural vegetation communities organized by patch type and minimum size.

Natural Vegetation Types	Patch Type	Minimum size (hectares)
forest	matrix	2,000
upland forest	matrix	2,000
upland decidous forest	matrix	2,000
upland mixed forest	matrix	2,000
upland coniferous forest	large	20
lowland forest	large	20
lowland deciduous forest	large	20
lowland mixed forest	large	20
lowland coniferous forest	large	20
filtered grassland	large	20
non-forested wetland	small	0.1

Please refer to appendix H for metadata.

Use:
The analysis can be used to identify the largest most intact patches for each of the 11 vegetation type categories. These data layers can also be used to analyze patch statistics for each of the 11 types such as mean and median patch size, range, total acreage, etc.

Limitations:
As mentioned earlier, IFMAP land coverage is limited in accuracy. In addition, the IFMAP land cover was documented from satellite imagery taken between 1999 and 2001. Some areas of land have been altered since that time period rendering the land cover outdated for those areas.

File names:
nva2 (grid)
nva2_buffered (grid)

Data source:
Michigan Geographic Framework statewide all roads layer version 5a
Lu2001v2_g – IFMAP circa 2000 land use data for entire state of Michigan in grid format.

Results:
Due to the large number of data layers associated with this analysis, the results section only focused on the all forest category. There were a total of 24,617 patches of forestland in the state totaling 17,860,005 acres (Table 7). When a minimum patch size of 5,000 acres was applied, total acres of all forest dropped to 15,024,720 acres (only a 16% decrease). However, when all roads are used to define patch boundaries, and a 300 meter buffer is applied to each road and non-natural landcover, forest area dropped to 628,640 acres (a 96.5 % decrease). This demonstrates that although forest (both upland and lowland combined) is the dominant land cover in the state, roads have a tremendous impact on Michigan's forest ecosystems (Figure 9).

Table 7. All forest patches with different road and buffer combinations applied.

Vegetation Type	road layer	Total acres of natural vegetation type	# of patches	minimum size patches (acres)	acres with road layer that meet minimum size	% acres with road layer that meet minimum size	buffer size in meters	acres with road layer and buffer	% acres with road layer and buffer that meet minimum size
All Forest	none	17,860,005	24,617	5,000	15,024,720	84%	0	15,024,720	100%
All Forest	none	17,860,005	24,617	5,000	15,024,720	84%	90	5,889,270	39%
All Forest	none	17,860,005	24,617	5,000	15,024,720	84%	210	2,185,384	15%
All Forest	none	17,860,005	24,617	5,000	15,024,720	84%	300	1,147,199	8%
All Forest	major	17,818,578	25,496	5,000	14,674,106	82%	0	14,674,106	100%
All Forest	major	17,818,578	25,496	5,000	14,674,106	82%	90	5,779,619	39%
All Forest	major	17,818,578	25,496	5,000	14,674,106	82%	210	2,177,455	15%
All Forest	major	17,818,578	25,496	5,000	14,674,106	82%	300	1,145,941	8%
All Forest	all	16,834,320	48,097	5,000	6,820,601	41%	0	6,820,601	100%
All Forest	all	16,834,320	48,097	5,000	6,820,601	41%	90	2,900,842	43%
All Forest	all	16,834,320	48,097	5,000	6,820,601	41%	210	1,206,356	18%
All Forest	all	16,834,320	48,097	5,000	6,820,601	41%	300	628,640	9%

Natural vegetation core areas - by ecoregional section

Description:
All natural vegetation types identified by the IFMAP land coverage were combined together to form a new natural vegetation core area data layer. All natural vegetation patches greater than a threshold size, with the threshold dependent on the modified ecoregional section were selected. The Upper Peninsula (UP) threshold was set at 5000 acres, the Northern Lower Peninsula (NLP) threshold was set at 2,500 acres, and the Southern Lower Peninsula (SLP) was set at 500 acres. These select patches were then buffered inward with a series of three buffer sizes (90 meter, 210 meter, and 300 meter). For each buffer, all natural vegetation patches greater than a threshold size, with the threshold dependent on the ecoregional section, were extracted. Water, which includes lakes, ponds, and large river segments, was originally included as part of the natural vegetation data layer. Once the buffers were applied, water bodies with a surface area greater than 10 acres were subtracted out of the data layer and the remaining patches were regrouped and extracted based on the ecoregional thresholds mentioned above.

Threshold sizes were set for each of the three ecoregions based on the percentage of natural lands remaining, degree of fragmentation, and mean patch size using all roads with no buffer to define patches. The Nature Conservancy suggests using a 5,000 acre minimal size for matrix patches, however, due to the wide variation in patch sizes between the UP and SLP, thresholds had to be customized to each ecoregional section. We decided to keep the 5,000 acre threshold for the UP due to its high percentage of natural lands (86 %) and large mean patch size (1,299 acres). A threshold of 2,500 acres was set for the NLP due to its moderate amount of natural lands (53%) and mean patch size (341 acres). Additionally, 2,500 acres is within the range needed for to support a female black bear and cubs (Roger and Allen 1987) and 75-80 % of all highly sensitive bird species (Herkert et al. 1993). The threshold for the SLP was set at only 500 acres due to its relatively low percentage of natural lands (25%) and small mean patch size (108 acres). However, 500 acres was found to be sufficient for supporting 80 % of all expected bird species (Tate 1998).

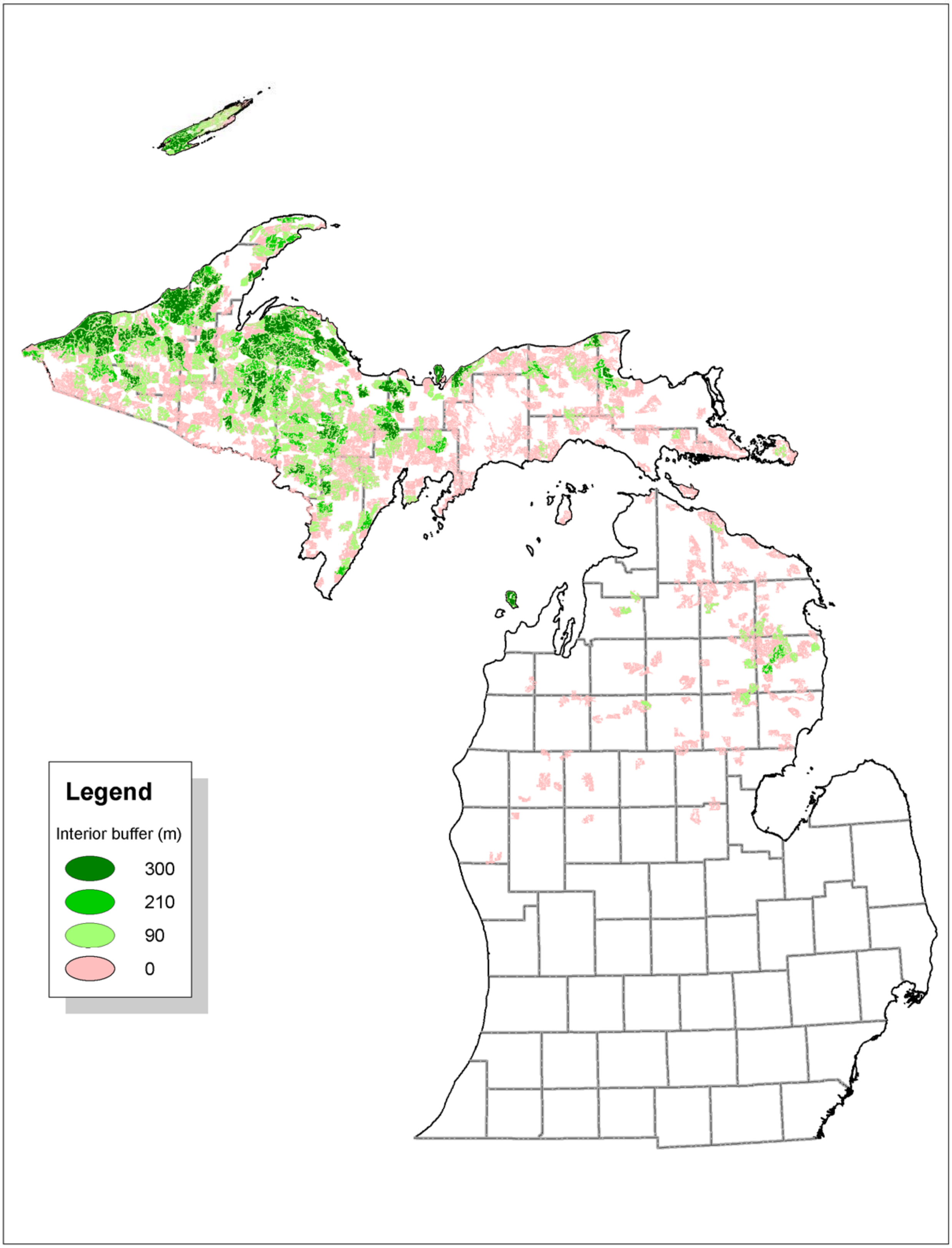


Figure 9. All forest patches with boundaries defined by all roads, with 0, 90, 210, and 300 meter buffers applied to roads and non-natural vegetative landcover.

Twenty-four different data layers were developed for natural vegetation core areas based on roads and buffers. Twelve data layers included water in the analysis, and the remaining 12 did not include water in the analysis. The 12 data layers are: 1) no roads – no buffer, 2) no roads - 90 m buffer, 3) no roads – 210 m buffer, 4) no roads – 300 m buffer, 5) major roads – no buffer, 6) major roads – 90 m buffer, 7) major roads – 210 m buffer, 8) major roads – 300 m buffer, 9) all roads – no buffer, 10) all roads – 90 m buffer, 11) all roads – 210 m buffer, and 12) all roads – 300 m buffer. The remaining 12 data layers are the same except that water was removed from the analysis.

Please refer to appendix I for metadata.

Use:
The natural vegetation core areas can be used to identify the largest patches of natural vegetation within each ecoregion.

Limitations:
As mentioned earlier, IFMAP land coverage is limited in accuracy. In addition, the IFMAP land cover was documented from satellite imagery taken between 1999 and 2001. Some areas of land have been altered since that time period rendering the land cover outdated for those areas.

File names:
natveg2 (grid)
_natveg2 (grid - water removed)

Data source:
Lu2001v2_g – IFMAP circa 2000 land use data for entire state of Michigan in grid format.
Michigan Geographic Framework statewide all roads layer version 5a

Results:
Total area of natural vegetation in the SLP equals 4,266,953 acres (20 % of the statewide total) (Table 8). This represents 27 % of the SLP region. Using 500 acres as a minimum patch size, the total area of natural vegetation in the SLP dropped to 3,065,733 acres (a 38 % decrease). Mean patch size was 4,194 acres. When all roads were used to define patch boundaries, and a 300 meter buffer was applied to each road and non-natural landcover, total area of natural vegetation in the SLP decreased to 14,373 acres. This represents only 0.3 % of the original area. These numbers indicate that natural vegetation in the SLP primarily consists of small, isolated, highly fragmented patches that are heavily impacted by roads (Figures 10 and 11).

Total area of natural vegetation in the NLP equals 7,325,525 acres (35 % of the statewide total) (Table 9). This represents 67 % of the NLP region. Using 2,500 acres as a minimum patch size, the total area of natural vegetation in the NLP dropped to 6,845,366 acres (a 7 % decrease). Mean patch size was 60,047 acres. When all roads are used to define patch boundaries, and a 300 meter buffer was applied to each road and non-natural landcover, total area of natural vegetation in the NLP decreased to 409,586 acres. This represents only 5.6 % of the original area. These numbers indicate that natural vegetation in the NLP primarily consists of moderately sized, somewhat fragmented patches that are impacted primarily by minor roads (Figures 10 and 11).

Table 8. Summary of natural vegetation core areas in the SLP ecoregional section.

Ecoregions (modified) water removed	road layer	Total acres of natural vegetation	# of patches	min. size (acres)	acres with road layer that meet minimum size	% acres with road layer that meet minimum size	buffer size in meters	acres with road layer and buffer	% acres with road layer and buffer that meet minimum size	Mean patch size
SLP	none	4,266,953	19,859	500	3,065,733	72%	0	3,065,733	100%	4,194
SLP	none	4,266,953	19,859	500	3,065,733	72%	90	328,973	11%	1,574
SLP	none	4,266,953	19,859	500	3,065,733	72%	210	126,979	4%	1,549
SLP	none	4,266,953	19,859	500	3,065,733	72%	300	51,526	2%	1,145
SLP	major	4,251,419	20,414	500	3,000,175	71%	0	3,000,175	100%	3,375
SLP	major	4,251,419	20,414	500	3,000,175	71%	90	328,973	11%	1,574
SLP	major	4,251,419	20,414	500	3,000,175	71%	210	126,979	4%	1,549
SLP	major	4,251,419	20,414	500	3,000,175	71%	300	51,526	2%	1,145
SLP	all	3,829,234	35,192	500	1,135,828	30%	0	1,135,828	100%	917
SLP	all	3,829,234	35,192	500	1,135,828	30%	90	144,204	13%	936
SLP	all	3,829,234	35,192	500	1,135,828	30%	210	39,883	4%	928
SLP	all	3,829,234	35,192	500	1,135,828	30%	300	14,373	1%	898

Table 9. Summary of natural vegetation core areas in the NLP ecoregional section.

Ecoregions (modified) - water removed	road layer	Total acres of natural vegetation	# of patches	min. size (acres)	acres with road layer that meet minimum size	% acres with road layer that meet minimum size	buffer size in meters	acres with road layer and buffer	% acres with road layer and buffer that meet minimum size	Mean patch size
NLP	none	7,325,535	4,712	2,500	6,845,366	93%	0	6,845,366	100%	60,047
NLP	none	7,325,535	4,712	2,500	6,845,366	93%	90	2,872,189	42%	16,699
NLP	none	7,325,535	4,712	2,500	6,845,366	93%	210	1,638,581	24%	13,655
NLP	none	7,325,535	4,712	2,500	6,845,366	93%	300	835,520	12%	9,495
NLP	major	7,305,038	5,229	2,500	6,845,366	94%	0	6,845,366	100%	60,047
NLP	major	7,305,038	5,229	2,500	6,845,366	94%	90	2,872,189	42%	16,699
NLP	major	7,305,038	5,229	2,500	6,845,366	94%	210	1,638,581	24%	13,655
NLP	major	7,305,038	5,229	2,500	6,845,366	94%	300	835,520	12%	9,495
NLP	all	6,859,681	20,080	2,500	2,730,501	40%	0	2,730,501	100%	5,450
NLP	all	6,859,681	20,080	2,500	2,730,501	40%	90	1,971,399	72%	5,357
NLP	all	6,859,681	20,080	2,500	2,730,501	40%	210	905,964	33%	5,148
NLP	all	6,859,681	20,080	2,500	2,730,501	40%	300	409,586	15%	5,319

Total area of natural vegetation in the UP was 9,502,487 acres (45 % of the statewide total) (table 10). This represented 88 % of the UP region. Using 5,000 acres as a minimum patch size, the total area of natural vegetation in the UP dropped to 9,354,185 acres (only a 2 % decrease). The mean patch size was 1,169,273 acres. When all roads were used to define patch boundaries, and a 300 meter buffer was applied to each road and non-natural landcover, total area of natural vegetation in the UP decreased to 2,659,822 acres. This represents 28 % of the original area. These numbers indicate that natural vegetation in the UP primarily consists of large, highly connected patches that are somewhat impacted by minor roads (Figures 10 and 11).

Table 10. Summary of natural vegetation core areas in the UP ecoregional section.

Ecoregion(modified)	road layer	Total acres of natural vegetation	# of patches	min. size (acres)	acres with road layer that meet minimum size	% acres with road layer that meet minimum size	buffer size in meters	acres with road layer and buffer	% acres with road layer and buffer that meet minimum size	Mean patch size (acres)
UP	none	9,502,487	1,944	5,000	9,354,185	98%	0	9,354,185	100%	1,169,273
UP	none	9,502,487	1,944	5,000	9,354,185	98%	90	6,859,935	73%	107,186
UP	none	9,502,487	1,944	5,000	9,354,185	98%	210	5,395,673	58%	78,198
UP	none	9,502,487	1,944	5,000	9,354,185	98%	300	4,242,582	45%	44,659
UP	major	9,484,693	2,296	5,000	9,291,547	98%	0	9,291,547	100%	154,859
UP	major	9,484,693	2,296	5,000	9,291,547	98%	90	6,824,489	73%	80,288
UP	major	9,484,693	2,296	5,000	9,291,547	98%	210	5,372,619	58%	62,472
UP	major	9,484,693	2,296	5,000	9,291,547	98%	300	4,224,697	45%	40,235
UP	all	9,247,664	7,117	5,000	7,019,981	76%	0	7,019,981	100%	18,093
UP	all	9,247,664	7,117	5,000	7,019,981	76%	90	4,997,897	71%	16,333
UP	all	9,247,664	7,117	5,000	7,019,981	76%	210	3,645,053	52%	16,129
UP	all	9,247,664	7,117	5,000	7,019,981	76%	300	2,659,822	38%	16,834

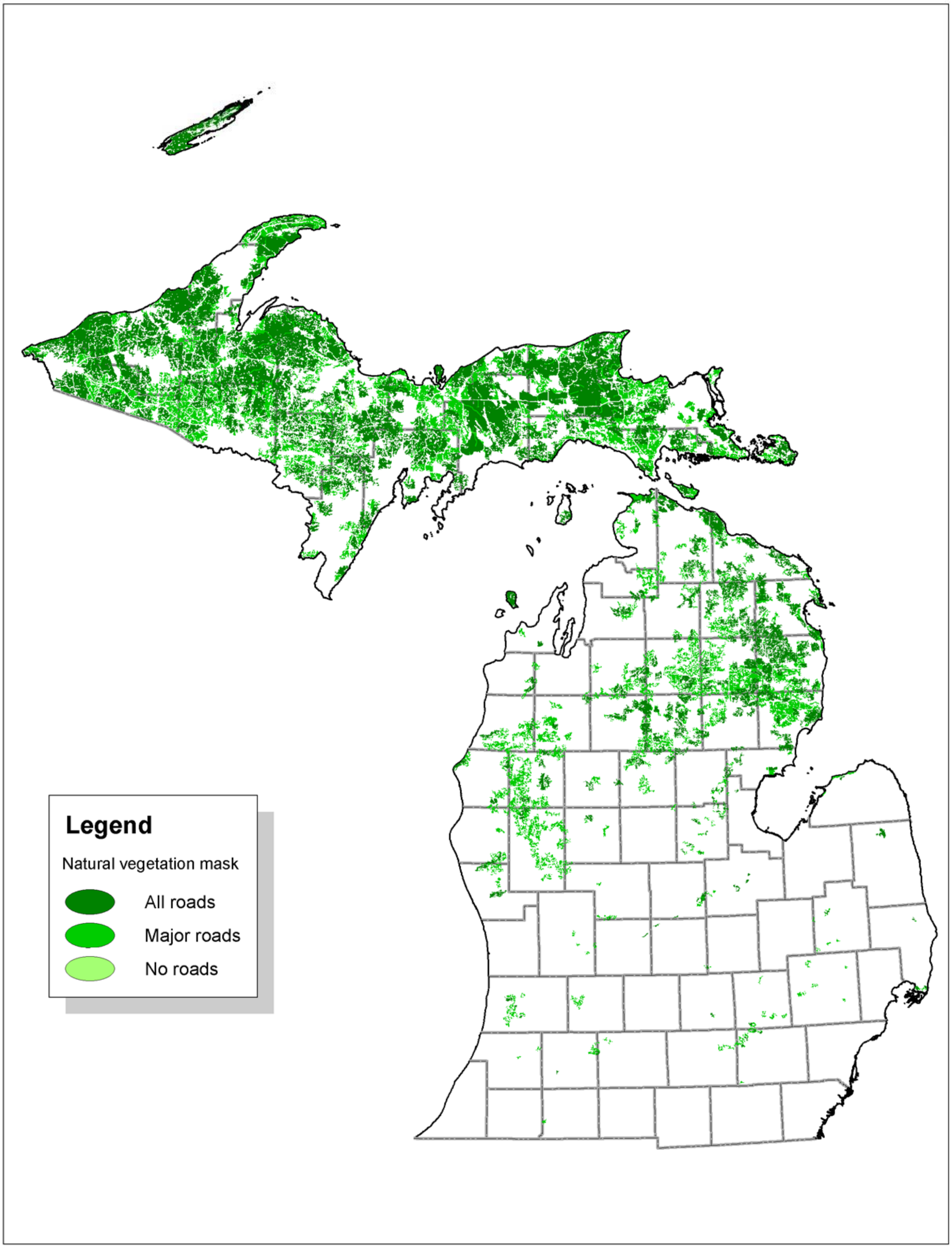


Figure 10. Natural vegetation core areas defined by the no road, major road, and all road data layers, and a 210 m buffer along roads and non-natural vegetation landcover.

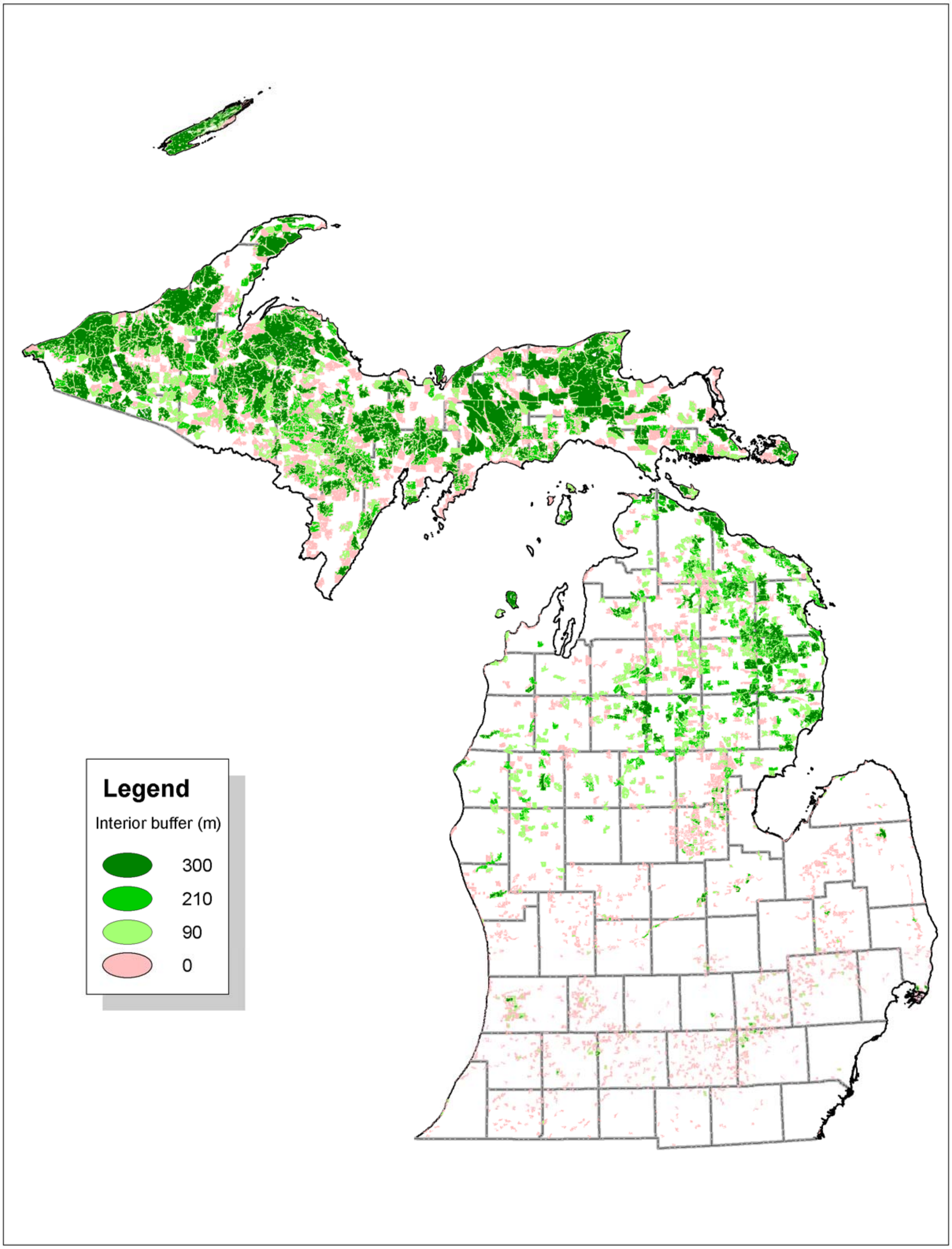


Figure 11. Natural vegetation core areas defined by all roads with a 0, 90, 210, 300 m buffer applied to roads and non-natural vegetation landcover.

Potentially unchanged natural vegetation core areas - by ecoregional section

Description:
The potentially unchanged natural vegetation core areas analysis identifies patches with pixels that appear to contain the same vegetation that was recorded in circa 1800. In order to accomplish this, MNFI staff created a table that crosswalks each of the circa 1800 vegetation types (31) to each of the 32 IFMAP level 2 class types. Each of the IFMAP level 2 classes were crosswalked to one of the eleven modified IFMAP vegetation classes created by MNFI, and then lumped together to form an unchanged vegetation data layer. All unchanged natural vegetation patches greater than a threshold size (see below) were selected. These select patches were then buffered inward by 90 meters. Again, patches greater than a threshold size were reselected. Water, which includes lakes, ponds, and large river segments, was originally included as part of the natural vegetation data layer. Once the 90 meter buffer was applied, water bodies greater than 10 acres were subtracted out of the data layer and the remaining patches were regrouped and extracted based on the ecoregional section thresholds.

Threshold sizes were set for each of the three ecoregional sections based on the percentage of potentially unchanged natural lands remaining, degree of fragmentation, and mean patch size. Due to the relatively small size of potentially unchanged natural vegetation patches across the state, it was determined that minimum thresholds would be set at 10% of the natural land patch minimum threshold sizes by ecoregional section. Therefore, the UP was set at 500 acres, the NLP was set at 250 acres, and the SLP was set at 50 acres.

Six different data layers of potentially unchanged natural vegetation core areas were developed for each ecoregional section based on roads and buffers (for a total of 18 data layers). The 6 data layers were: 1) no roads – no buffer, 2) no roads - 90 m buffer, 3) major roads – no buffer, 4) major roads – 90 m buffer, 50 all roads – no buffer, and 6) all roads – 90 m buffer.

Please refer to appendix J for metadata.

Use:
The potentially unchanged vegetation analysis can be used to identify what appears to be the least modified or altered patches of natural vegetation by ecoregional section. Unchanged vegetation was used to identify those areas that appear to be unchanged between circa 1800 and circa 2000. It can be assumed that these patches have a higher probability of being in high quality condition compared to patches that appear to be changed. This data layer can also be used to analyze unchanged natural vegetation patch statistics such as mean and median patch size, maximum size, and total acreage either at the statewide scale or by ecoregional section.

Limitations:
As mentioned earlier, IFMAP land cover is limited in accuracy. In addition, vegetation coverage was documented from satellite imagery taken between 1999 and 2001, and some areas have been altered since that time period. The circa 1800 vegetation data layer is based on general land office survey notes taken along section lines in the early to mid 1800's. This limited information from surveyor notes had to be extrapolated out to the remainder of the section (1 square mile), which means the majority of area within each section is based on scientific interpretation rather than empirical data.

File name:
unchanged (grid)

Data source:
Michigan Geographic Framework statewide all roads layer version 5a
Lu1800_g – circa 1800 vegetation for entire state of Michigan in grid format
Lu2001v2_g – IFMAP circa 2000 land use data for entire state of Michigan in grid format

Results:
Total area of potentially unchanged natural vegetation in the SLP was 663,803 acres (10.5 % of the statewide total) (Table 11). This represented only 4.3 % of the SLP region. Using 50 acres as a minimum patch size, the total area of potentially unchanged natural vegetation in the SLP dropped to 395,140 acres (a 40% decrease). The mean patch size was 126 acres. When all roads are used to define patch boundaries, and a 300 meter buffer is applied to each road and non-natural landcover, total area of potentially unchanged natural vegetation in the SLP decreased to 6,241 acres. This represents .9 % of the original area of potentially unchanged natural vegetation. These numbers indicate that potentially unchanged natural vegetation in the SLP consists of very small, isolated, and highly fragmented patches that are heavily impacted by both major and minor roads (Figure 12).

Total area of potentially unchanged natural vegetation in the NLP was 1,652,985 acres (26 % of the statewide total) (Table 11). This represented only 15 % of the NLP region. Using 250 acres as a minimum patch size, the total area of potentially unchanged natural vegetation in the NLP dropped to 1,071,634 acres (a 35 % decrease). The mean patch size was 1,142 acres. When all roads were used to define patch boundaries, and a 300 meter buffer was applied to each road and non-natural landcover, total area of potentially unchanged natural vegetation in the NLP decreased to 110,485 acres. This represents 6.7 % of the original area of potentially unchanged natural vegetation. These numbers indicate that potentially unchanged natural vegetation in the NLP consists of moderately sized, somewhat fragmented patches that are impacted by minor roads (Figure 12).

Total area of potentially unchanged natural vegetation in the UP was 4,032,176 acres (63.5 % of the statewide total) (Table 11). This represented 37.5 % of the UP region. Using 500 acres as a minimum patch size, the total area of potentially unchanged natural vegetation in the UP dropped to 3,273,235 acres (a 29 % decrease). The mean patch size was 4,696 acres. When all roads are used to define patch boundaries, and a 300 meter buffer was applied to each road and non-natural landcover, total area of potentially unchanged natural vegetation in the UP decreased to 668,238 acres. This represents only 16.6 % of the original area of potentially unchanged natural vegetation. These numbers indicate that potentially unchanged natural vegetation in the UP consists of very large, connected patches that are impacted by minor roads. The largest patches of potentially unchanged vegetation in the state are concentrated in the northern half of the eastern UP (Figure 12).

Table 11. Summary of potentially unchanged vegetation core areas statewide.

Ecoregion (Modified)	road layer	Total acres of potentially unchanged natural vegetation	# of patches	min. patch size (acres)	acres with road layer that meet minimum size	% acres with road layer that meet minimum size	buffer size in meters	acres with road layer and buffer	% acres with road layer and buffer that meet minimum size	Mean patch size (acres)
UP	none	4,032,176	9,386	500	3,273,235	81%	0	3,273,235	100%	4,696
UP	none	4,032,176	9,386	500	3,273,235	81%	90	941,821	29%	1,351
UP	major	4,025,336	9,553	500	3,253,778	81%	0	3,253,778	100%	4,253
UP	major	4,025,336	9,553	500	3,253,778	81%	90	845,117	26%	3,422
UP	all	3,894,087	12,529	500	2,820,870	72%	0	2,820,870	100%	2,345
UP	all	3,894,087	12,529	500	2,820,870	72%	90	668,238	24%	1,877
NLP	none	1,648,104	11,661	250	1,071,634	65%	0	1,071,634	100%	1,142
NLP	none	1,648,104	11,661	250	1,071,634	65%	90	213,692	20%	1,068
NLP	major	1,652,985	11,538	250	1,059,367	64%	0	1,059,367	100%	1,101
NLP	major	1,652,985	11,538	250	1,059,367	64%	90	210,306	20%	922
NLP	all	1,510,390	14,266	250	750,674	50%	0	750,674	100%	590
NLP	all	1,510,390	14,266	250	750,674	50%	90	110,485	15%	511
SLP	none	663,803	13,690	50	395,140	60%	0	395,140	100%	126
SLP	none	663,803	13,690	50	395,140	60%	90	10,963	3%	169
SLP	major	660,273	13,631	50	393,055	60%	0	393,055	100%	125
SLP	major	660,273	13,631	50	393,055	60%	90	10,787	3%	166
SLP	all	549,943	12,870	50	294,670	54%	0	294,670	100%	103
SLP	all	549,943	12,870	50	294,670	54%	90	6,241	2%	104

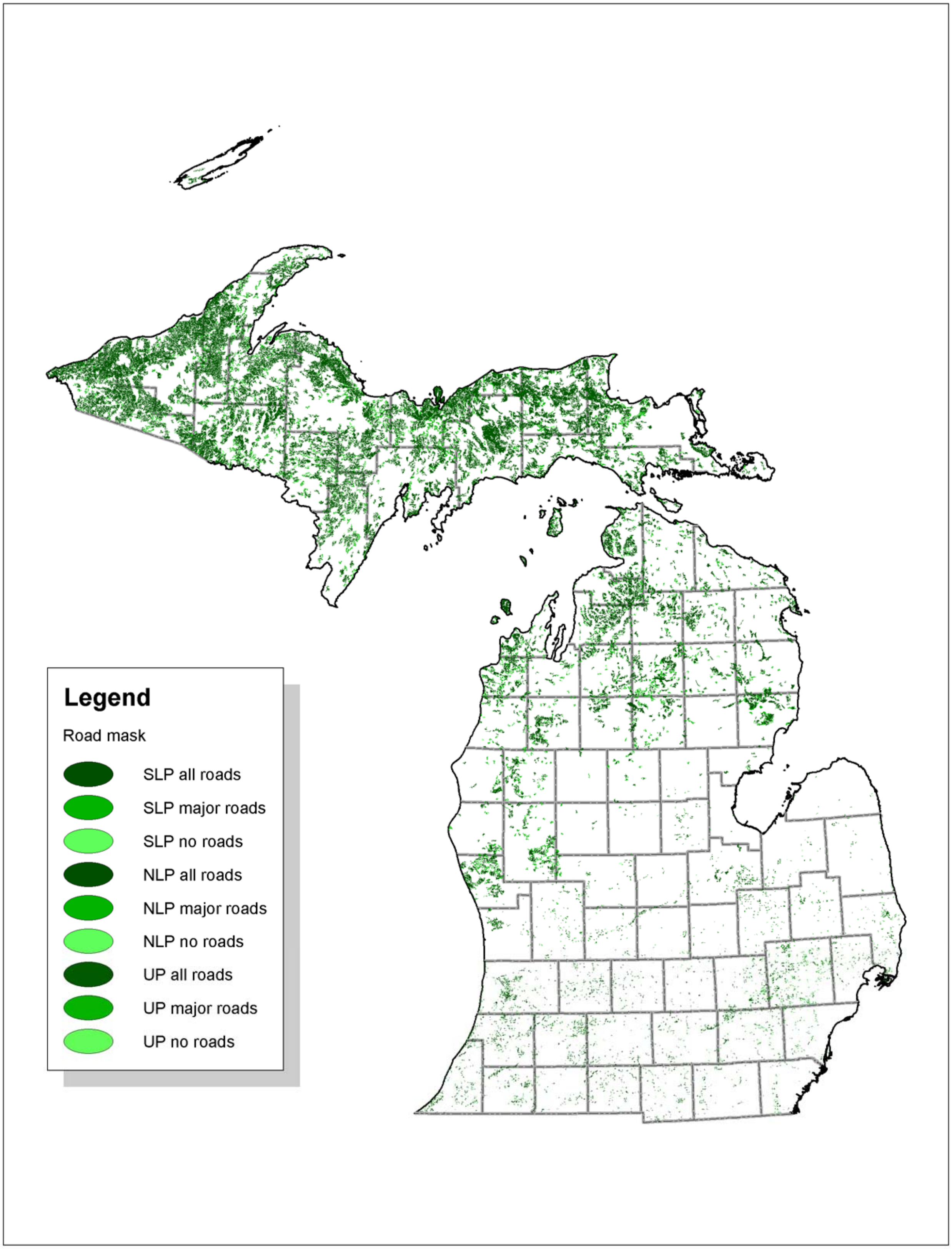


Figure 12. Potentially unchanged vegetation core areas defined by no road, major road, and all road data layers with a 0 m buffer.

Large Functional Landscapes

Description:
The large functional landscape analysis is a statewide look at natural vegetation core areas, without differentiating by ecoregion. In that sense, these patches are identical to the patches created for the natural vegetation core areas analysis. The difference is that these natural vegetation core areas were selected based on the matrix community criterion of 5,000 acres or greater as defined by The Nature Conservancy (Anderson et al. 1999). Patches greater than the minimum threshold are buffered inward using three different buffer sizes (90 m, 210 m, 300 m). After buffering, patches greater then the 5,000 acre criterion were reselected and retained. Water, which includes lakes, ponds, and large river segments, was originally included as part of the natural vegetation data layer. After each buffer was applied, water was subtracted out of the landscape, and the remaining patches regrouped, and reselected based on the minimum size threshold of 5,000 acres.

Twenty-four different data layers were developed for large functional landscape patches based on different road and buffer combinations. Twelve data layers included water in the analysis, and the remaining 12 did not include water in the analysis. The 12 data layers are: 1) no roads – no buffer, 2) no roads - 90 m buffer, 3) no roads – 210 m buffer, 4) no roads – 300 m buffer, 5) major roads – no buffer, 6) major roads – 90 m buffer, 7) major roads – 210 m buffer, 8) major roads – 300 m buffer, 9) all roads – no buffer, 10) all roads – 90 m buffer, 11) all roads – 210 m buffer, and 12) all roads – 300 m buffer. The remaining 12 data layers are the same as above except that water was removed from the analysis.

Please refer to appendix K for metadata.

Use:
The purpose of this analysis was to identify the largest most intact areas of natural vegetation in the state – sites that have the potential to function as matrix communities now or in the future. All natural vegetation types were combined to create one natural vegetation data layer. The reason for combining them together is that matrix communities typically contain numerous large and small patch natural community types.

Limitations:
As mentioned earlier, IFMAP land cover is limited in accuracy. In addition, vegetation coverage was documented from satellite imagery taken between 1999 and 2001. Some areas have been altered since that time period.

File names:
natveg2_matrix (grid)
natveg2_matrix_water_out (grid water removed)

Data source:
Michigan Geographic Framework statewide all roads layer version 5a
Lu2001v2_g – IFMAP circa 2000 land use data for entire state of Michigan in grid format.

Results:
Total area of natural vegetation in the state of Michigan (including water) was 22,084,814 acres (Table 12). Using a minimum patch size of 5,000 acres to define large functional landscapes, and removing water from these patches, the area of natural vegetation decreased to 18,749,300 (a 15 % decrease). When all roads were used to define patch boundaries, and a 300 m buffer was applied to each road and non-natural landcover, large functional landscapes decreased to 2,825,288 acres, or 12.8% of the original area of natural vegetation in the state. This demonstrates that 85% of the vegetation in Michigan is considered to be part of a large functional landscape patch, and that minor roads have a high impact on large functional landscapes in the state. The vast majority of large functional landscape patches are located in the UP (Figures 13 and 14).

Table 12. Summary of large functional landscape patches statewide.

Matrix Vegetation water removed	road layer	Total acres of natural vegetation	# of patches	min. size (acres)	acres with road layer that meet minimum size	% acres with road layer that meet min. size	buffer size in meters	acres with road layer and buffer	% acres with road layer and buffer that meet minimum size
Matrix	none	22,084,814	18,634	5,000	18,749,300	85%	0	18,749,300	100%
Matrix	none	22,084,814	18,634	5,000	18,749,300	85%	90	11,437,341	61%
Matrix	none	22,084,814	18,634	5,000	18,749,300	85%	210	7,025,589	37%
Matrix	none	22,084,814	18,634	5,000	18,749,300	85%	300	4,994,044	27%
Matrix	major	22,029,008	19,657	5,000	18,239,182	83%	0	18,239,182	100%
Matrix	major	22,029,008	19,657	5,000	18,239,182	83%	90	11,270,153	62%
Matrix	major	22,029,008	19,657	5,000	18,239,182	83%	210	6,954,357	38%
Matrix	major	22,029,008	19,657	5,000	18,239,182	83%	300	4,957,123	27%
Matrix	all	20,909,709	45,280	5,000	8,934,329	43%	0	8,934,329	100%
Matrix	all	20,909,709	45,280	5,000	8,934,329	43%	90	6,123,369	69%
Matrix	all	20,909,709	45,280	5,000	8,934,329	43%	210	3,927,944	44%
Matrix	all	20,909,709	45,280	5,000	8,934,329	43%	300	2,825,288	32%

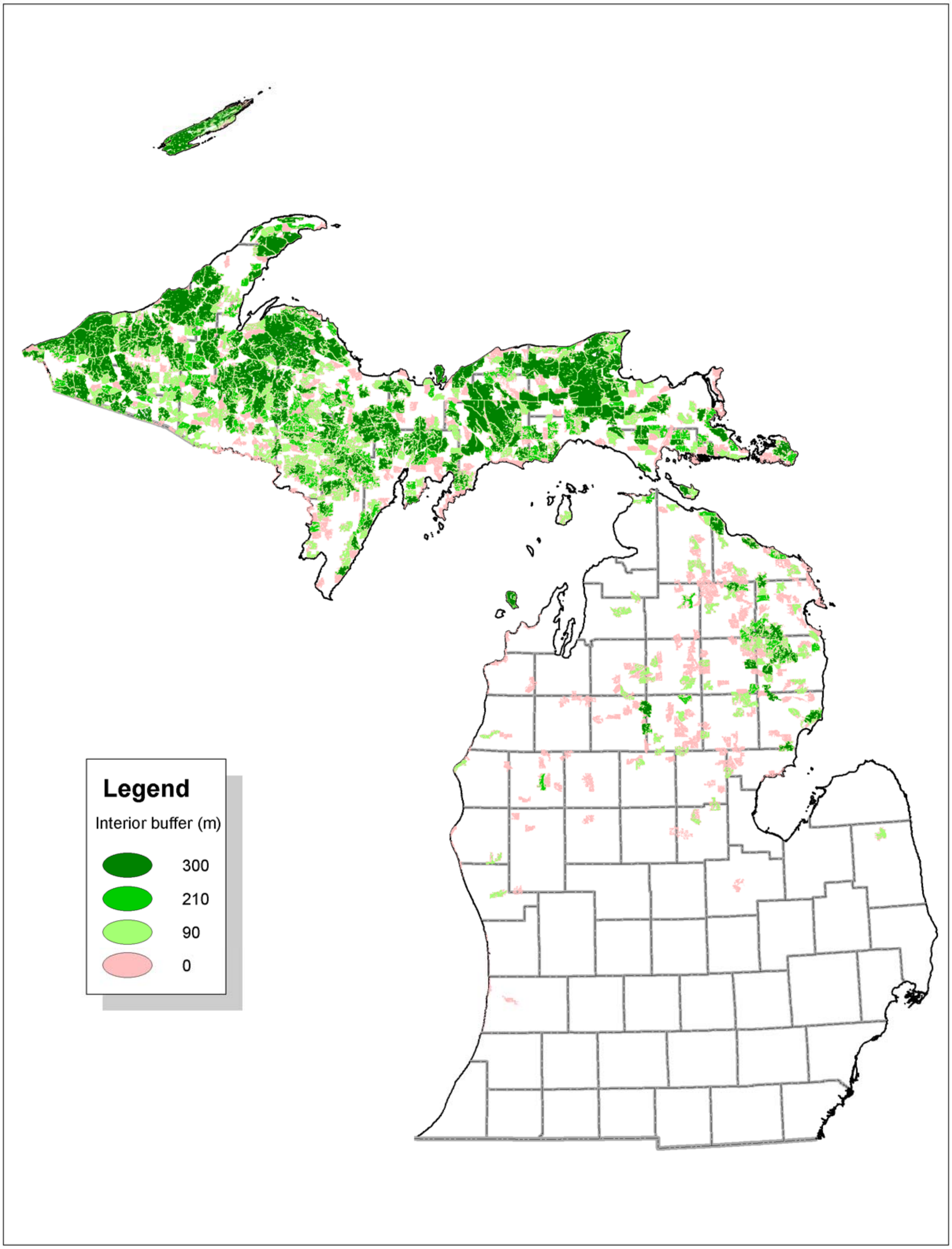


Figure 13. Large functional landscape patches defined by all roads with 0, 90, 210, and 300 m buffers applied.

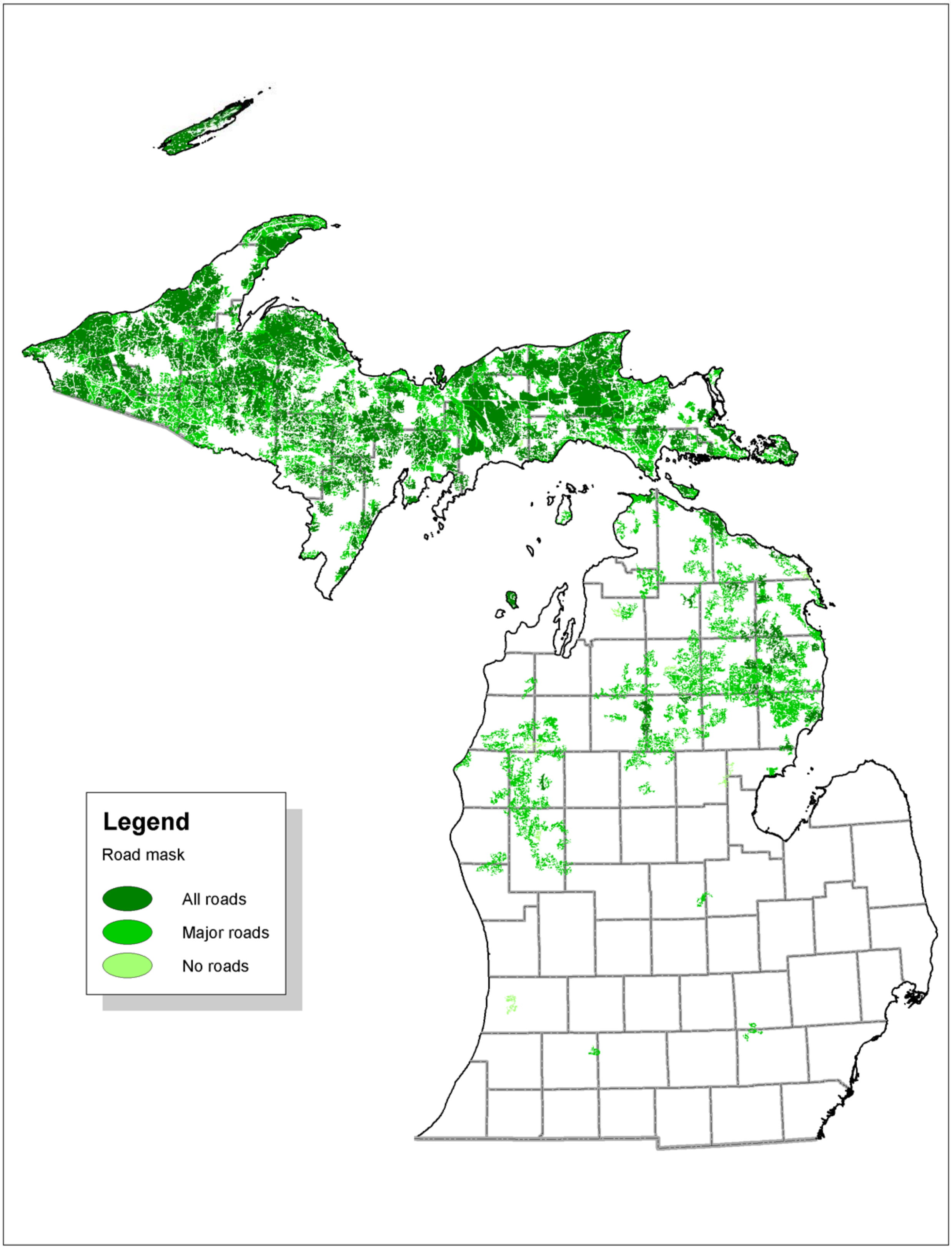


Figure 14. Large functional landscape patches defined by no road, major road, and all road data layers with a 210 m buffer applied.

Fine Filter - Element Occurrence Data

Description:

The Michigan Natural Features Inventory has been inventorying and tracking Michigan's threatened, endangered, and special concern species and high quality natural communities since 1979. As of September, 2006, MNFI tracked 417 plant species, 248 animal species, and 74 natural community types. In addition to species and natural communities, MNFI also tracks other natural features such as colonial bird nesting colonies and significant geological features. The tracked species include those with Federal and State legal protection and special concern species, which have no legal protection. Like the special concern species, natural communities also have no legal protection status. As of September, 2006, The MNFI database contained approximately 14,532 records of these natural features (plants, animals, and natural communities). Data sources include museum and herbarium collections, published reports, MNFI field surveys, and information from cooperators. Database records span a range from historic information to very current information from the latest field season. The MNFI database is continually being updated and is the most complete record of Michigan's sensitive species and natural features.

The MNFI database is a Natural Heritage database and utilizes Natural Heritage methodology and data standards originally designed by The Nature Conservancy and now maintained by Natureserve (www.natureserve.org). The MNFI database is more than a presence/absence database. Among other information, it contains dates of sightings, global and state imperilment rankings for species, and a quality (or viability) ranking for individual occurrences. Definitions of the global and state (or sub-national) rankings can be found in appendix A. The quality ranking is an A – D scale with A being the highest quality. Other codes such as E for extant, H for historic, and X for extirpated are also used. Extant is used when not enough information is available to assess population viability. The standards for applying a quality rank to an occurrence vary by species and community, but generally fall into three main categories: size, condition, and context. See the chapter entitled approach for more information.

Limitations:

The primary limitations to MNFI's element occurrence database are: 1) it contains static information – each element occurrence is updated infrequently 2) a lack of a statewide systematic survey, and 3) the presence of very old and/or general (non location specific) records. Biological information from the field is collected annually from MNFI staff and other reliable contributors. Once this information is entered into the database, it may be decades before it gets updated. For example, approximately 36 % of the records in the database are over 20 years old. More significantly, there has never been a systematic survey of element occurrences in the state. This means that something can be said about the biological significance of an area containing element occurrence records, however nothing can be said definitively about the biological significance of areas with no known element occurrence records. This is where the quote "absence of evidence is not evidence of absence" comes into play. Related to this, is that there have been small areas of the state that have been systematically surveyed; however they are predominantly owned by public agencies or non-governmental organizations such as The Nature Conservancy.

Fine Filter - Element Occurrence Data Analysis

EO Frequency Count

Description:
The EO frequency count is a count of all element occurrences that fall within a given public land survey system (PLSS) section. The model utilizes a statewide GIS data layer (Environmental Systems Research Institution (ESRI) shapefile) of the PLSS sections. A numeric count field is added to the section shapefile theme table. Each section shape is selected in turn and intersected with the MNFI GIS database. The number of occurrences intersecting each section shape is counted and that value is calculated into the count field in the section shapefile theme table. A cutoff date of September 1, 2006 was used to create the EO frequency datasets. All records added to the Michigan Natural Features database after this date are not included in this analysis.

A total of 6 data layers were developed for the terrestrial EO frequency count. They are differentiated by element categories and last observed dates. The 9 data layers are: 1) all species (no natural communities) – all dates, 2) all species (no natural communities) – only dates ≥ 1985, 3) only terrestrial species – all dates, 4) only terrestrial species – only dates ≥ 1985, 5) all element occurrences – all dates, and 6) all element occurrences – only dates ≥ 1985.

Use:
The EO frequency count is a relatively simple representation of the MNFI data. It is designed to show users where there are concentrations of known species or natural community occurrences in the MNFI database. While the EO frequency count provides limited information, it does fulfill its intended purpose. Users can see if there are known occurrences in the vicinity of a proposed project or delineate those areas where there are concentrations of occurrences. All species information is removed so locations of particularly sensitive species cannot be determined from the model.

Limitations:
The primary disadvantage is that it provides very limited information. The user only knows that the known boundary of an occurrence overlaps the boundary of the area of interest. No allowance is made for the age of the record, relative importance of the species, or the extent of potential habitat within the occurrence boundary.

File names:
Ter_EO_trs_0906.shp
freq_ter_trs_v9-06.shp

Data source:
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:
Values vary depending on which dates and natural feature elements are utilized in the analysis. Using only terrestrial species and all last observed dates in the database, frequency values for PLSS sections range from a low of 0 to a high of 65 (Figure 15). Using the Jenk's optimization classification method to define groupings, < 1 % (51) of all PLSS sections fell into the highest category (scores 34 - 65). Geographic areas that fell into the highest category included: northern half of Isle Royale, southwest corner of the Lower Peninsula, and eastern Washtenaw County (figure 15).

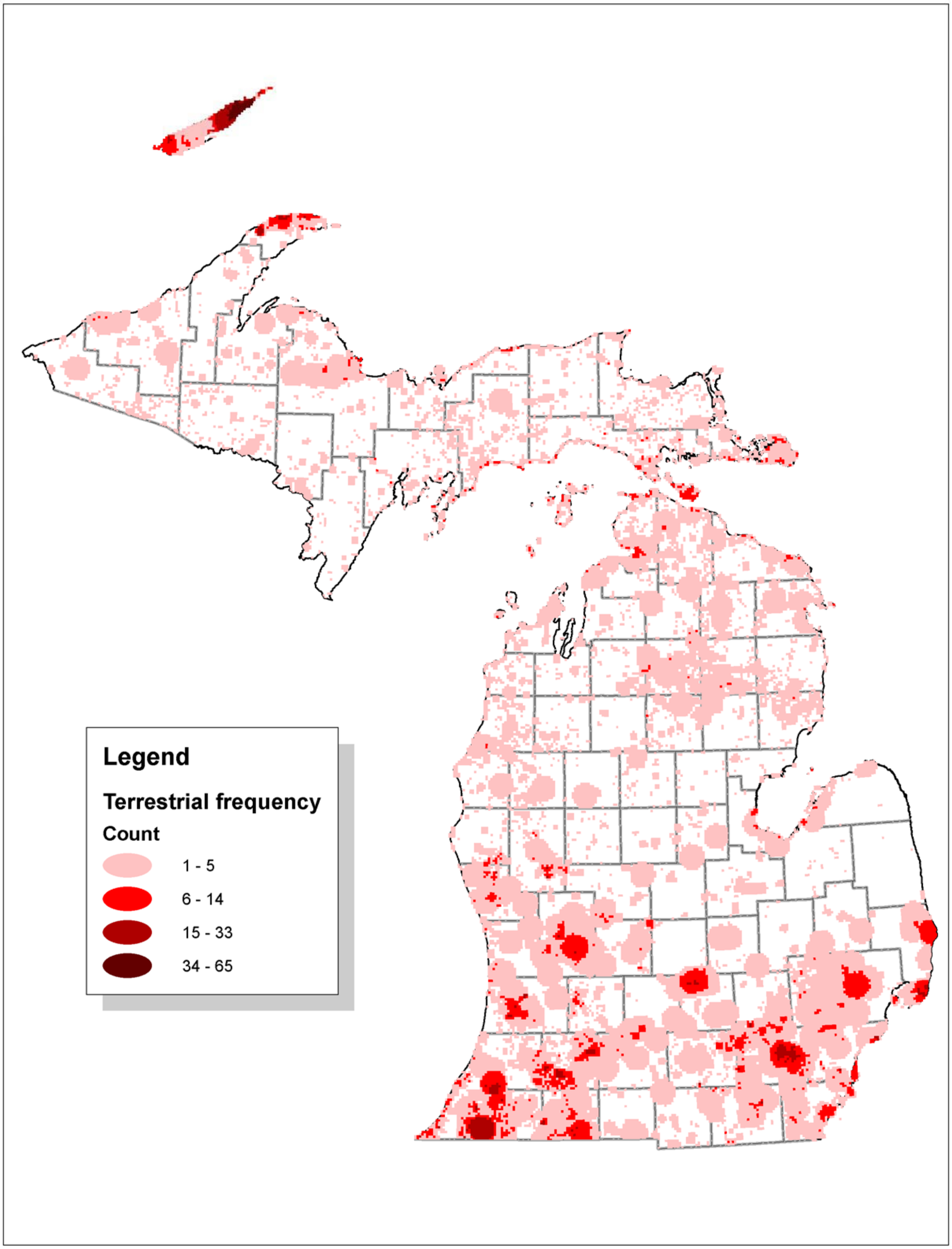


Figure 15. Frequency of rare terrestrial species using all last observed dates.

EO Likelihood

Description:

The overall modeling process of EO likelihood consists of grouping species into habitat guilds, creating a habitat layer for each guild, using the habitat layer to redefine the spatial extent of the appropriate occurrences, intersecting the spatially redefined occurrences with political boundaries (PLSS unit), and then assigning each political unit a likelihood value. The process starts by grouping species into habitat classes and assigning a habitat identifier code to each species occurrence. Features in the MNFI database other than species and natural communities, such as geological formations, are removed from the analysis.

Next a habitat layer is created for each habitat class. The habitat layers are then used to redefine the spatial extent of the occurrences. This is accomplished by selecting all the occurrences with a given habitat code then clipping the selected occurrences using the appropriate habitat layer as the clipping overlay theme. The result of this operation produces a new theme for each habitat group. In each new theme the spatial extent of each occurrence is replaced by the spatial extent of the habitat within the original boundary of the occurrence. The new theme retains all the database attributes of the original occurrence database. Where fragmented habitat patches occur within an occurrence boundary, the occurrence will be converted from a single shape to multiple shapes. The clipping operation was not performed on natural community occurrences because the communities have a defined spatial extent. The natural communities are selected out of the occurrence database and converted to a separate layer.

The themes for each habitat group and the natural community themes are then all merged together. After merging the themes for each habitat type into a single theme, the merged theme is dissolved on the unique code number assigned to each individual occurrence. This operation consolidates all the separate shapes for each occurrence into a single shape. Each occurrence is then assigned a value based on the age of the record. This value is used to represent the likelihood of the occurrence still existing. Occurrences with a last observed date of no later than 1982 are assigned a value of one, occurrences between 1970 and 1982 are assigned a value of 0.5, and occurrences prior to 1972 are assigned a value of 0.25. All natural community records are assigned a value of one.

To create the EO likelihood value for the PLSS data set, all records in the PLSS data set are selected and assigned a “No Status” value. Next the records in the species database with the lowest likelihood of still existing (value = 0.25) are selected. The PLSS data set is intersected with the species database and the selected PLSS records are assigned a value of “Low.” Next those records with a moderate likelihood of still existing are selected (value = 0.5). The PLSS data set is intersected with the species database and the selected PLSS records are assigned a value of “Moderate.” Finally the records in the species database with the highest likelihood of still existing (value = 1) are selected. The PLSS data set is intersected with the species database and the selected PLSS records are assigned a value of “High.” Performing the selections and intersections in this order insures that a higher likelihood value in any PLSS feature will override a lower likelihood value. A cutoff date of September 1, 2006 was used to create EO likelihood datasets. All records added to the Michigan Natural Features database after this date are not included in this analysis.

A total of six data layers were developed for the terrestrial EO likelihood count. They are differentiated by element categories and last observed dates. The six data layers are: 1) all species (no natural communities) – all dates, 2) all species (no natural communities) – only dates ≥ 1985, 3) only terrestrial species – all dates, 4) only terrestrial species – only dates ≥ 1985, 5) all element occurrences – all dates, and 6) all element occurrences – only dates ≥ 1985.

Use:
The EO likelihood model is designed to help protect biodiversity and minimize potential regulatory problems by directing development away from those areas with a high likelihood of encountering a sensitive species. Because no specific species information is presented, the model reduces the sensitivity of the underlying MNFI data. A high probability indicates that the area of interest contains the spatial extent of an occurrence, there is potential habitat within the area, and the occurrence has been observed in the recent past. A low probability indicates that the area contains the spatial extent of an historic species occurrence and there is potential habitat within the area. While the low likelihood indicates that the underlying occurrences are historic, there is still a possibility that the species persists in appropriate habitat. In the recent past, MNFI botanists have reconfirmed three 100 year old plant records. A moderate likelihood indicates, by default, something between the other two values.

The EO likelihood model provides users with a higher level of information than the simple EO frequency count. Unlike the EO frequency count, which only implies that the extent of an occurrence lies within an area of interest, the EO likelihood model delineates those areas where there is a higher likelihood of encountering a known occurrence of a sensitive species or natural community. Also, by utilizing potential habitat within the known extent of the occurrences, areas without potential habitat are eliminated from consideration. The EO likelihood model can be used in the context of both land use planning efforts and conservation planning efforts. By delineating areas with a high likelihood of encountering a sensitive species or natural community, the model can be used to direct development away from those areas, or to identify areas worthy of conservation efforts.

Limitations:
One shortcoming of the EO likelihood model is that all high likelihood areas are treated the same. Whether there is one recent occurrence in the area or thirty recent occurrences, the same high likelihood value is assigned to the area. There is also no allowance for the relative imperilment of the species found in any unit of interest, and there is no numeric value assigned to any of the units of interest that allow them to be compared to each other.

File names:
Ter_EO_trs_0906.shp
likelihood_ter_trs_v9-06.shp

Data source:
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:
The number of PLSS sections that fell into any one category varied depending on the last observed dates of the natural feature elements used in the analysis. Using only rare terrestrial species and all last observed dates in the MNFI database, 17 % of all PLSS sections in the state fell into the high probability category (Figure 16).

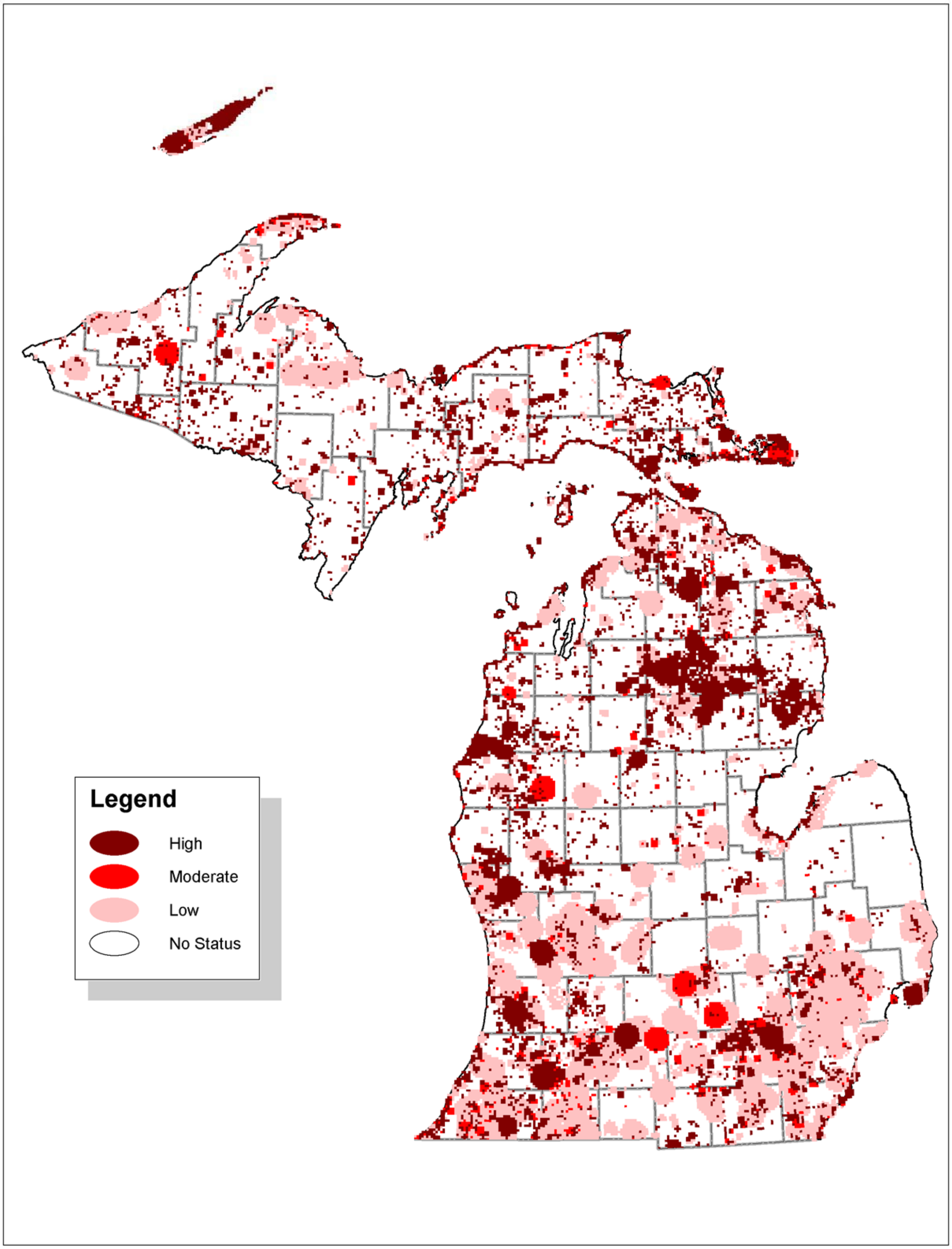


Figure 16. Likelihood of a known rare terrestrial species occurrence still occurring in its last observed location using all last observed dates.

Bio-rarity Score

Description:

In addition to the EO likelihood value described above, each element occurrence is also assigned three other values based on: 1) the species global status, 2) the species state status, and 3) on the occurrence's viability rank. The greater the threat of imperilment to the species, the higher the value assigned to the occurrence. In a similar manner, the higher the quality or viability of each occurrence, the higher the value assigned to it. The biodiversity value of each occurrence is then calculated by adding the values for the global status, state status, and the quality ranking, then multiplying the sum by the EO likelihood value described above. To calculate the biodiversity value of a given PLSS feature, each feature in the PLSS theme is selected in sequence. Next, all the species occurrences intersecting the PLSS feature are selected. The biodiversity values of the selected species occurrences are summed and assigned to the PLSS feature. The result is a value for each PLSS unit that is the sum of the biodiversity values of all occurrences falling within the PLSS unit. A cutoff date of September 1, 2006 was used to create the bio-rarity datasets. All records added to the Michigan Natural Features database after this date are not included in this analysis.

A total of six data layers were developed for the terrestrial bio-rarity score. They are differentiated by element categories and last observed dates. The six data layers are: 1) all species (no natural communities) – all dates, 2) all species (no natural communities) – only dates ≥ 1985, 3) only terrestrial species – all dates, 4) only terrestrial species – only dates ≥ 1985, 5) all element occurrences – all dates, and 6) all element occurrences – only dates ≥ 1985.

Use:

Unlike the EO likelihood model, the bio-rarity score allows similar areas to be compared to each other to determine their relative contributions to biodiversity. Because resources for conservation are generally limited, the bio-rarity score can help direct limited resources to those areas where the resources will have the greatest conservation impact.

Limitations:

As with other element occurrence based information, this data layer is limited by: 1) static information, which is updated infrequently, 2) incomplete data, and 3) old and/or general (non location specific) records.

File names:

Ter_EO_trs_0906.shp

br_ter_trs_v9-06.shp

br_ter85_trs_v9-06.shp

Data source:

Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:

Values vary depending on which dates and natural feature elements are utilized in the analysis. Using only rare terrestrial species and all last observed dates in the MNFI database, bio-rarity values for PLSS sections range from a low of 0 to a high of 357.88. Using quantiles to statistically define groupings, PLSS sections with bio-rarity scores ≥ 23.13 fell into the top 10 % of scores. A few spatially distinct areas that fell into the highest category included: northern half of Isle Royale, Allegan

State Game Area, Fort Custer Recreation Area, southeast Newaygo County, southern Oceana and northern Muskegon Counties, northern Lake Michigan and Lake Huron shorelines, and the central high plains of the northern Lower Peninsula (Figure 17 and 18). These results may be due to survey bias and/or the naturally high concentrations of natural features in these areas.

Best two occurrences of each terrestrial species by sub-subsection

Description:
The two highest ranking occurrences of each rare terrestrial plant and animal tracked by MNFI were identified for each sub-subsection (as described by Albert et. al., 1995). There are a total of 398 terrestrial plants (appendix A) and 174 animals (appendix B) currently tracked by MNFI. There are a total of 38 sub-subsections, plus 7 sub-sections that do not contain any sub-subsections, in Michigan (for a total of 45 units used in this analysis). A cutoff date of September 1, 2006 was used to create this dataset. All records added to the MNFI database after this date were not included in the analysis.

Use:
In some cases, important element occurrences may be located outside areas deemed significant due to other natural assets such as size, intactness, connectivity, and quality. Identifying areas with high quality element occurrences regardless of natural vegetation quality or landscape context can be important for ensuring adequate biological representation, and in turn protecting potential genetic variability.

How many occurrences of each element are enough for sufficient representation is a difficult question to answer. Two was chosen simply because it is more than one. However, given 45 units and the wide geographic range of some of these species and communities, 2 element occurrences per unit could theoretically add up to 90 occurrences of each element statewide.

Limitations:
As with the other element occurrence based information, this data layer is limited by: 1) static information, which is updated infrequently, 2) incomplete data, and 3) old and/or general (non location specific) records.

File names:
best2_ter_subsubsection_trs_0906.shp
best2_ter_subsub_summed_trs_0906.shp

Data source:
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:
As a result of this analysis, **3,768 occurrences** (out of 9,985 total terrestrial element occurrences) were identified as one of the best two occurrences of each terrestrial species by sub-subsection. This represents approximately **38%** of all terrestrial species element occurrences.The three sub-subsections with the highest number of best two terrestrial element occurrences are: 1) Battle Creek Outwash Plain (340 EO's), 2) Maumee Lake Plain (236 EO's), and 3) Southern Lake Michigan Lake Plain (231 EO's). All three are located in the southern Lower Peninsula (Table 13, Figure 19).

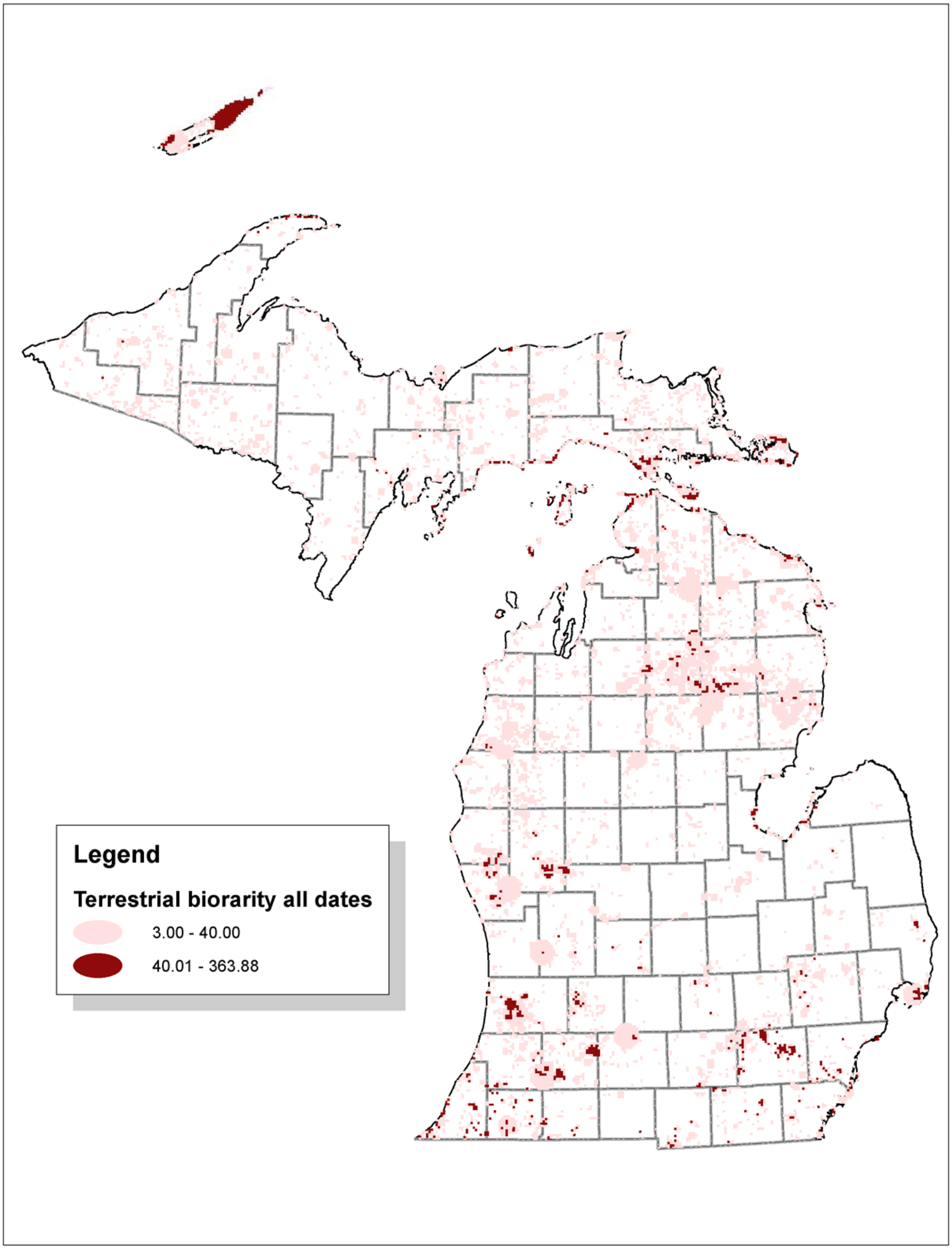


Fig. 17. Bio-rarity scores for all element occurrences using all last observed dates - top 10%.

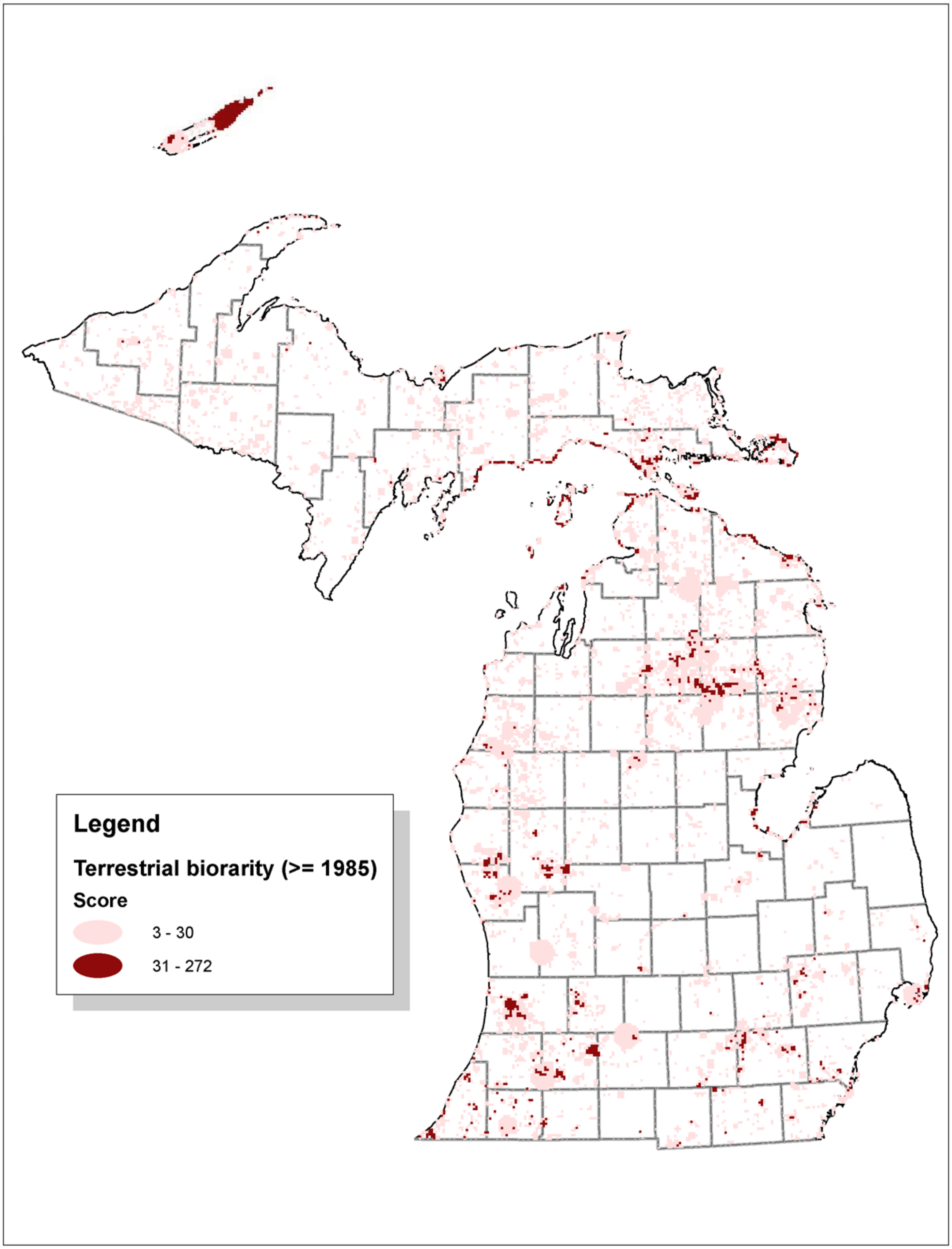


Figure 18: Bio-rarity scores for rare terrestrial species with last observed dates ≥ 1985 - top 10%.

Table 13. Total number of best two terrestrial element occurrences by sub-subsection or subsection.

Sub-subsection or subsection	Name of sub-subsection or subsection	Total # of best 2 terrestrial EO's
0		31
611	**Maumee Lake Plain**	**236**
612	Ann Arbor Moraines	199
613	Jackson Interlobate	185
621	**Battle Creek Outwash Plain**	**340**
622	Cassopolis Ice-Contact Ridges	172
631	Berrien Springs	150
632	**Southern Lake Michigan Lake Plain**	**231**
633	Jamestown	22
641	Lansing	197
642	Greenville	61
651	Sandusky Lake Plain	101
652	Lum Interlobate	23
660	Saginaw Bay Lake Plain	83
711	Standish	44
712	Wiggins Lake	5
721	Cadillac	42
722	Grayling Outwash Plain	92
723	Vanderbilt Moraines	57
730	newaygo Outwash Plain	108
740	Manistee	137
751	Williamsburg	7
752	Traverse City	41
761	Onaway	73
762	Stutsmanville	14
763	Cheboygan	84
811	St. Ignace	159
812	Rudyard	31
813	Escanaba/Door Peninsula	90
821	Seney Sand Lake Plain	72
822	Grand Marais Sandy End Moraine and Outwash	100
831	Northern Lake Michigan Till Plain	53
832	Gwinn	14
833	Deerton	11
910	Spead Eagle-Dunbar Barrens	39
920	Michigame Highland	67
931	Brule and Paint Rivers	13
932	Winegar Moraine	46
950	Lac Veaux Desert Outwash Plain	3
961	Gogebic-Penokee Iron Range	45
962	Ewen	24
963	Baraga	18
971	Gay	13
972	Calumet	101
973	Isle Royale	113
980	Lake Superior Lake Plain	21
Total		3,768

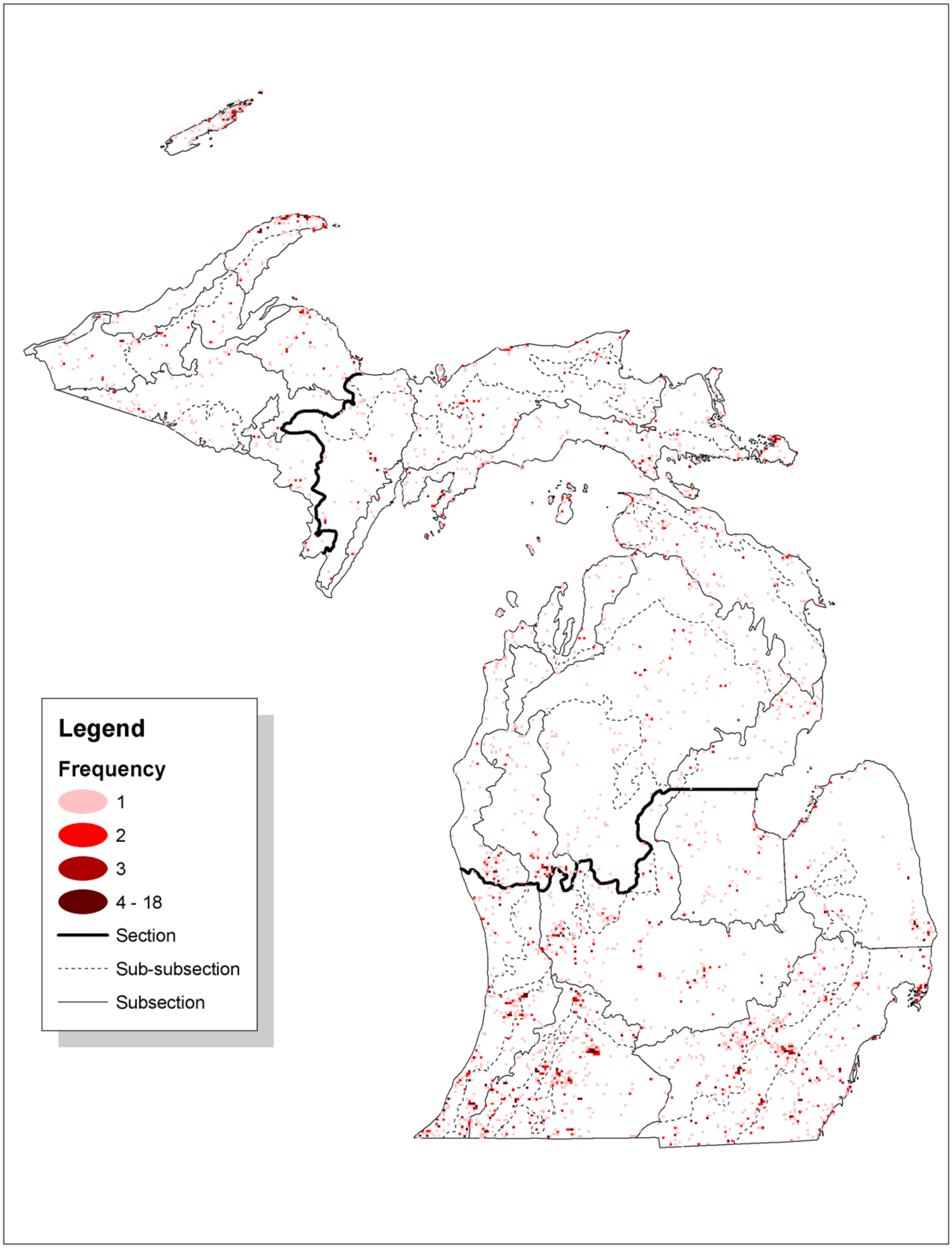


Figure 19. Best two terrestrial element occurrences by sub-subsection or subsection.

High quality natural communities

Description:
The MNFI database contains records of high quality and/or rare natural communities. Currently, MNFI tracks 74 different natural community types (Appendix B). As of September 28, 2006, the database contained **1,371** natural community records which represent approximately **9%** of the total records for plants, animals, and natural communities. High quality natural communities were defined as those communities with a B/C element occurrence rank or higher. A "C" ranked community, which was not included in the high quality category, means that the natural community is moderately degraded and long-term viability is estimated to be fair. A cutoff date of September 28, 2006 was used to create this dataset. All records added to the MNFI database after this date were not included in this analysis.

Use:
High quality natural communities represent the best, most viable known occurrences of the 74 different natural community types found in Michigan (as recognized by MNFI). Natural communities are important because they provide the environment necessary for plants and animals to persist and evolve over the long-term. High quality natural communities provide the genetic material needed for changing environmental conditions and restoration projects. They also are a good benchmark for guiding the planning, implementation, and monitoring of natural community restoration and management projects.

Limitation:
As with the other element occurrence based information, this data layer is limited by: 1) static information, which is updated infrequently, 2) incomplete data, and 3) old and/or general (non location specific) records. In addition, EO ranks for natural communities have a certain degree of inconsistency due to human judgment, changes in EO rank specifications over time, and an emphasis on qualitative criteria. In addition, approximately 64 natural community occurrences were missing acreage information.

File names:
community_w_best_attributes.shp
natcomm_bcrank.shp

Data sources:
Biot_p – Biotics polygon database created directly from Biotics from version with a last observed date of 09/28/2006.
Biot_x – Biotics point database created directly from Biotics from version with a last observed date of 09/28/2006.

Results:
Of the 1,371 natural community element occurrences in the MNFI database, 68 % (932) of these occurrences had an element occurrence rank of BC or higher (A, AB, B, BC) (Table 14). These ranks were interpreted to mean that these occurrences are high quality and viable over a long period of time. The spatial extent of natural communities with a BC rank or higher totaled 390,919 acres. This represents approximately 1 % of the landscape in Michigan (Figure 20).

Table 14. Summary of high quality natural communities with an EO rank of ≥ BC.

Total # of natural community EO's	Total acres	Total # ≥ B/C rank	% of total	Total acres ≥ B/C rank	% of Total acres
1,371	431,964	932	68%	390,919	90%

Best occurrences of each natural community type
Description:
The highest quality occurrences of Michigan's 74 natural community types (Appendix B) were identified at four scales: statewide, Ecological section, Ecological subsection, and Ecological sub-subsection (Albert 1995). At each scale, the three highest-quality examples of each community type were identified. The rankings were nested so that the highest quality occurrence of a natural community at the broad scale (statewide or section) was also the highest quality occurrence at the appropriate local scale (subsection and sub-subsection). It is important to note that the MNFI natural community classification was revised after this analysis was completed.

Rankings were primarily based on existing EO data in the MNFI database. All occurrences of each natural community type are ranked according to condition/quality, size, and landscape context. Rankings for these factors are combined to calculate an overall EO Rank on an A-D scale, with A-ranked occurrences representing the highest quality sites, C-ranked occurrences meeting the minimal standards for a community to be included in the MNFI database as an element occurrence, and D-ranked communities representing occurrences for rare communities that are not represented by any A-C ranked (high quality) examples. For the purposes of determining the highest quality EOs for each community type, C-ranked occurrences were generally omitted from consideration, unless no A- or B-ranked occurrences were documented at a particular scale.

Due to the fact that element occurrences have been documented and ranked by different surveyors over the course of approximately 25 years, and given that the tools and methods for assessing community quality have evolved over that time, A-ranked occurrences were not necessarily assumed to be of higher quality than AB- or B-ranked occurrences. For each community type, field notes and the most recent aerial photographs (1998) were consulted to identify the highest quality occurrences at each scale. Digital maps for each occurrence were checked against hand-drawn maps for accuracy, and, in many cases, occurrences were remapped. Two primary reasons for remapping were inaccurate digitization of the original maps and post-survey changes in spatial extent of occurrences due to anthropogenic disturbance or development. In some instances, significant changes in acreage associated with remapping warranted lowering or raising the overall EO Rank.

In some cases, especially for natural communities with a high number of occurrences (e.g., prairie fen, bog), there are many occurrences of equal rank at one or multiple scales. For example, in subsection 7.3, there are five B-ranked bog occurrences. In sub-subsection 6.1.3, there are three A-ranked prairie fen occurrences. In these instances, occurrences were ranked relative to each other based on the best available information regarding condition/quality, size, and landscape context, in the following manner.

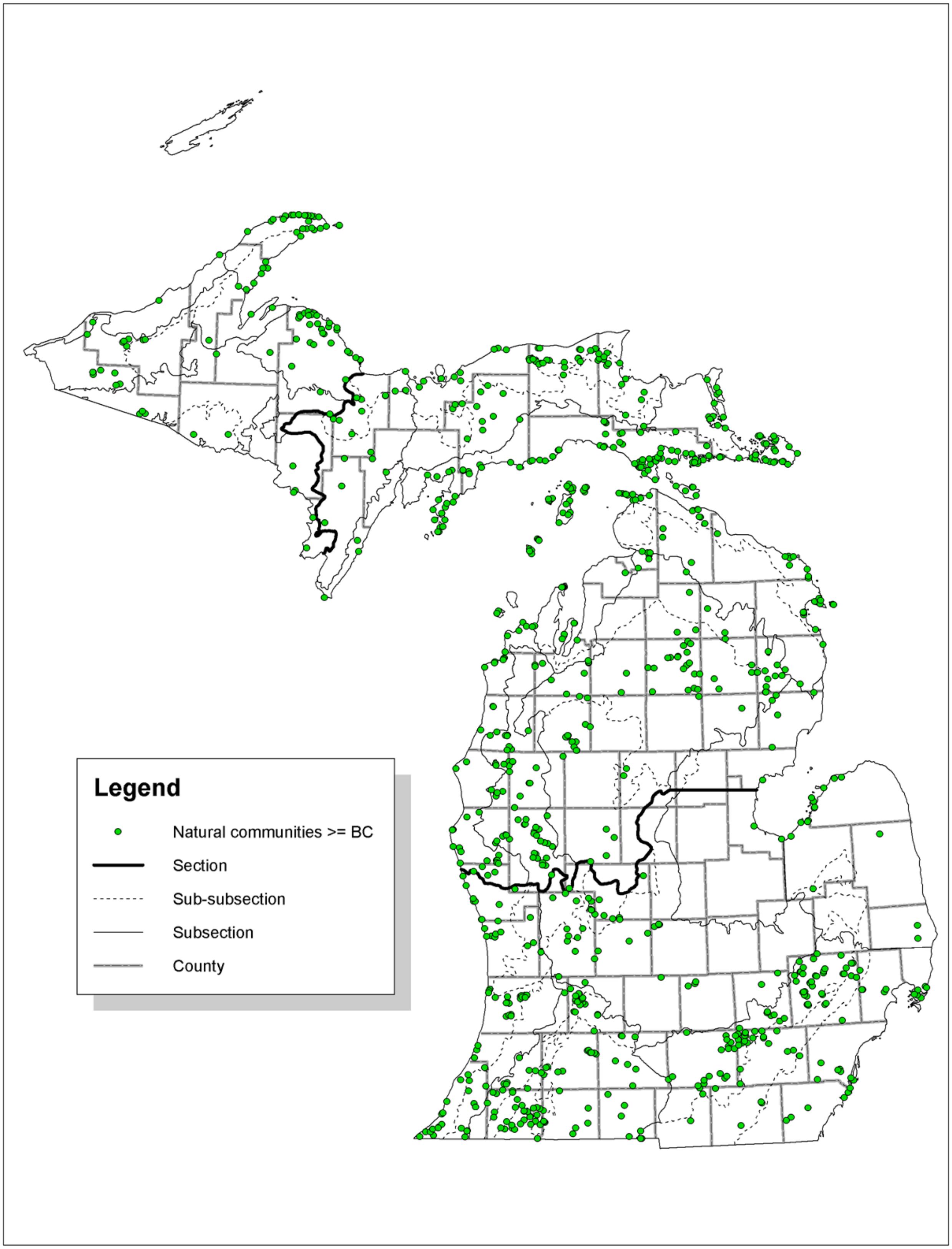


Figure 20. High quality natural communities with an EO rank of ≥B/C.

1) Condition

Condition ranking was based primarily on field notes and interpretation of aerial photos. Community intactness, structure, anthropogenic impacts, presence/abundance of invasive species, vascular plant species diversity, and presence/representation of typical, indicator, or rare vascular plant species were assessed. Community intactness and anthropogenic impacts were assessed from field notes in addition to inspection of 1998 aerial photographs. Information on invasive species, structure, diversity, and presence of rare species relied on existing field notes, although some aspects of structure could be confirmed through inspection of aerial photographs.

One caveat particular to species-level data is that some community occurrences were more thoroughly surveyed (either spatially or temporally) than other sites. Therefore, apparent differences in diversity between one site and another of similar rank may be an artifact of sample effort rather than an actual biological difference between the sites. In addition, the manner in which a community occurrence is mapped often affects its condition rank, which in turn affects the overall EO Rank.

2) Landscape context

Historically, high quality occurrences of natural communities in the MNFI database were ranked primarily or entirely based on condition/quality ranks, as long as minimum size criteria were met. However, the field of conservation has moved towards landscape-level approaches, and landscape context is vitally important to viability of natural community occurrences and the conservation of biodiversity over the short and especially long term. A 30-acre old-growth mesic southern forest bordered by residential development on all sides is not as viable as a 30-acre old-growth mesic southern forest surrounded by 150 acres of second- and third-growth forest in an agricultural setting. For sites of similar EO ranks, landscape context was used to determine the highest quality occurrences. Landscape context consists of two levels: buffer of associated natural communities and overall landscape condition. These levels were broken down using the following criteria, ranked from best condition to worst condition.

- *Landscape buffer condition*
  - Buffered by associated natural communities
  - Buffered, but not by associated natural communities
  - Agricultural buffer
  - Developed buffer

- *Overall landscape condition*
  - Natural - Landscape is largely natural cover.
  - Partially agriculture - EO in partially agricultural landscape.
  - Agriculture - EO in predominantly agricultural landscape.
  - Urban - EO surrounded in part or wholly by urban/suburban development, regardless of remaining buffer type (natural, agriculture).

Buffers were visually inspected using 1998 aerial photographs for high quality EOs in order to determine the highest quality community occurrence of a similar or identical EO Rank. In some instances, landscape context was poor enough to warrant lowering the overall EO rank for particular occurrences. This was especially true in fast-developing regions of the state where large amounts of land were converted from natural cover or agriculture to suburban and exurban development in the time between the original date the community occurrence was surveyed and 1998.

3) Size
Sites of small size are more vulnerable to successional changes, dominance by exotic species, and "island" effects than sites of large size. Large sites are more likely to support higher-level ecosystem functions and are less vulnerable to local extirpations and elimination via natural or non-natural successional processes. Size was used as a tiebreaker if condition and landscape context were of similar rank, or if an overwhelming difference in size balanced out slightly lower condition and landscape context ranks. Due to differences in element occurrence mapping strategy used by different surveyors, size was checked against condition to ensure apparent "size" based on EO acreage accurately reflected the size of the high quality community occurrence.

One consideration outside of the traditional EO specifications was also used to determine which occurrences were highlighted. Certain communities (e.g., prairie fen) are characterized by subtypes. If these subtypes are unique (e.g., lakebed marl fens dominated by calciphiles vs. streamside prairie fens dominated by prairie forbs and grasses), representation of the variation on the landscape was addressed in situations where high quality occurrences of more than one subtype existed.

Based on the above criteria and considerations, the three highest quality element occurrences for each of the 74 natural community types currently known from Michigan were identified at each of the four scales (statewide, Section, Subsection, Sub-subsection), with the understanding that the accuracy of this assessment is limited by the amount of biological information available for each occurrence.

Use:
High quality natural communities represent the best, most viable known occurrences of the 74 different natural community types found in Michigan (as recognized by MNFI). Natural communities are important because they provide the environment necessary for plants and animals to persist and evolve over the long-term. High quality natural communities provide the genetic material needed for changing environmental conditions and restoration projects. They also are a good benchmark for guiding the planning, implementation, and monitoring of natural community restoration and management projects.

Limitations:
Determination of the highest-quality examples of each community type relies on existing information, some of which dates to the early 1980s. Selection of approximately three occurrences for each community at each scale should compensate for the potential uncertainty relating to accuracy. Quality (especially with regards to vascular plant diversity) relies heavily on sampling method and effort. High diversity in particular community occurrences will be incorporated into the overall ranking system, but apparent low diversity (e.g., short plant species lists) often reflects sampling effort rather than complete biological inventory.

File names:
natcomm_combined.shp
natcomm_state.shp
natcomm_section.shp
natcomm_subsections.shp
natcomm_subsubsection.shp

Data source:
Biot_x – Biotics point database created directly from Biotics from version with a last observed date of 09/28/2006.

Results:
Further analysis needs to be completed by identify any significant trends regarding the three best occurrences of each natural community type at the statewide scale (Figure 21). Areas of relatively high concentrations of high quality natural communities included: 1) Pinckney-Waterloo Recreation Areas, 2) southwestern Huron County (along the Saginaw Bay shoreline), 3) northern Marquette County, and 4) the tip of the Keweenaw Peninsula.

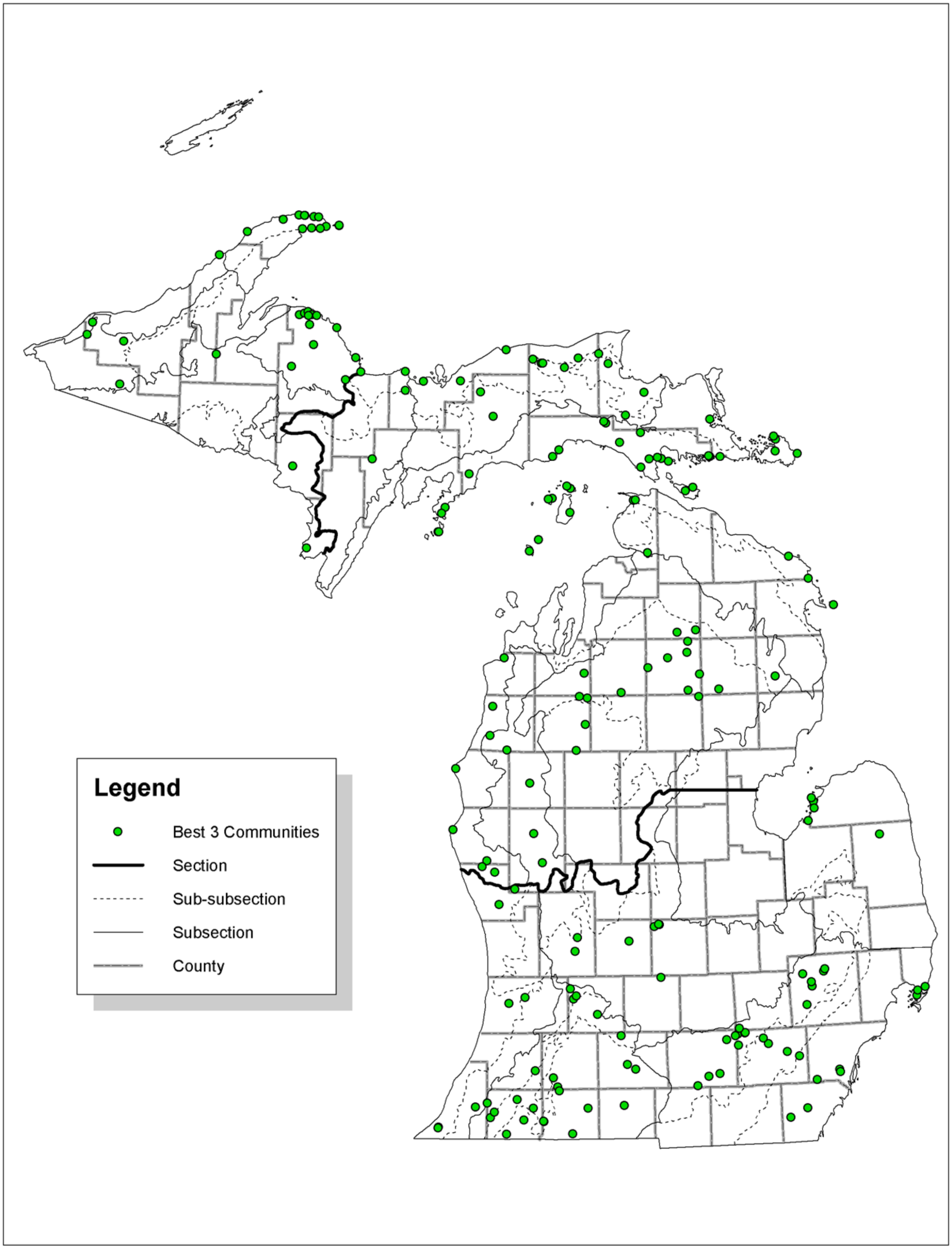


Figure 21. Three best occurrences of each natural community type at the statewide scale.

Aquatic Biodiversity Assessment Methodology

Introduction

The analysis used in the assessment of Michigan's aquatic biodiversity was based on two major categories of data: Landscape-based classifications for ecosystems and element occurrences of natural features. Since MNFI does not currently track aquatic natural communities, the aquatic assessment had to rely heavily on previously developed classifications and data by other entities. The two landscape-based ecosystem classifications were developed from multiple projects. The river classification framework used was first proposed by Seelbach et al. (1997) and was then revised by Brenden et al. (2008). This latest version was modeled using expert opinion as the final review. The lake classification framework used was developed by Higgins et al. (1998). Both of these frameworks are based on landscape-level data. The element occurrence dataset is a continuously updated database developed and maintained by the Michigan Natural Features Inventory (MNFI). Using the ecosystem classification frameworks, we developed new data layers that can be used to identify and prioritize potentially unique aquatic ecosystems, important areas for Great Lakes migrating species, intact headwater watersheds, and functional sub-watersheds. The MNFI element occurrence database identifies places on the land that contain unique elements of biodiversity – rare species and high quality natural communities, which MNFI refers to as element occurrences (EOs). The database, which is updated periodically throughout the year, contains a wealth of detailed information that was used to identify and prioritize areas based on frequency, likelihood of persistence, viability, and/or rarity of EOs. Both aquatic ecosystems and EOs of natural features are discussed in more detail below.

Categories of ecosystem level datasets developed by this project:

1. Unique river and lake ecosystems – by EDU and statewide
2. High quality rivers and lakes – by EDU and statewide
3. Rivers with access to the Great Lakes
4. Level of intactness of headwater watersheds – statewide
5. Functional sub-watersheds and watersheds – statewide

Categories of MNFI EO based datasets developed by this project:

1. EO frequency count
2. EO likelihood
3. Bio-rarity score
4. Rare species richness by sub-watershed
5. Species of greatest conservation need richness by sub-watershed
6. Best two occurrences of each rare aquatic species by watershed

For a list aquatic datalayers and descriptions see Appendix M. The list of EO based aquatic datalayers can be found in appendix L.

Defining uniqueness

Defining what is rare or unique is often subjective and can be difficult to quantify. Rare species are often determined using geographic distribution, habitat specificity, and population size (Rabinowitz 1981, Rabinowitz et al. 1986). However, community rarity or uniqueness has received much less attention (Izco 1998). We do not know how many ecosystems are needed to ensure continued persistence but we expect that frequency of occurrence and geographical range are important components. Uniqueness is affected by the number of individual ecosystems, the classification framework used, and how uniqueness is defined.

We define ecosystem uniqueness using geographic range and frequency of occurrence. We considered those ecosystem types occurring in only one watershed statewide as having a restricted geographic range and hence unique. Additionally, we defined uniqueness as those lakes or rivers that have the fewest occurrences and that make up 5% and 1% of the total number of lakes or rivers in Michigan or within an EDU. We defined uniqueness using the 5% and 1% to provide options. We felt that this scheme captured what we intuitively felt was unique or rare, and that it was easily applied to different classifications. If new classifications are introduced in Michigan this analysis could be easily reassessed.

Determining representation

There is little guidance for abundance and distributional goals for the preservation of ecosystems. Although most literature agrees that smaller and rarer ecosystems should be represented in higher quantities across the landscape than larger and more common ecosystems, specific numbers are not agreed upon. One school of thought suggests using a percentage of the historic distribution, but these percentages vary greatly from 10% to 40% (Tear et al. 2005). Even following the lowest percentage could require large numbers of sites to be protected which could be impractical and unmanageable. Yet others suggest targeting a specific number of ecosystems, but again these numbers vary and can seem too limited (Smith et al. 2001). The question of how much is enough to protect species and ecosystems is unknown. We chose to represent all unique ecosystems, as well as high quality common ecosystems as follows: 10 small rivers, 5 medium rivers, 1 large river, 10 unconnected ponds or small lakes, 5 connected ponds or small lakes, 5 medium lakes, and 1 large lake within each EDU. These were minimum quotas to ensure representation. However, when there were ties in the scores for quality, all occurrences with that score were selected.

Determining quality

It should be noted that all of the quality analysis conducted on aquatic ecosystems in this report rely on the surrounding terrestrial landscape and not field data. Aquatic ecosystems are so tied and intricately linked to the surrounding lands and watershed that it is difficult to separate the aquatic ecosystem from the terrestrial landscape. The coarse filter approach is generally based on identifying areas of land that have intact natural processes. For terrestrial ecosystems it is relatively easier to determine the size needed to allow for natural processes to occur in different types of ecosystems or natural communities. Aquatic ecosystems are inherently more difficult to assess because the surrounding landscape has such a direct influence. For example, it is easy to draw a boundary around a lake. The natural processes that function within that lake are sediment and nutrient dynamics, internal water movements, water retention, turbidity, water temperature, and oxygen concentration, to name a few. Since most of these processes rely on external inputs from the landscape or water bodies within the watershed of the lake, the lake can not function without these external inputs. Because these inputs are difficult and time-consuming to gather information on, we had to rely on landscape or terrestrial surrogates to determine if natural ecosystem processes are occurring in the aquatic systems.

Coarse-Filter: Aquatic Ecosystem Data

Watershed and sub-watershed defined

Description:
Throughout this document we use the terminology watershed and sub-watershed. Watershed is defined as the 8-digit hydrologic units or HUC's, and sub-watershed is defined here as the 12-digit HUC's, sometimes called sub-basins. There are 57 watersheds and 2,319 sub-watersheds in Michigan.

Limitations:
Hydrologic units (or HUC's) were initially delineated to break the state up into similarly sized units based on hydrology. These units are often termed sub-watersheds. However, they are not hydrologically accurate. A true watershed is defined by all waters draining from an area to a particular point. HUC's often break up true watersheds such that a point in a HUC can actually get all of its water from a completely different HUC. We used HUC's as a way to summarize the data with full knowledge that the use of these units does not provide a full picture of the area needed to protect or manage for important species or ecosystems.

File name:
mi_subwatersheds.shp

Data source:
The 8 digit HUCs are from the National Hydrography Dataset (NHD). The 12 digit HUCs are from the DEQ, but they did not cover all of Michigan. Parts of Ohio and Indiana's 12 digit Watershed boundary units (WBUs) were used to fill in the missing area, and the final layer was clipped to the Michigan state boundary.

River classification

Description:
Riverine ecosystems were delineated using river valley segments (VSECs) as defined by the DNR Fisheries Division as of August 2007 (Seelbach et al. 1997, Brenden et al. 2008). VSECs are relatively large stretches of river that have similar hydrology, limnology, channel morphology, and riparian dynamics. VSECs often change at stream junctions or landform boundaries. VSECs use catchment size, hydrology, water chemistry, water temperature, valley character, and channel character as the basis for delineation. VSECs are made up of reaches, which are segments with similar hydrologic characteristics, such as a stretch of stream between two confluences or a lake. A reach is the smallest unit in the hydrology data layer. VSECs defined the boundaries of river ecosystems in this analysis.

The classification we used to determine different types of river ecosystems is based on size, water temperature, and gradient. Physical, chemical, and biological changes occur on a longitudinal gradient from the headwaters to the very large rivers (Vannote et al. 1980). Headwaters and small tributaries tend to be shaded and rely on energy inputs from riparian vegetation; their macroinvertebrate communities tend to be dominated by shredders. Medium rivers tend to be less shaded and rely on energy inputs from primary production; their macroinvertebrate communities tend to be dominated by grazers. Large rivers tend to rely on energy inputs from upstream and their macroinvertebrate communities tend to be dominated by collectors. Fish, mussel, and aquatic plant communities all vary as well. Rivers do vary from this general model (the river continuum concept), however it provides insight into how size is an important factor in determining and defining river communities. Water temperature is also important because species have optimum temperature preferences. Gradient provides a measure of channel morphology which correlates to valley shape, sinuosity, water velocity, and substrate size. All three factors are important in determining species compositions in rivers.

Four size classes were defined using drainage areas of VSECs, following the Wildlife Action Plan (Eagle et al. 2005): headwaters and small tributaries are less than 40 mi^2, medium rivers are between 40 and 179 mi^2, large rivers are between 180 and 620 mi^2, and very large rivers are greater than 620 mi^2. Four classes of temperature were defined for each VSEC, generally defined as: cold (<19°C), cool (19-21°C), and warm (>21°C). Three classes of gradient were defined: low (an average gradient less than 0.001), moderate (between 0.001 and 0.006), and high (greater than 0.006). Gradient classes were defined using the 25th and 75th percentiles of all stream reach gradients. See figures 23 and 23 for map of classification framework used.

Limitations:
Classification requires discrete boundaries however riverine ecosystems are essentially a continuum. As a result, river classification is inherently difficult. The main limitation to using VSECs is that the current VSEC framework is still under construction. We used the most current version (August, 2007), yet the MDNR Fisheries Division is continuing to refine and evaluate the framework. They are working on finalizing version 3. Since there has been significant work already towards evaluation of VSECs, we decided to proceed with our analysis using this version, which had change quite a bit from version 1. We do not expect major changes in the boundaries of the current VSECs, the reach identifier (pugap_code) is provided in the analysis. One limitation with our classification is that the gradient classes are not necessarily ecologically based. However, we were unable to find literature backing specific gradient breaks. To build a stronger classification, future research is needed to determine or document gradient classes that are ecologically meaningful.

File name: vsec_size_temp.shp, vsec_gradient.shp

Data source:
Institute for Fisheries Research, Michigan Department of Natural Resources, version as of August 2007. groundwater_vsec_statewide_6_29_07.shp

Lake classification

Description:
Lake ecosystems were classified using Higgins et al. (1998), which was based on available GIS data. Most of the data used in this classification were queried from or calculated using queried information from available data layers. Lakes were classified based on size, connectivity, shoreline complexity, and proximate geology.

These particular variables were used based on available data, literature, and expert review. Size provides a measure of the availability and types of habitat in a lake (Eagle et al. 2005). Most small lakes are shallow, unstratified, have relatively high nutrient concentrations, and are somewhat likely to have low oxygen levels in winter. Additionally, they can either be turbid due to wind resuspension with no rooted plants or dominated by rooted plants with clear water. Succession is also a factor with these ecosystems because over time they fill in with sediments and become marsh. Small lakes can range from not stratified to fully stratified throughout the summer, and low winter oxygen levels can lead to winter kills. In lakes that stratify, a true pelagic or open-water zone develops and is distinct from the shallow littoral (or nearshore) zone. In medium lakes stratification and winter oxygen levels are also variable. They tend to have more complexity in their shoreline (lakes with many bays) and basin (lakes with more than one deep hole). Large lakes tend to be more homogenous in their chemical and biological makeup, but more diverse in their habitats than smaller lakes. They also are dominated by the pelagic zone. Connectivity refers to whether or not there are stream connections to the lake. Streams can influence a lake through the input or removal of water and nutrients as well as an exchange of species. Shoreline complexity becomes more important as lake size increases, increasing habitat variation. We used proximate geology as a surrogate for lake hydrology. All of these factors can influence species composition and communities. Typically ponds only have one community of fish, however as size increases, the pelagic habitat becomes more abundant and a pelagic fish community will be also present.

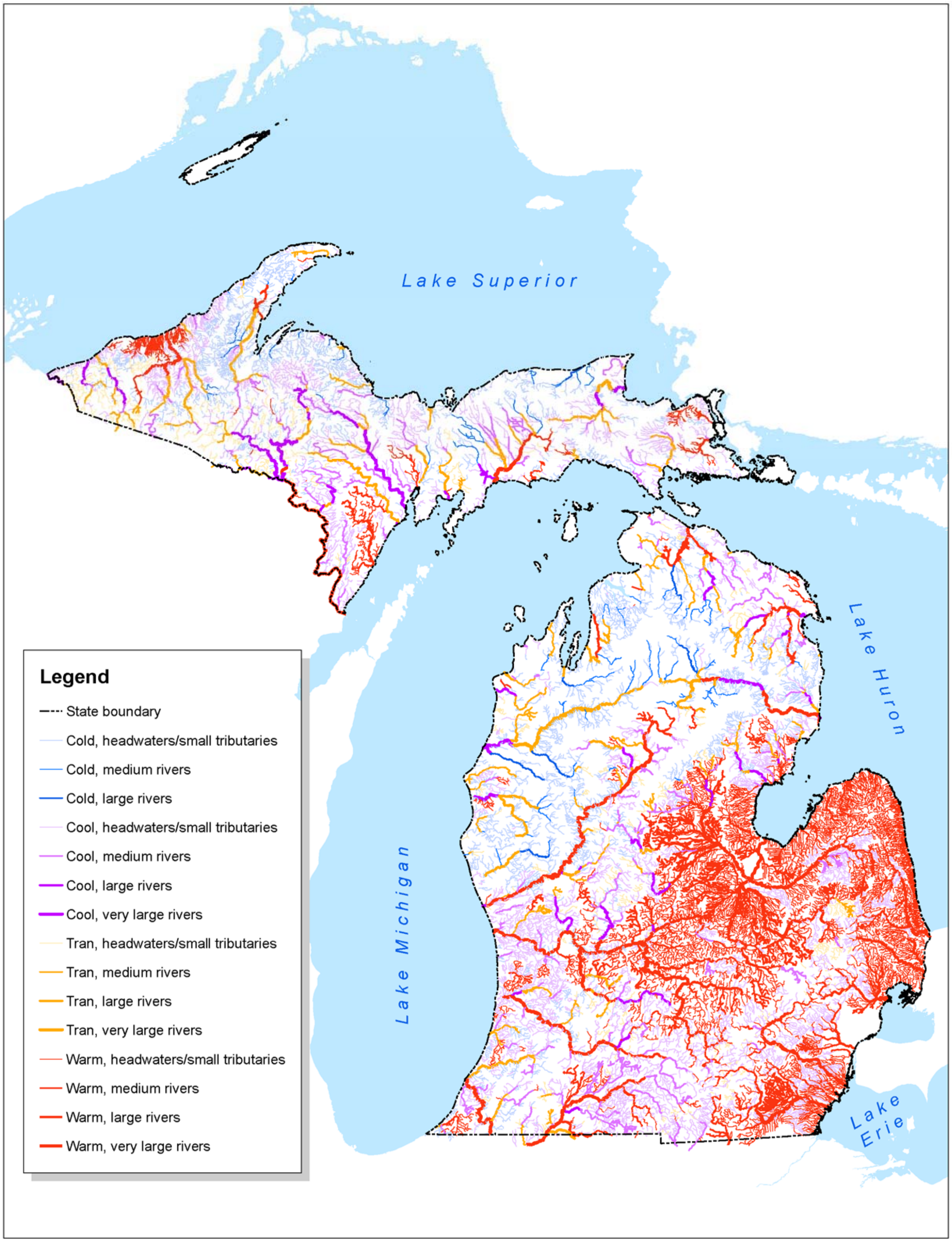


Figure 22. Map of size and temperature river classification framework used in analysis.

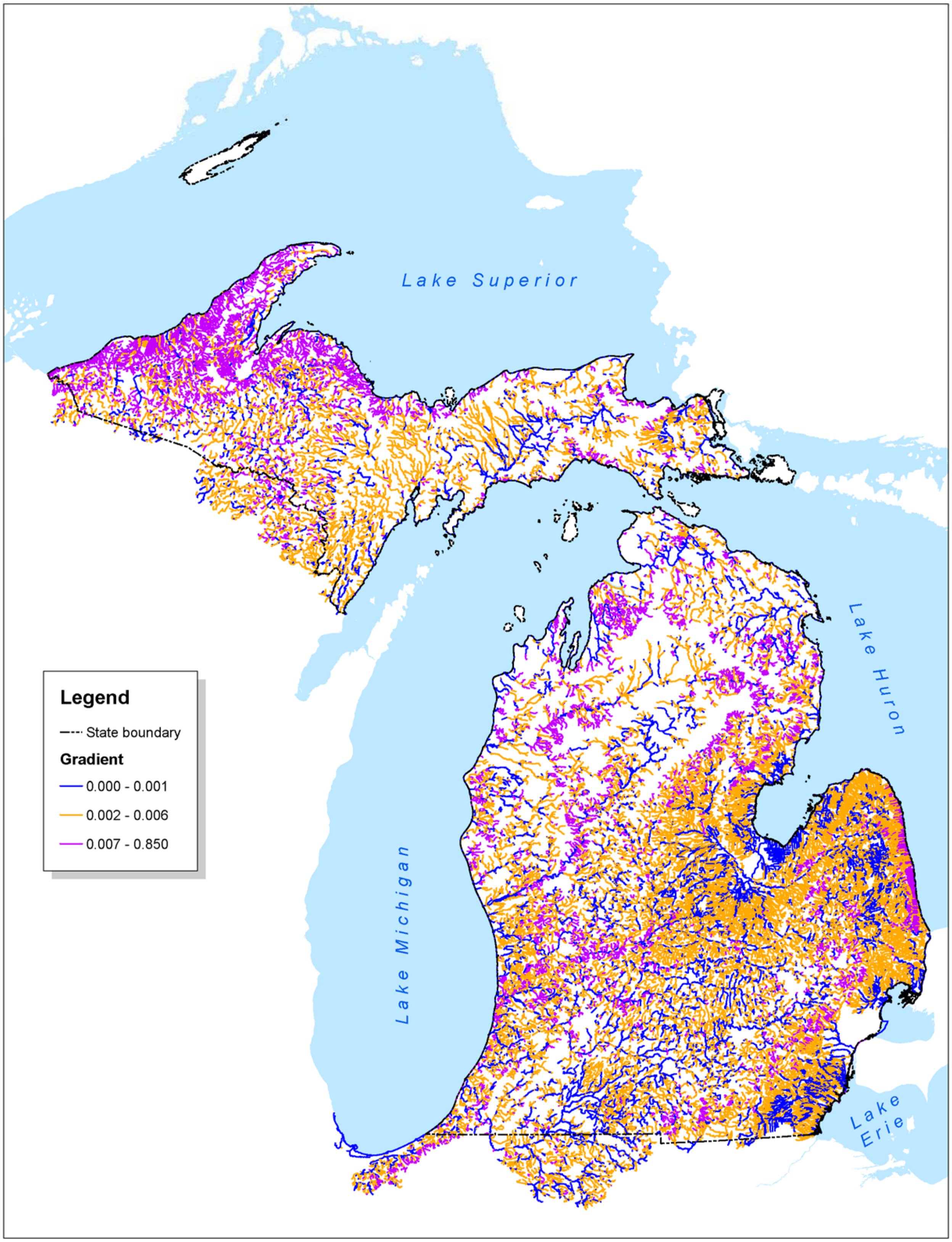


Figure 23. Map of gradient classification framework used in analysis.

We modified the size classes that Higgins et al. (1998) used as follows: ponds are >2 and <= 10 acres, small lakes are >10 and <100 acres, medium lakes are >= 100 and < 1000 acres, and large lakes are >1000. These size classes generally follow the Wildlife Action Plan (ponds <5 acres, small lakes 5-99 acres, medium lakes 100-999 acres, and large >1000 acres), however we increased the size range of ponds because water bodies less than 10 acres are often treated differently than larger lakes. For example, they are not typically surveyed or monitored. See Figures 24 and 25 for map of classification framework used.

It should be noted that the Institute of Fisheries Research (MNDR) and Michigan State University are currently working on a lake classification for Michigan. For this effort we used Higgins et al. (1998) because it was both available and statewide in coverage. As more detailed and accurate classifications for Michigan become available, they should be evaluated for use in a statewide biodiversity assessment.

Limitations:
This classification is based on coarse scale data. To date there has been no ground-truthing and little analysis to determine accuracy and precision of assigned lake types in this classification. There are also many “single occurrence” lake types in this classification that may not be ecologically meaningful but artifacts of the classification process, which needs to be recognized in the unique lakes analysis. Although there are some critical issues with using this classification, it is currently the only lake classification for Michigan that is statewide and available in GIS format.

Lake ecosystems undergo succession and begin to fill in with sediment; this process is important to keep in mind when setting conservation priorities, especially for ponds. MNFI typically distinguishes ponds from marshes if they have an open water area. Those “ponds” that have macrophytes across the entire water surface were identified as marsh for our work. Sampling for ponds can be difficult because they can be difficult to find, and during dry years could be designated as a marsh. We hope that by representing a variety of different types (Abell et al. 2002) of ponds that we will account for this process at least partially.

File name: milakes_conn_shoreline.shp, milakes_proxgeol.shp

Data source:
The Nature Conservancy – Great Lakes Program, Higgins et al. 1998: milakes_w_attributes.shp

Great Lakes

Classification of areas within the Great Lakes is still largely in its infancy. The MNFI database contains point and polygon data for rare species found within the Great Lakes, however this data may or may not show important or critical areas for these species. Because most Great Lakes species can have large scale movements, single date location data does not provide adequate information when determining important areas for management and conservation. In addition, there have been other efforts focused on modeling important habitats for fish that we will currently defer to (Koonce et al. 1999). Due to lake of good information, habitats within the Great Lakes will not be considered in this analysis.

Great Lakes nearshore areas are addressed in the terrestrial portion of this assessment. However, in the future this analysis should be revisited with both terrestrial and aquatic functions and processes in mind. The current analysis may miss out on important processes and functions of nearshore areas for fully aquatic species since this analysis was mainly based on coastal wetlands and did not include

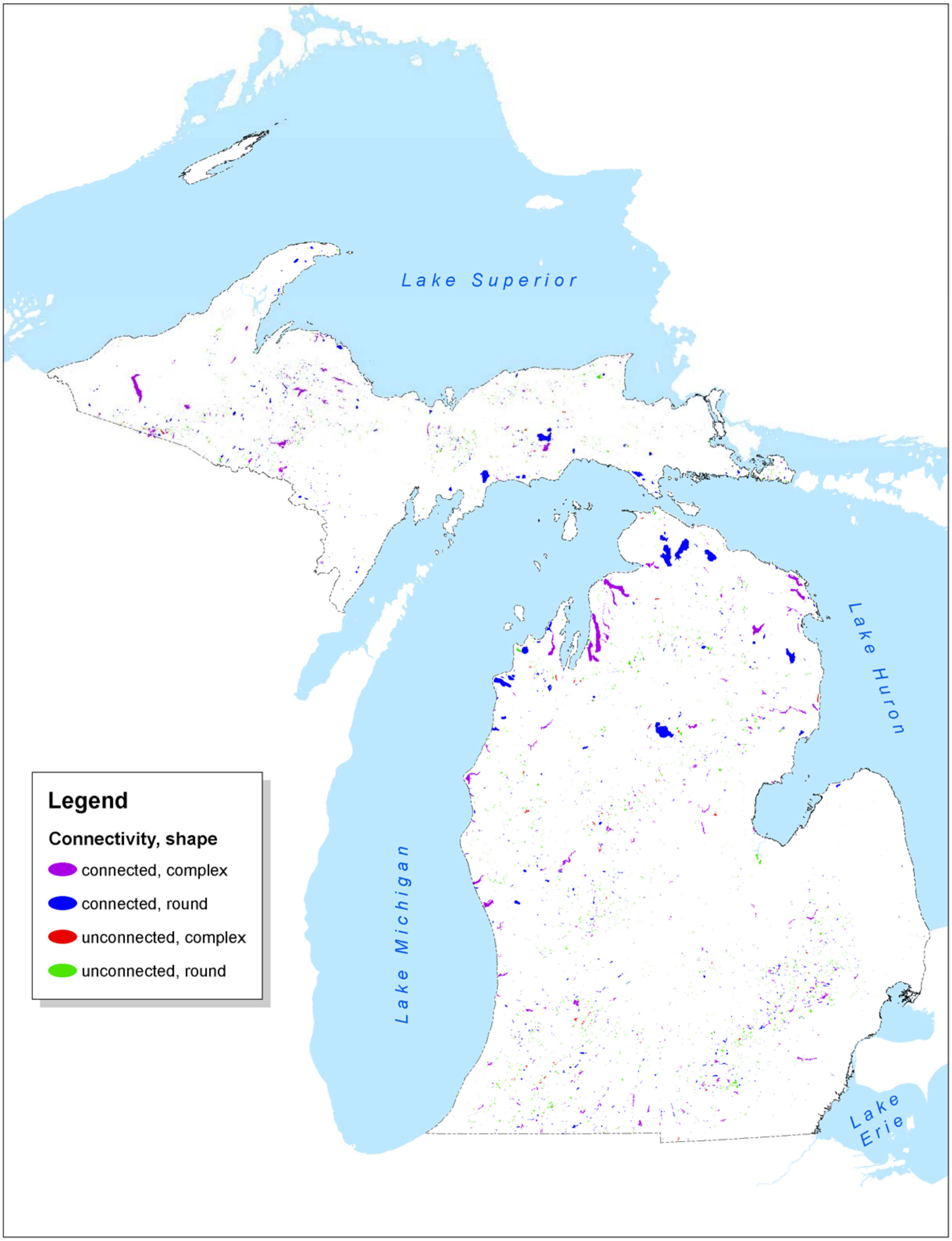


Figure 24. Map of connectivity and shoreline complexity for lake classification framework used in analysis.

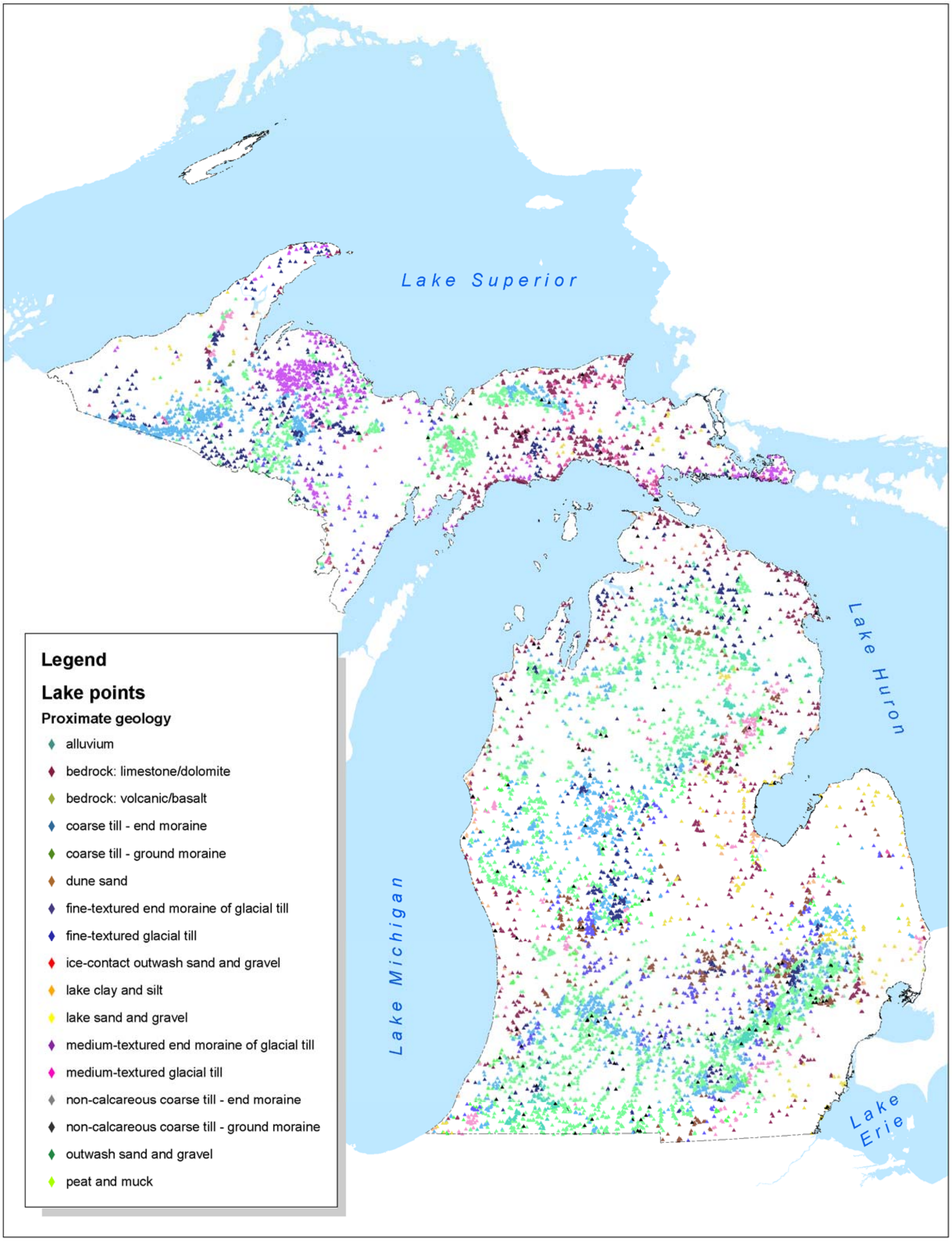


Figure 25. Map of proximate geology lake classification framework used in analysis.

other types of shoreline / nearshore types. The Institute of Fisheries Research and the University of Michigan are currently working on Great Lakes classification in Michigan. The US Geological Survey is also undertaking efforts to classify habitats in the Great Lake region through their Aquatic GAP program. As these efforts become available they should be examined for their use in expanding the statewide biodiversity assessment.

Coarse-Filter: Aquatic Ecosystem Analysis

Unique River Ecosystems statewide and by EDU

Description:
River ecosystems or VSECs were classified as unique using a 5% and 1% rule at two scales: EDU and statewide. See previous section on defining uniqueness for more detail.

Use:
By highlighting unique VSECs, we hope to capture potentially unique and important ecosystems that contribute to the diversity regionally and statewide. These layers will provide a relatively simple representation of where unique ecosystems are located within an EDU and statewide, and will help direct future survey efforts to determine true rarity, importance, and condition of these ecosystems.

Limitations:
Unique VSECs identified may be an artifact of the classification process and the accuracy of available digital data. As a result, true rarity is uncertain. But it does provide a basis that will help direct future survey efforts and analysis. In addition, we do not include a landscape context analysis with this layer because we are looking for rarity and not necessarily the best of the unique ecosystems. See river classification section for limitations associated with data used in this analysis.

File names:
vsec_unique_statewide_5pct.shp, vsec_unique_statewide_1pct.shp
vsec_unique_edu_5pct.shp, vsec_unique_edu_1pct.shp

Data source:
Institute for Fisheries Research, Michigan Department of Natural Resources, version as of August 2007: groundwater_vsec_statewide_6_29_07.shp

Results - statewide:
There were 29,037 river reaches used in our analysis, which were aggregated into VSECs. Seventy-six VSECs were removed from the analysis because they were not fully classified, leaving a total population of 9,961 VSECs statewide. These VSECs were categorized into one of 45 river types (there were a possible total of 48). Overall, river types were well represented statewide (Table 15). The number of VSECs within a type for headwaters and small tributaries ranged from 97 to 1,793, medium rivers ranged from 3 to 155, large rivers ranged from 1 to 78, and very large rivers ranged from 2 to 92. No headwaters and small tributaries were designated as unique statewide; large rivers and very large rivers dominated unique river ecosystems statewide (Table 15). This may be an artifact of the classification framework we used.

Using the 5% rule, a total of 498 VSECs were targeted to be designated as unique (9,961*.05=498). Due to the number of VSECs within a type, a total of 524 VSECs were selected as unique statewide (Figure 26). The types of rivers selected as unique were very large rivers (except warm, low gradient types), all large rivers, all high gradient medium rivers, and cold low gradient medium rivers. The number of VSECs designated as unique increases from the southeast part of the state to the northwest part of the state. The Southeast Michigan Interlobate and Lake Plain (16+2) EDU had the fewest VSECs selected as unique statewide with 26, whereas the Central Upper Peninsula (8) EDU had the most VSECS designated with 105 (Table 16).

Using the 1% rule, a total of 109 VSECs were selected as unique statewide (Table 15, 16). Again, very large rivers were selected as well as mainly high gradient large rivers, and high gradient medium rivers (Figure 27). The Southeast Lake Michigan (3) EDU had the fewest designated as unique statewide with 2 VSECs and the Northern Lake Michigan, Lake Huron, and Straits of Mackinac (5) EDU has the most with 46 VSECs when using the 1% rule (Table 17).

Results – in EDU:

The number of VSECs in an EDU ranged from 722 to 2,049 and the number of river types ranged from 22 to 40 (Table 18); 48 was the maximum potential. The minimum number of VSECs in river types for all EDU's was one and the maximum number ranged from 225 to 760. Although no headwaters and small tributaries were designated as unique statewide, they were designated as unique within EDUs.

Using the 5% rule, a total of 36 to102 VSECs were targeted as unique dependent upon EDU (Figure 28). In the end, a total of 566 VSECs were selected as unique across EDUs (Table 19). The number of river types and VSECs designated as unique ranged from 11 to 22 and 37 to 124, respectively. The Northern Lake Michigan, Lake Huron, and Straits Of Mackinac (5) EDU had the most VSECs selected, where as the Eastern Upper Peninsula (7) EDU had the least. All river sizes were represented in the selected unique ecosystems.

Using the 1% a total of 129 VSECs were selected as unique in EDUs (Table 20, 21, Figure 29). The number of river types and VSECs selected as unique across EDUs ranged from 6 to 10 and 12 to 26, respectively. In this analysis, the Southeast Lake Michigan (3) EDU had the most VSECs selected and the Eastern Upper Peninsula (7) EDU and the Western Upper Peninsula and Keweenaw Peninsula (6+12) EDU had the fewest. Not all river sizes were represented across EDUs.

Table 15. Summary of classification of river valley segments (VSECs) and statewide uniqueness analysis.

	Headwaters / Small Tributaries	Medium Rivers	Large Rivers	Very Large Rivers
Number of VSECs	8513	904	346	198
Number of river types	12	12	12	9
Minimum number of VSECs in a river type	97	3	1	2
Maximum number of VSECs in a river type	155	155	78	92
Number of river types in only one watershed	0	0	1	0
Maximum number of watersheds a river type occurred	51	40	27	22
Number of unique VSECs (5%)	0	72	346	106
Number of unique river types (5%)	0	5	12	8
Number of unique VSECs (1%)	0	29	35	45
Number of unique river types (1%)	0	3	6	6

Table 16. Number of statewide unique VSECs in each EDU using the 5% and 1% rule.

	2+16	3	4	5	7	8	6+12
Number of unique VSECs statewide (5%)	26	80	81	145	31	105	56
Number of unique VSECs statewide (1%)	3	2	5	46	8	29	16

Table 17. Names of rivers within EDUs that have unique VSECs using the 1% rule statewide.

EDU	Rivers with unique VSECs
Southeast Michigan Interlobate and Lake Plain (16+2)	Huron, Saline, and unnamed
Southeast Lake Michigan (3)	Coldwater and Portage
Saginaw Bay (4)	unnamed, Hemmingway and Whittle Drain, North Branch of the Flint River, Pine River, Sugar River, and Tittabawassee River
Northern Lake Michigan, Lake Huron, and Straits Of Mackinac (5)	Ausable River (mainstem and north branch), Baker Creek, Black River, Boardman River, Crumley Creek, Flinton Creek, Hudson Creek, Little Manistee River, Manistee River, Manton Creek, Muskegon River, Pere Marquette River, Pine River, South Branch of the White River, Sturgeon River, Thunder Bay River, and West Branch of Big Creek.
Eastern Upper Peninsula (7)	Tahquamenon River and Two Hearted River
Central Upper Peninsula (8)	unnamed, Daults Creek, Dead River, Huron River, Menominnee River, Michigamee River, Silver Creek, Silver River, Six-mile Creek, Sturgeon River, West Branch Huron River, West Branch Sturgeon River, Yellow Dog Creek
Western Upper Peninsula and Keweenaw Peninsula (6+12)	Black River, Ontonagon River (main, east, middle, and west branches), Jackson Creek, Montreal River, Pelton River, Portage River, Presque Isle River, Slate River, Sparkling Creek, and Sturgeon River

Table 18. Summary of general river and VSEC statistics within EDUs.

	Ecological Drainage Unit						
	2+16	3	4	5	7	8	6+12
Number of river miles	4,648	9,127	**13,091**	7,416	3,034	4,559	3,463
Total number of VSECs	1,024	**2,043**	1,913	1,888	722	1,414	957
Number of actual river types	22	29	31	**40**	32	37	36
Minimum number of VSECs in river types	1	1	1	1	1	1	1
Maximum number of VSECs in river types	283	580	760	623	225	383	306
Number of headwater / small tributary VSECs	898	**1,768**	1,648	1,546	623	1,191	839
Number of medium VSECs	94	170	164	**192**	71	143	70
Number of large VSECs	18	66	69	**87**	17	50	39
Number of very large VSECs	14	39	32	**63**	11	30	9

Table 19. Summary of unique river ecosystems by EDUs based on the 5% rule.

		2+16	3	4	5	7	8	6+12
Unique	Number of river types	11	13	16	**22**	16	18	20
	Number of VSECs	57	119	101	**124**	37	74	54
	Number of headwaters/ small VSECs	11	**20**	11	10	6	9	5
	Number of medium VSECs	14	**46**	37	16	9	22	21
	Number of large VSECs	18	40	42	**56**	11	22	19
	Number of very large VSECS	14	13	11	**42**	11	21	9
Common	Number of river types	12	18	17	19	16	21	19
	Number of VSECs	967	1924	1812	1764	685	1314	903

Table 20. Summary of unique river ecosystems by EDUs based on the 1% rule.

		2+16	3	4	5	7	8	6+12
Unique	Number of river types	6	7	10	9	9	8	9
	Number of VSECs	16	26	25	20	12	18	12
	Number of headwaters/ small tributary VSECs	3	0	3	0	3	0	2
	Number of medium VSECs	7	7	8	5	0	5	4
	Number of large VSECs	0	19	13	10	4	4	4
	Number of very large VSECS	6	0	1	5	5	9	2
Common	Number of river types	17	24	23	32	23	31	30
	Number of VSECs	1,008	2,017	1,888	1,868	710	1,370	945

Table 21. Names of additional rivers within EDUs that have unique VSECs using the 1% rule in each EDU.

EDU	Rivers with unique VSECs
Southeast Michigan Interlobate and Lake Plain (16+2)	Clinton River, and the St. Joseph River (main stem, east fork west branch, west branch)
Southeast Lake Michigan (3)	15 new rivers
Saginaw Bay (4)	Au Gres River, Cedar River, North Branch Chippewa River, Gamble Creek, Silver Creek, and West Branch Rifle River
Northern Lake Michigan, Lake Huron, and Straits Of Mackinac (5)	Carp Lake River
Eastern Upper Peninsula (7)	Manistique River and Munuscony Rivers
Central Upper Peninsula (8)	Black Creek, Escanaba River, Otter River, Walton River, and the West Branch of the Cedar River
Western Upper Peninsula and Keweenaw Peninsula (6+12)	Flintsteel River, Little Gratiot River, Salmon Trout River, Tenmile Creek, and Tobacco River

High-Quality Common River Ecosystems within EDUs

Description:
River ecosystems or VSECs were classified as common in an EDU using a greater than 5% rule; see previous section on defining uniqueness for more detail. Quality of common VSECs were assessed using Wang et al.'s (2006) analysis of landscape-level GIS data (Table 22). Quality will be relative within each EDU.

Use:
This analysis provides a relatively simple representation of where potential high-quality river ecosystems are located in each EDU and will help direct survey efforts to determine true condition and importance.

Limitations:
One main limitation of this data layer is that it does not include representation of all common river ecosystems. In addition, no field survey data was used to determine true condition and integrity of the ecosystems, so the individual VSECs highlighted may not be the best representatives available. Local factors that are not captured in this analysis could drive the quality of ecosystems. However, it does provide a basis to start from that will help direct future survey efforts. See river classification section for limitations associated with data used in this analysis.

File name:
vsec_HQ_edu.shp

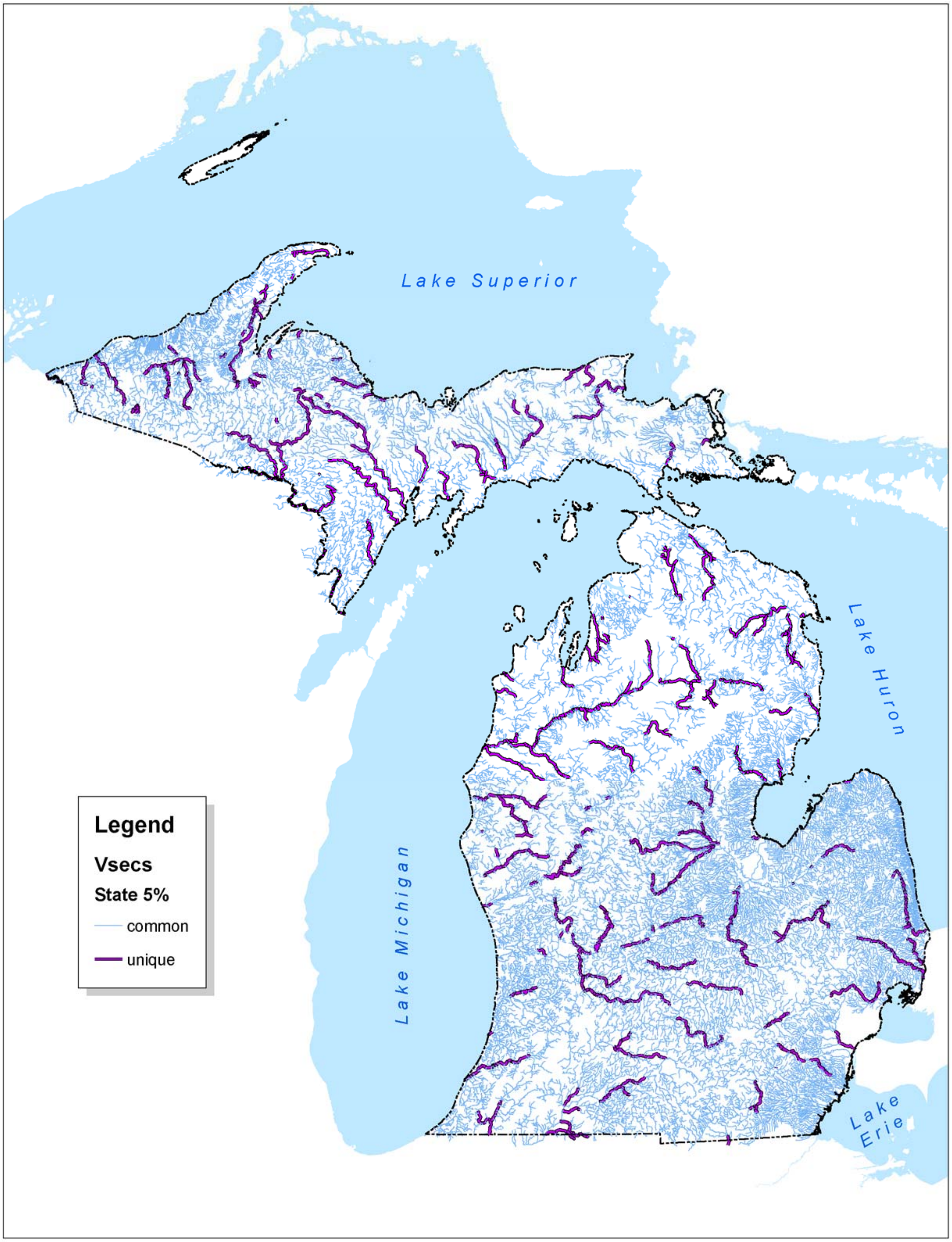


Figure 26. Unique river ecosystems in Michigan using the 5% rule.

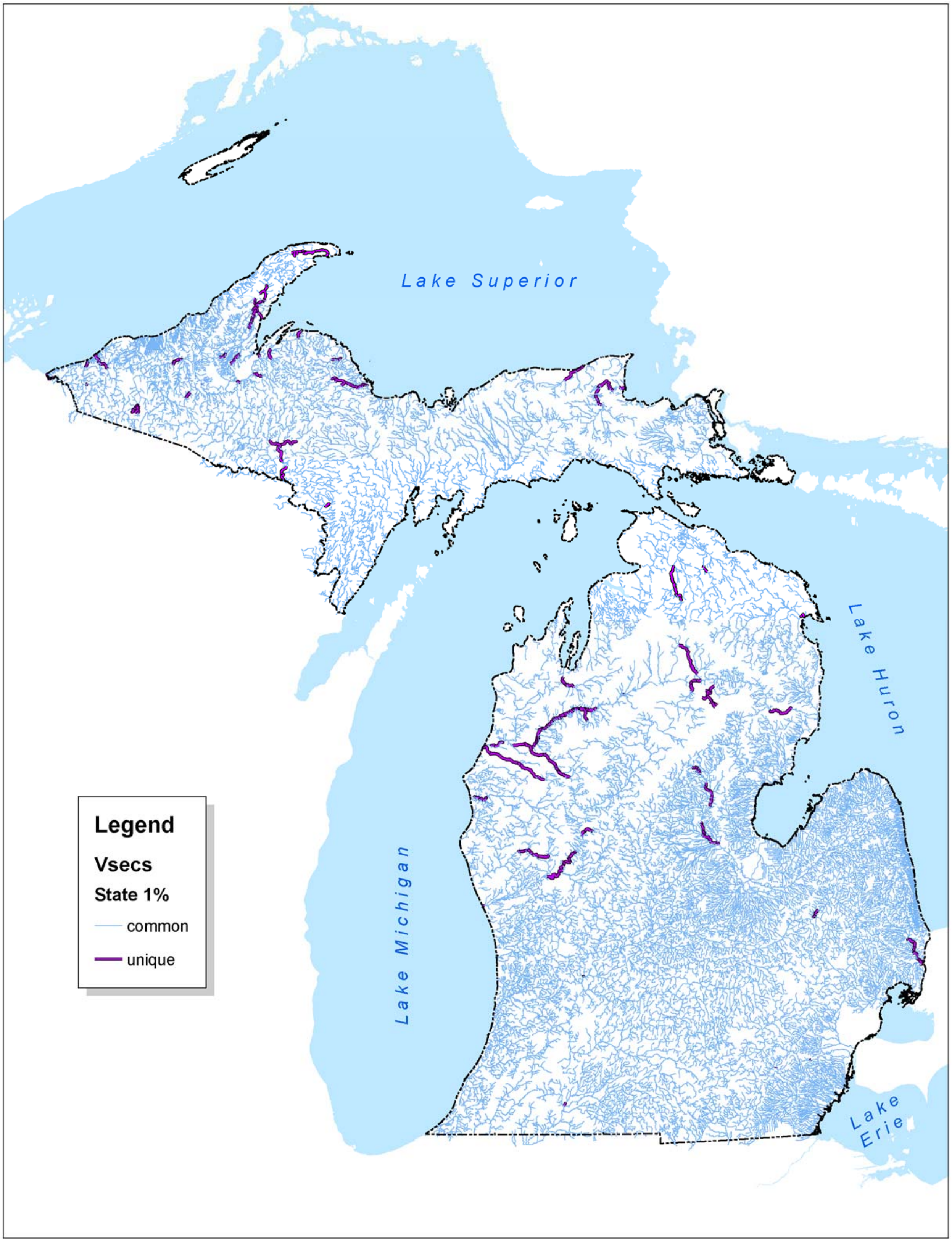


Figure 27. Unique river ecosystems in Michigan using the 1% rule.

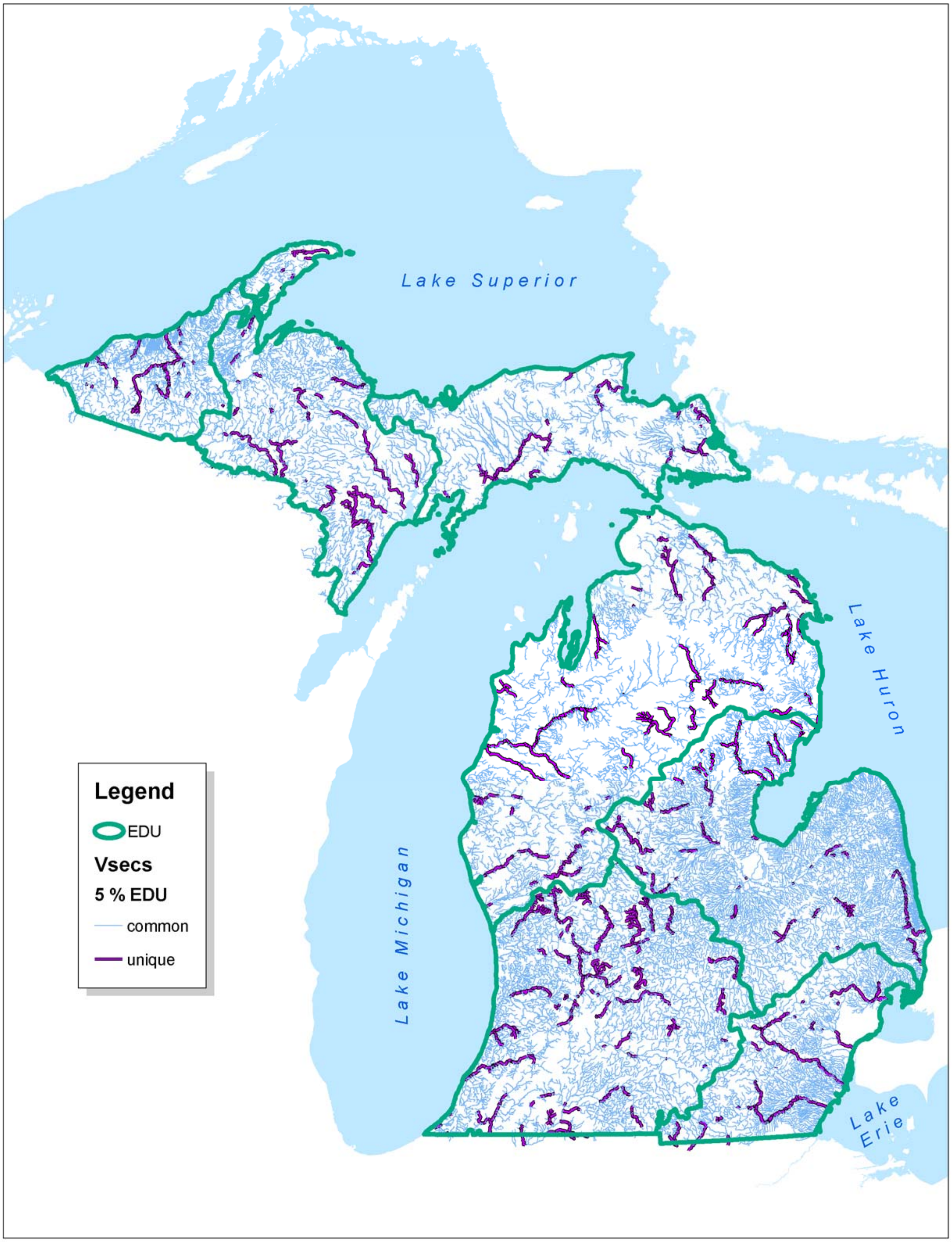


Figure 28. Unique river ecosystems in Michigan by EDU for the 5% rule.

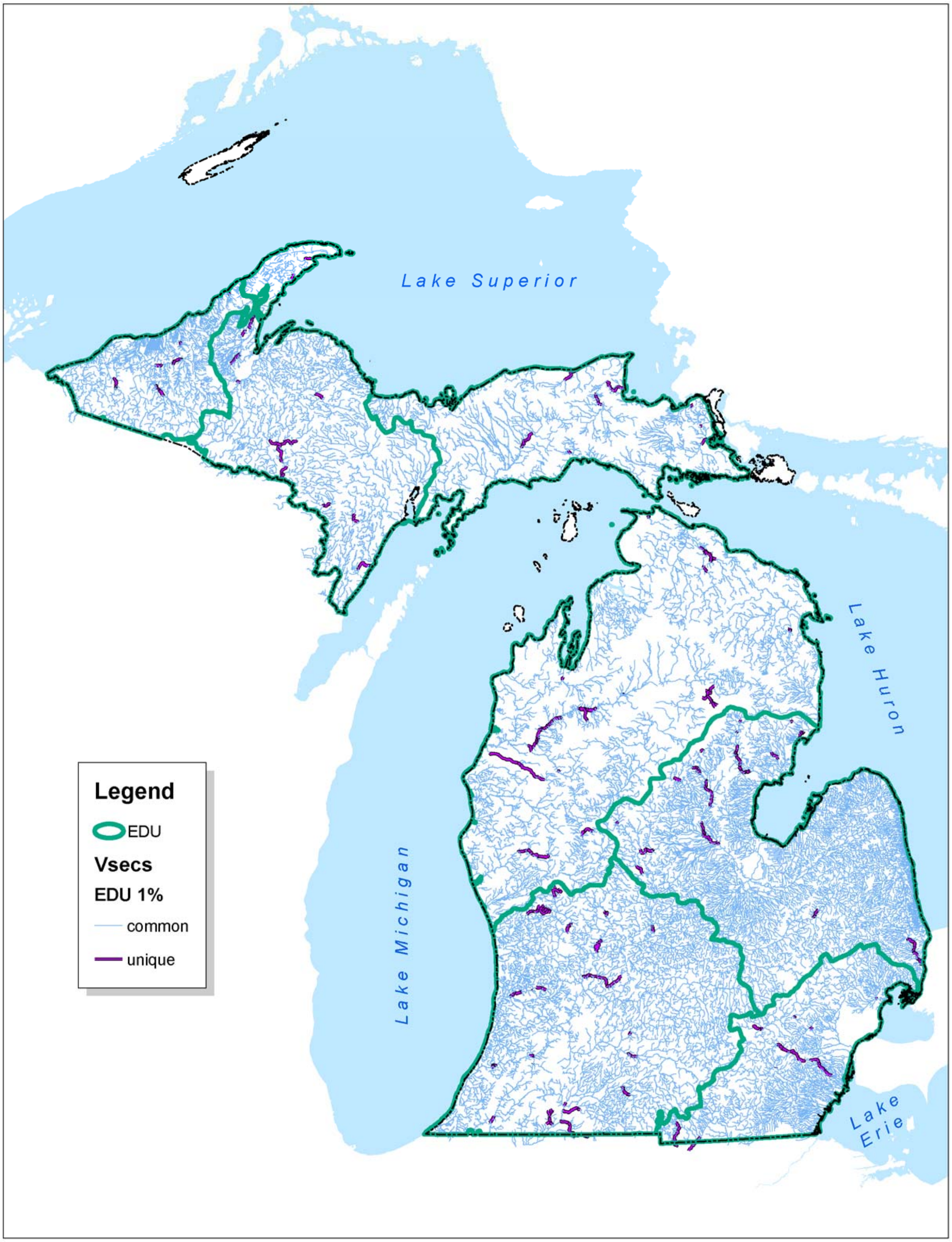


Figure 29. Unique river ecosystems in Michigan by EDU for the 1% rule.

Data source:
Institute for Fisheries Research, Michigan Department of Natural Resources, version as of August 2007: groundwater_vsec_statewide_6_29_07.shp

Institute for Fisheries Research, Michigan Department of Natural Resources: mi_epastar_nhd_stresref.shp

Results:
Of the 9,935 VSECs, 9,369 were classified as common in an EDU using the greater than 5% rule. Using the disturbance classification created by Wang et al. (2006), we selected the highest quality of the common river ecosystems (Figure 30). However, the Wang et al. (2006) analysis was conducted at the reach level. VSECs are made up of multiple reaches, and consequently, VSECs were not consistently classified in their disturbance classification. Reaches within a single VSEC could have different associated quality. For example, if a VSEC was made up of 4 reaches, each reach could have a different disturbance class (e.g. reference, no impact, degraded, reference). Therefore, only those reaches classified as reference within common VSECs were selected in our analysis (Table 23). Future work should review the entire VSEC and identify those common VSECs with an overall high quality.

The most common type of headwater and small tributary streams were cool or warm with moderate gradient. The most common type of medium rivers was warm moderate gradient. The most common type of large river and very large river types were warm, low gradient.

Table 22. Landscape variables used to determine quality (from Wang et al. 2006). Network watershed encompasses all areas upstream from the stream reach.

Variables for all streams
- Active mining (#/10000 km^2)
- Network watershed agricultural land use (%)
- Network watershed urban land use (%)
- MDEQ's permitted point source facilities (#/100 km^2)
- MDEQ's permitted point source facilities having direct connection with stream (#/100 km^2)
- USEPA's toxic release inventory sites (#/10000 km^2)
- Population density (#/km^2)
- Road crossing (#/km^2)
- Road density (km/km^2)
- Total nitrogen plus (phosphorus*10) loading (kg/l/yr)
- Watershed area treated with manure from barn yards (m/km)

Additional variables for coldwater streams
- Total nitrogen plus (phosphorus*10) yield (kg/l/year)

Additional variables for warmwater streams
- Dam density (#/100 km^2)
- USEPA's toxic release inventory sites discharging into surface water (#/10000 km^2)

Table 23. Summary of the number of river reaches classified as common ecosystems.

River size	Count
headwaters/small tributaries	26,100
medium rivers	4,361
large rivers	686
very large rivers	511

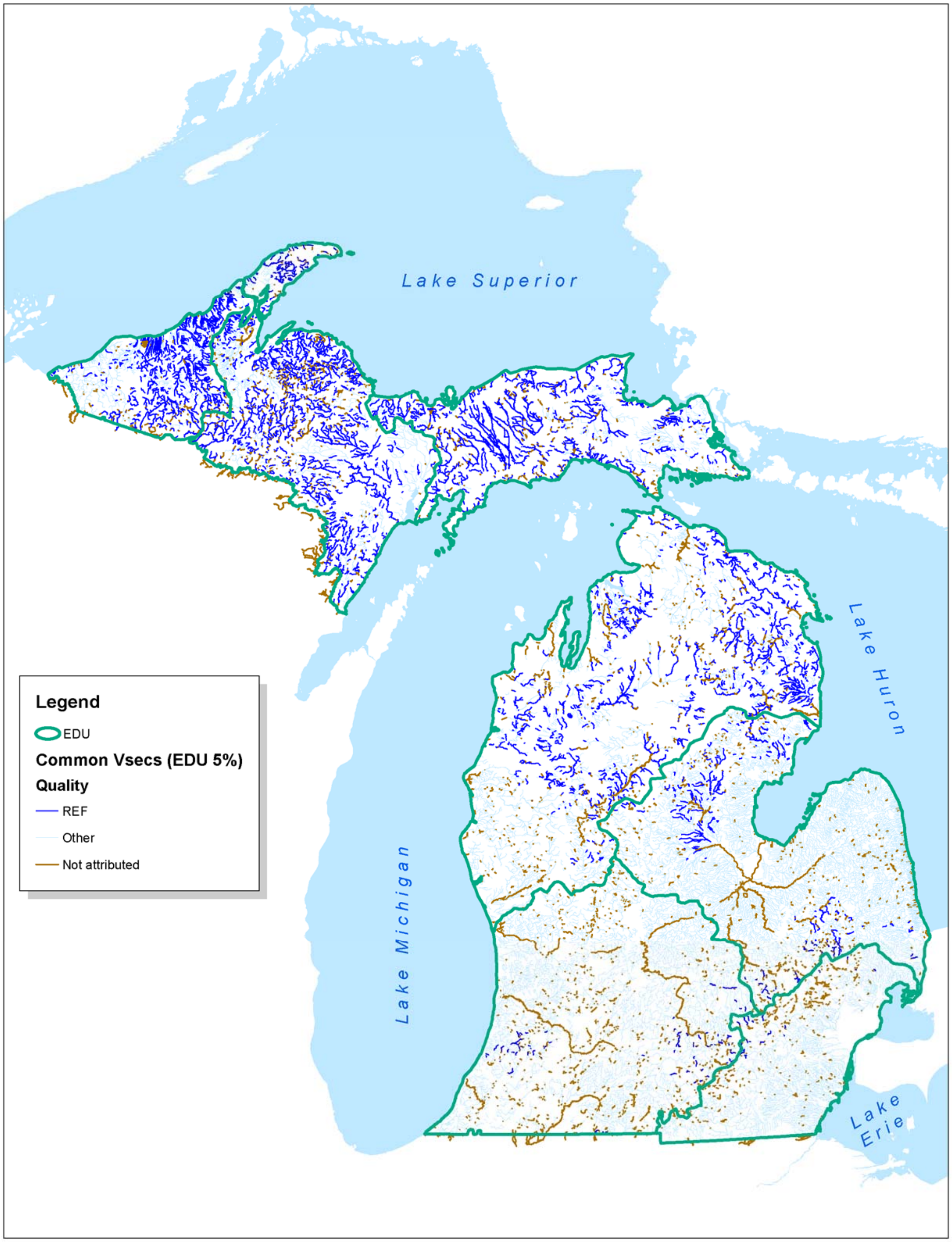


Figure 30. High quality river ecosystems in Michigan by EDU.

Rivers with Unimpeded Access To The Great Lakes

Description:
This shapefile shows river stretches still accessible to the Great Lakes. These data were obtained from Institute of Fisheries Research, Michigan Department of Natural Resources.

Use:
This layer identifies rivers that may have important habitats for migrating fish species, such as suckers, redhorse, salmon, and sturgeon, and ecosystem function in terms of connectivity.

Limitations:
This layer provides limited information since it is not coupled with migrating or exotic species data.

File name:
mi_epastar_nhd_damseg.shp

Data source:
mi_epastar_nhd_damseg.shp**.** Produced and supplied by Great Lakes GIS project of the University of Michigan and Michigan Department of Natural Resources, Institute for Fisheries Research, Ann Arbor, Michigan, USA, (May, 2007).

Results:
Many of the rivers highlighted in Figure 31 in the Saginaw Bay (4) EDU area are ditched streams that may be seasonal and may not be important to migrating fish species. Future work should compare accessible rivers with known species data to help determine priority areas for migrating fish.

Intact Headwaters in Michigan

Description:
A land cover analysis was conducted to identify intactness of headwater (stream order 1) watersheds. Headwater watersheds with 100% natural cover were identified. Additionally, percent naturalness for all headwater watersheds was provided.

Use:
Headwaters are critical ecosystems that can serve as refuge areas, sources of organic material, and stream cooling. They are important areas for fish, macroinvertebrates, amphibians, and reptiles. These ecosystems are also very sensitive to disturbance and any negative impacts to them can cause negative impacts downstream.

Limitations:
Land coverage data is limited in accuracy and is static. IFMAP land coverage is limited in accuracy. In addition, the IFMAP land cover was documented from satellite imagery taken between 1999 and 2001. Some areas of land have been altered since that time period rendering the land cover outdated for those areas.

File name:
headwaters100Natural.shp
headwatersPctnatural.shp

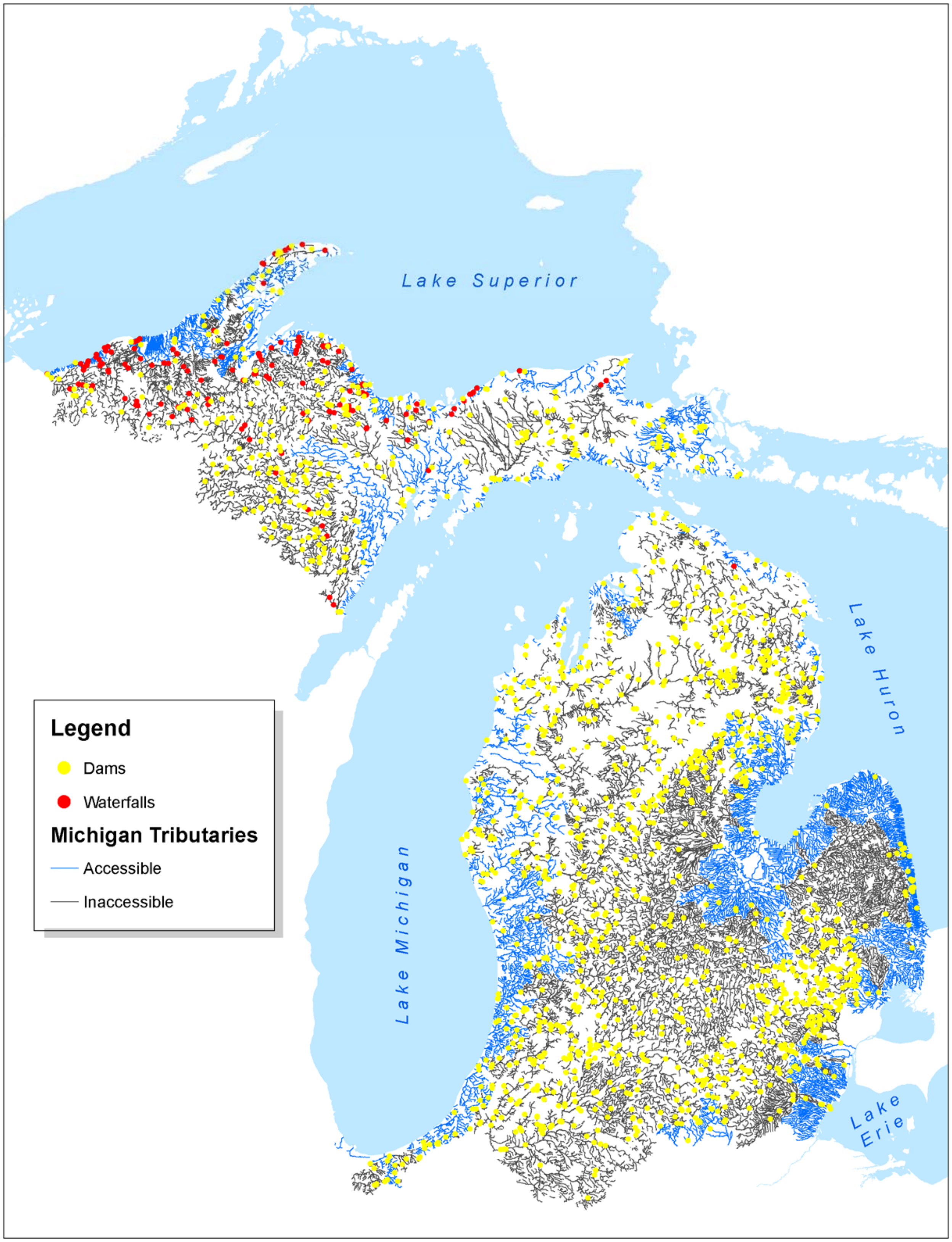


Figure 31. Rivers in Michigan with unimpeded access to the Great Lakes.

Data sources:
Michigan Department of Natural Resources. 2003. Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Lower Peninsula and Upper Peninsula) GIS data layer, version 1 (2003). lu2000_f.

reach_watersheds.shp. Date unknown. Produced and supplied by Great Lakes GIS project of the University of Michigan and Michigan Department of Natural Resources, Institute for Fisheries Research, Ann Arbor, Michigan, USA, (May, 2007).

mi_nhd_gap.shp. Date unknown. Produced and supplied by the University of Michigan and Michigan Department of Natural Resources, Institute for Fisheries Research, Ann Arbor, Michigan, USA, (September, 2005).

Results:
There are 43,288 miles of river in Michigan according to the data layer we used, and more than half of them, 25,227 miles, are first order streams. There are 19,426 first order reach watersheds out of 35,858 reach watersheds in Michigan. Headwater (first order) watersheds account for 22,802,925 acres in Michigan. There are 1,116 headwater watersheds with 100% natural land cover and they make up about 670,274 acres in Michigan. Most of the 100% natural headwater watersheds occur in the Upper Peninsula, however there are also some located in the Lower Peninsula (Figure 32). The majority of the natural headwaters were found in the Central Upper Peninsula (7) EDU, and the fewest were found in the Southeast Michigan Interlobate and Lake Plain (16+2) EDU (Table 24). By decreasing the threshold to 87% naturalness, more headwater watersheds in the southern Lower Peninsula were included (Figure 33).

Table 24. Number of 100% natural headwater watersheds in each EDU.

EDU	Count
3	9
4	32
5	93
6+12	322
7	201
8	**457**
16+2	2

Unique Lake Ecosystems in by statewide and by EDU

Description:
Lake ecosystems were classified as unique using a 5% and 1% rule; see previous section on defining uniqueness for more detail.

Use:
By highlighting unique lakes, we hope to capture potentially unique and important ecosystems that contribute to the diversity of Michigan and the Great Lakes Region. This analysis will provide a relatively simple representation of where in Michigan unique ecosystems are located and will help direct future survey efforts to determine true rarity, importance, and condition of these ecosystems.

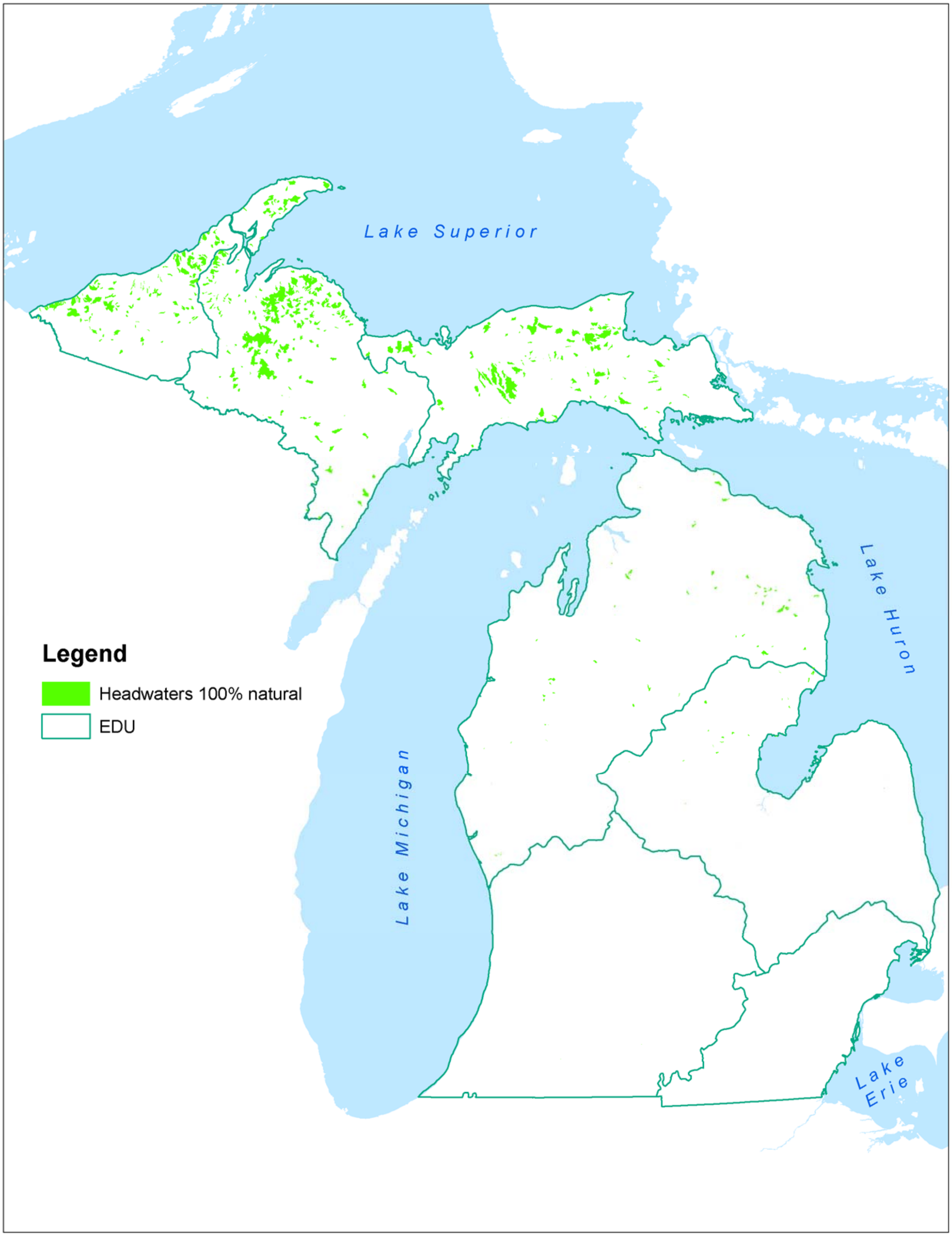


Figure 32. Intact watersheds of headwater streams in Michigan.

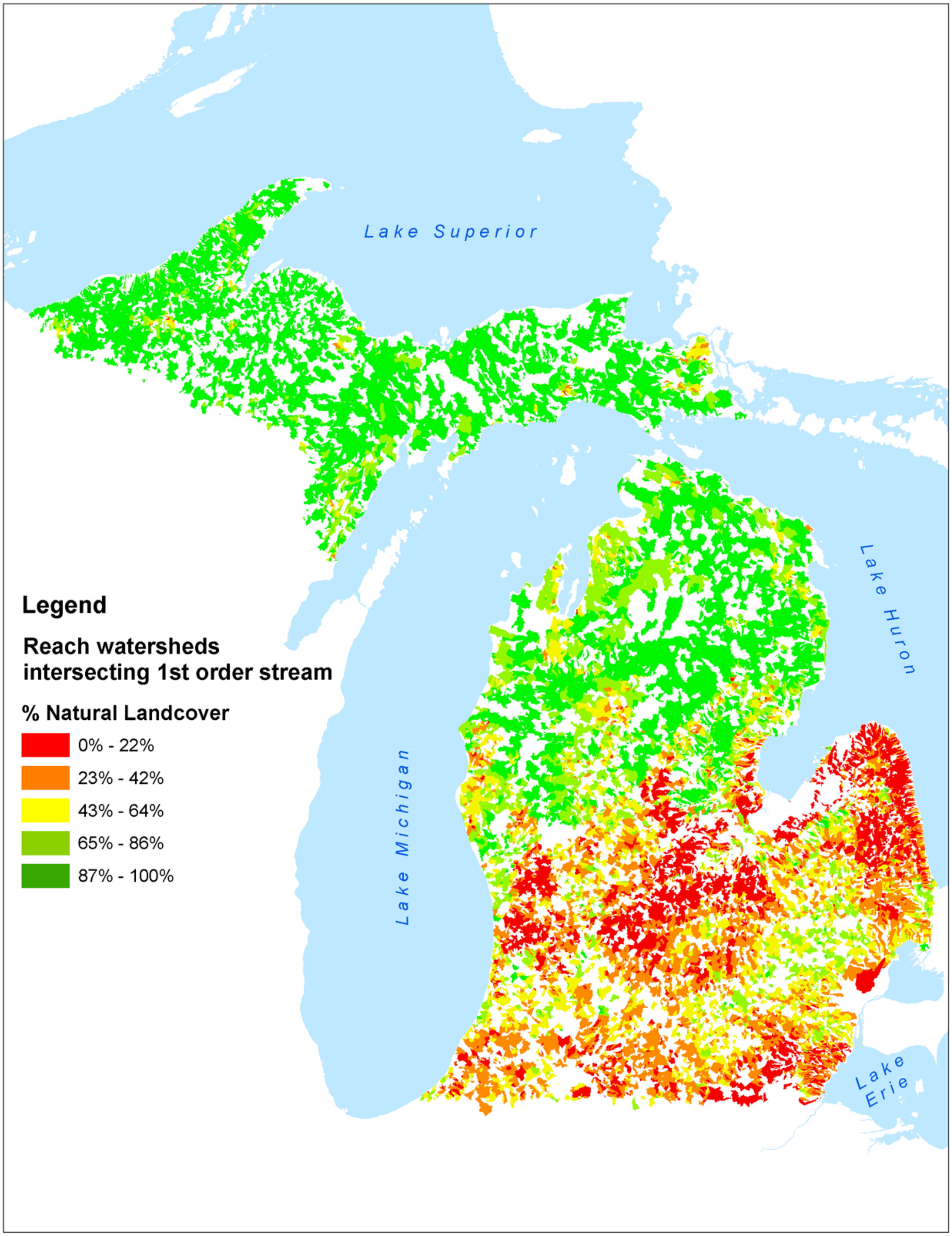


Figure 33. Percent natural land cover in watersheds of headwater streams in Michigan.

Limitations:
Unique lake types identified may be an artifact of the classification process and the accuracy of available digital data. Although true rarity is uncertain, this analysis provides a basis that will help direct future survey efforts. In addition, a landscape context analysis is not included with this layer because we are looking for rarity and not necessarily the best of the unique. See lake classification section for limitations associated with data used in this analysis.

File name:
lake_unique_statewide_5pct.shp, lake_unique_statewide_1pct.shp
lake_unique_edu_5pct.shp, lake_unique_edu_1pct

Data source:
The Nature Conservancy – Great Lakes Program, Higgins et al. 1998
milakes_w_attributes.shp

Results - statewide:
There were 10,772 lakes used in our analysis. Originally, the dataset we used had a universe of 11,172 lakes but 372 were removed due to small size (<=2 acres), lack of proximate geology value, or lack of EDU assignment. The current EDU layer does not cover most islands and the boundary lines are at a coarser scale than the state boundary. Statewide there are 157 lake types. Twenty-three lake types occurred in only one watershed. The number of lakes within a type for ponds ranged from 1 to 1,226, for small lakes from 1 to 1,128, for medium lakes from 1 to 116, and for large lakes from 1 to 18 (Table 25). There were 61 lake types with five or fewer lakes. Lakes were identified as unique within each of the four size classes.

Table 25. Summary of classification of lakes and uniqueness analysis.

	Ponds	Small Lakes	Medium Lakes	Large Lakes
Total number of lakes*	5,136	4,837	873	86
Number of lakes in analysis	5,101	4,805	792	74
Number of lake types	38	52	50	17
Minimum number of lakes in a lake type	1	1	1	1
Maximum number of lakes in a lake type	1,226	1,128	116	18
Number of lake types in only one watershed	7	3	8	5
Maximum number of watersheds a lake type occurred	44	45	28	12
Number of unique lake types (5%)	14	24	40	17
Number of unique lakes (5%)	53	165	281	74
Number of unique lake types (1%)	12	13	17	14
Number of unique lakes (1%)	23	35	38	32

Using the 5% rule, a total of 539 lakes were targeted as unique, the actual number selected was 573 assigned among 95 lake types (Figure 34). Lakes selected as unique were scattered across the state and no pattern was apparent. The Eastern Upper Peninsula (7) EDU had the fewest lakes identified, while the Northern Lake Michigan, Lake Huron, and Straits of Machinac (5) EDU had the most (Table 26) lakes identified.

Table 26. Number of statewide unique lakes in each EDU using the 5% and 1% rule.

	16+2	3	4	5	7	8	6+12
Number of unique lakes statewide (5%)	46	98	104	127	28	88	82
Number of unique lakes statewide (1%)	11	16	21	32	8	21	19

Using the 1% rule, a total of 108 lakes were selected as unique statewide (Table 25). The Eastern Upper Peninsula (7) EDU again had the fewest lakes selected, whereas the Northern Lake Michigan, Lake Huron, and Straits of Mackinac (5) EDU had the most (Figure 35) lakes identified.

Results – by EDU:

The number of lakes in an EDU ranged from 550 to 2,547 and the number of lake types ranged from 56 to 99 (Table 27). The minimum number of lakes in a lake type for all EDUs was one and the maximum ranged from 92 to 379.

Table 27. Summary of general lake statistics within EDUs.

	16+2	3	4	5	7	8	6+12
Number of lakes	1,123	**2,547**	1,446	2,304	1,362	1,413	550
Number of ponds	522	**1,238**	769	970	605	710	287
Number of small lakes	511	**1,126**	589	1,089	647	594	222
Number of medium lakes	89	177	82	**207**	100	100	37
Number of large lakes	1	6	6	**38**	10	9	4
Number of possible lake types	176	176	**208**	192	160	**208**	176
Number of actual lakes types	79	88	**99**	94	78	85	56
Minimum number of lakes in a type	1	1	1	1	1	1	1
Maximum number of lakes in a type	169	367	92	379	198	135	134

Using the 5% rule, a total of 33 to 131 lakes were targeted as unique dependent upon EDU (Figure 36). A total of 577 lakes were selected as unique across EDUs (Table 28). The Western Upper Peninsula and Keweenaw Peninsula (6+12) EDU had the fewest lakes identified and the Southeast Lake Michigan (3) EDU had the most lakes identified. The Northern Lake Michigan, Lake Huron, and Straits of Mackinac (5) EDU had the highest number of unique lake types. Overall, unique lakes selected were typically spread out throughout an EDU and were distributed across size classes. In general, small lakes and medium lakes were represented more than ponds and large lakes.

Table 28. Summary of unique lake ecosystems by EDU based on the 5% rule.

		16+2	3	4	5	7	8	6+12
Unique	Number of lake types	38	46	44	**48**	37	47	28
	Number of lakes	65	**131**	74	123	74	77	33
	Number of ponds	12	**31**	8	15	15	19	6
	Number of small lakes	21	29	22	**37**	29	27	11
	Number of medium lakes	31	**65**	38	46	20	26	12
	Number of large lakes	1	6	6	**25**	10	5	4
Common	Number of lake types	41	42	55	46	41	38	28
	Number of lakes	1058	2416	1372	2181	1315	1336	517

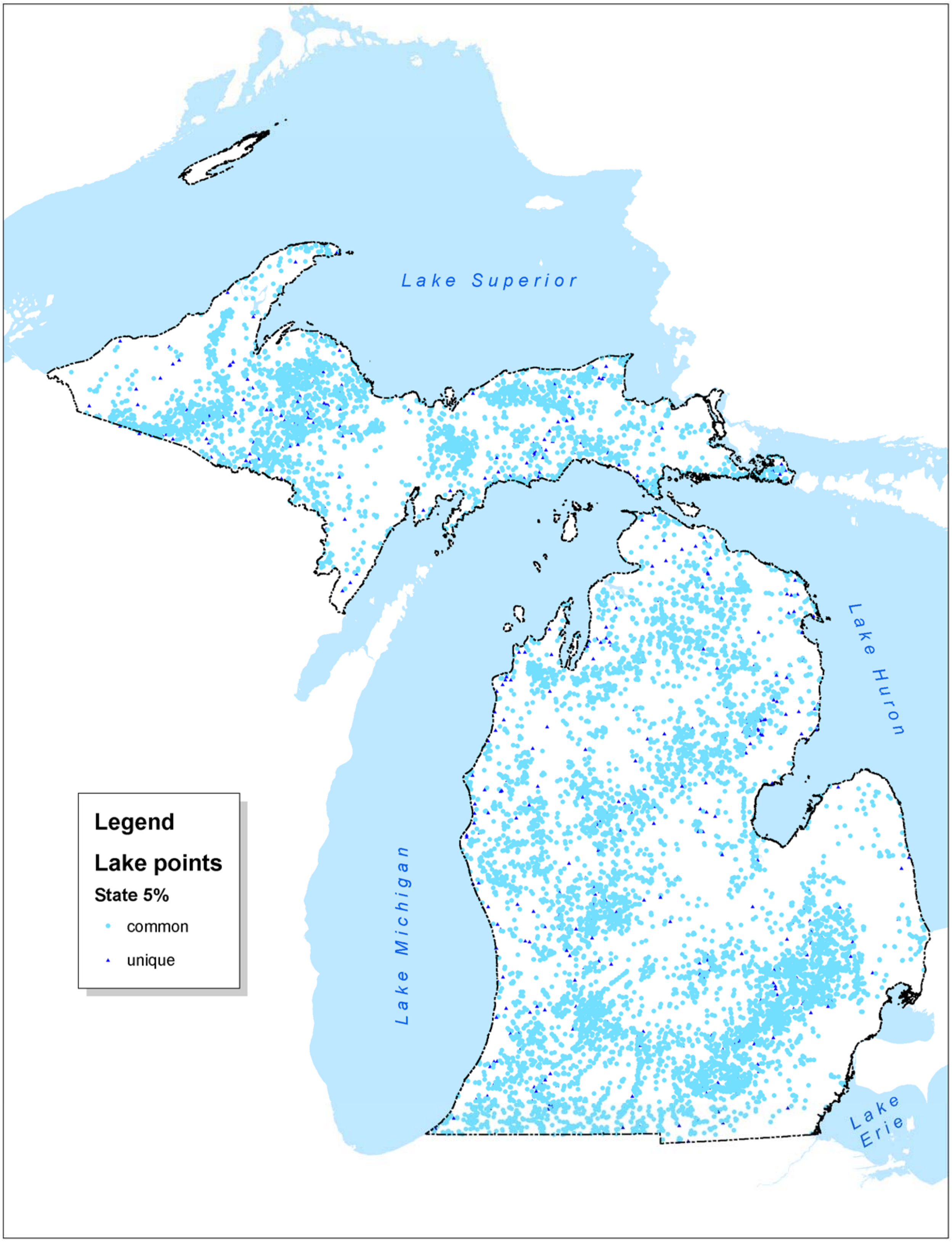


Figure 34. Unique lake ecosystems in Michigan using the 5% rule.

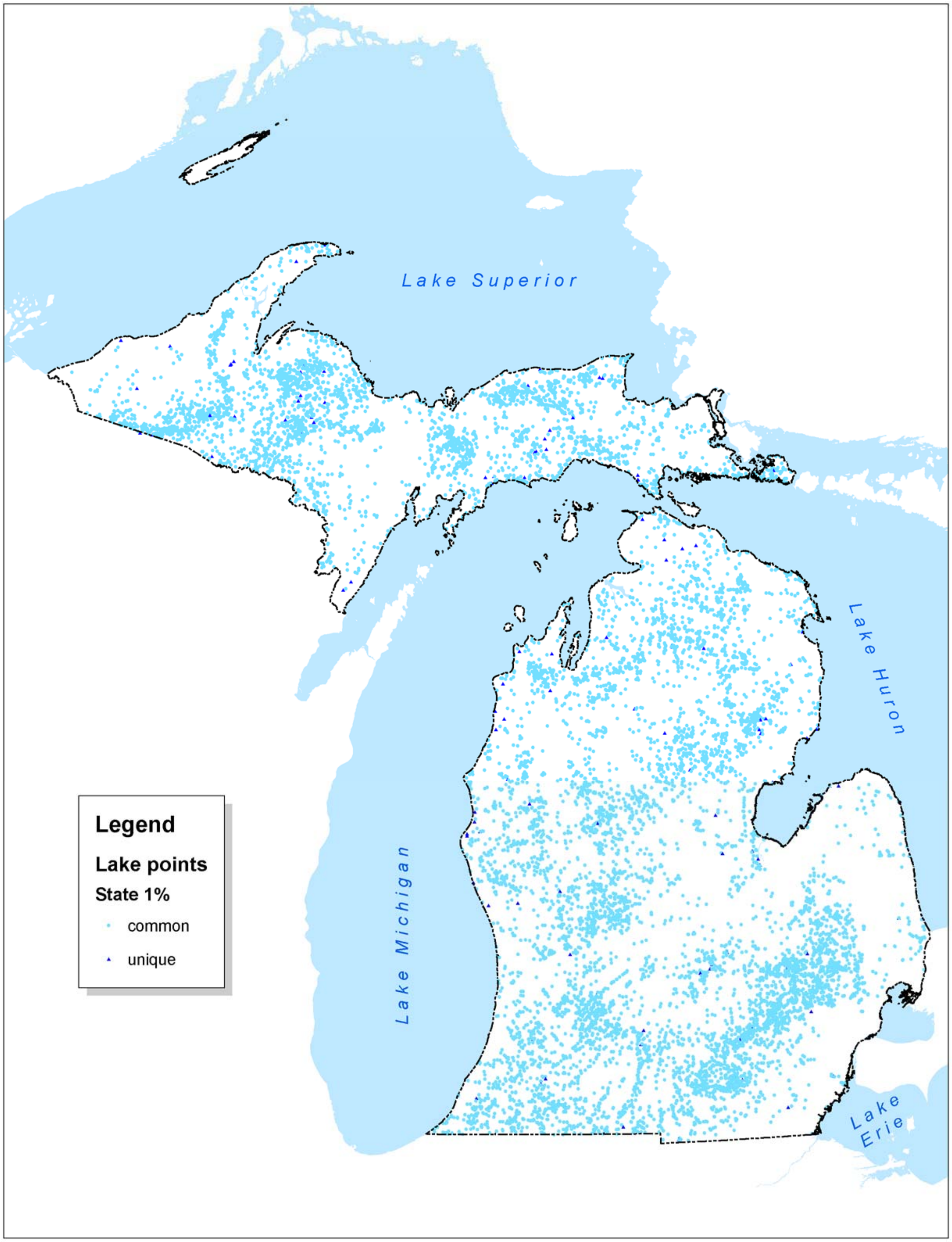


Figure 35. Unique lake ecosystems in Michigan using the 1% rule.

Using the 1% rule, a total of 185 lakes were selected as unique across EDUs (Table29). The number of lakes and lake types designated as unique ranged from 17 to 41 and 17 to 26, respectively. The Eastern Upper Peninsula (7) EDU had the fewest lakes selected, whereas the Southeast Lake Michigan (3) EDU had the most (Figure 37). All lakes size classes were represented, except in the Southeast Lake Michigan (3) EDU where no large lakes were designated as unique. In general, ponds and large lakes were less represented than small and medium lakes.

Table 29. Summary of unique lake ecosystems by EDU based on the 1% rule.

		16+2	3	4	5	7	8	6+12
Unique	Number of lake classes	19	**26**	23	25	17	25	23
	Number of lakes	19	**41**	23	37	17	25	23
	Number of ponds	2	5	2	8	3	**9**	4
	Number of small lakes	7	**14**	8	7	6	5	7
	Number of medium lakes	9	**22**	9	15	5	8	8
	Number of large lakes	1	0	4	**7**	3	3	4
Common	Number of lake classes	60	62	76	69	61	60	33
	Number of lakes	1104	2506	1423	2267	1372	1388	527

High-Quality Common Lake Ecosystems within EDUs

Description:

Lake ecosystems were classified as common in an EDU using a greater than 5% rule; see previous section on defining uniqueness for more details. Quality of common lakes was assessed by calculating percent natural land use and road density in a 500 m buffer around each lake (Soranno et al. in prep). Values of the landscape variables were put into classes and lakes were ranked according to lowest road density and highest percent natural land use. Land use (Allen 2004) is known to affect the quality of aquatic ecosystems and species. Road density was included as part of the landscape context analysis because we felt true land use may be masked in the IFMAP data. Natural vegetation buffers often surround lakes, even if housing density is high. Quality was relative within each EDU.

For this analysis we targeted 10 unconnected ponds or small lakes, 5 connected ponds or small lakes, 5 medium lakes, and 1 large or very large lake ecosystem in each EDU with the best landscape context. No threshold values for quality were used, just target numbers of lakes. The best qualilty lakes were seleceted until we got our target number. However, more lakes than the target number could be selected if many lakes had the same quality value.

Use:

This analysis provides a relatively simple representation of where potential high-quality lake ecosystems are located in each EDU, and helps direct survey efforts to determine true condition and importance.

Limitations:

One main limitation of this data layer is that it does not include representation of all common lake ecosystems. In addition, no field survey data was used to determine true condition and integrity of the ecosystems. Individual lakes highlighted may not be the best representatives available, because local factors that are not captured in this analysis could drive the quality of an ecosystems. However this analysis does provide a basis to help direct future survey efforts. See lake classification section for limitations associated with data used in this analysis.

Figure 36. Unique lake ecosystems in Michigan by EDU using the 5% rule.

Figure 37. Unique lake ecosystems in Michigan by EDU using the 1% rule.

File name:
lake_HQ_edu.shp

Data sources:
The Nature Conservancy – Great Lakes Program, Higgins et al. 1998
milakes_w_attributes.shp

Michigan Department of Natural Resources. 2003. Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Lower Peninsula and Upper Peninsula) GIS data layer, version 1 (2003). lu2000_f. Forest, Minerals and Fire Management Division, Michigan Department of Natural Resources (MDNR), Lansing, Michigan.

Michigan Center for Geographic Information. 2006. Michigan Geographic Framework v6b. roads_only_6b.shp.

Results:
As to be expected, more high quality ponds were selected than larger lakes (Table 30). The Eastern Upper Peninsula (7) EDU had the most high quality lakes selected in each of the four size classes, and the Saginaw Bay (4) EDU had the fewest (Figure 38), likely due to the paucity of lakes in that EDU.

Table 30. Summary of the number of high quality lakes by size class in each EDU.

	2 +16	3	4	5	7	8	6 + 12	Total:
Ponds	26	55	32	52	**147**	60	29	401
Small lakes	20	40	8	13	**91**	26	24	222
Medium lakes	6	7	4	43	**66**	50	21	197
Large lakes	0	1	1	0	**4**	0	1	7
Total:	52	103	45	108	**308**	136	75	827

Functional (or least modified) sub-watersheds

Description:
This analysis integrated land cover, fragmentation, and pollution analyses into a shapefile that highlights functional sub-watersheds (huc-12). Three different analyses (land cover, fragmentation, and pollution) were conducted and scored between 1 and 5 using quantiles, 1 being the least disturbed and 5 being the most disturbed. A single metric was pooled to determine the 2 least disturbed sub-watersheds within each watershed and the least disturbed sub-watersheds statewide.

Use:
The quality of an aquatic ecosystem is largely dependent upon its landscape context, which include those areas upstream. To truly protect or manage a river or lake its contributing watershed must be taken into account. This analysis provides a method for assessing the quality of sub-watersheds based on available data. This information can be used to direct future surveys or target conservation efforts.

Limitations:
We call this analysis "functional sub-watersheds," however true functionality is unknown. This layer is essentially our "best-guess" based on available data. Functionality and disturbance are complicated processes, and in this analysis we are only targeting a few potential indicators.

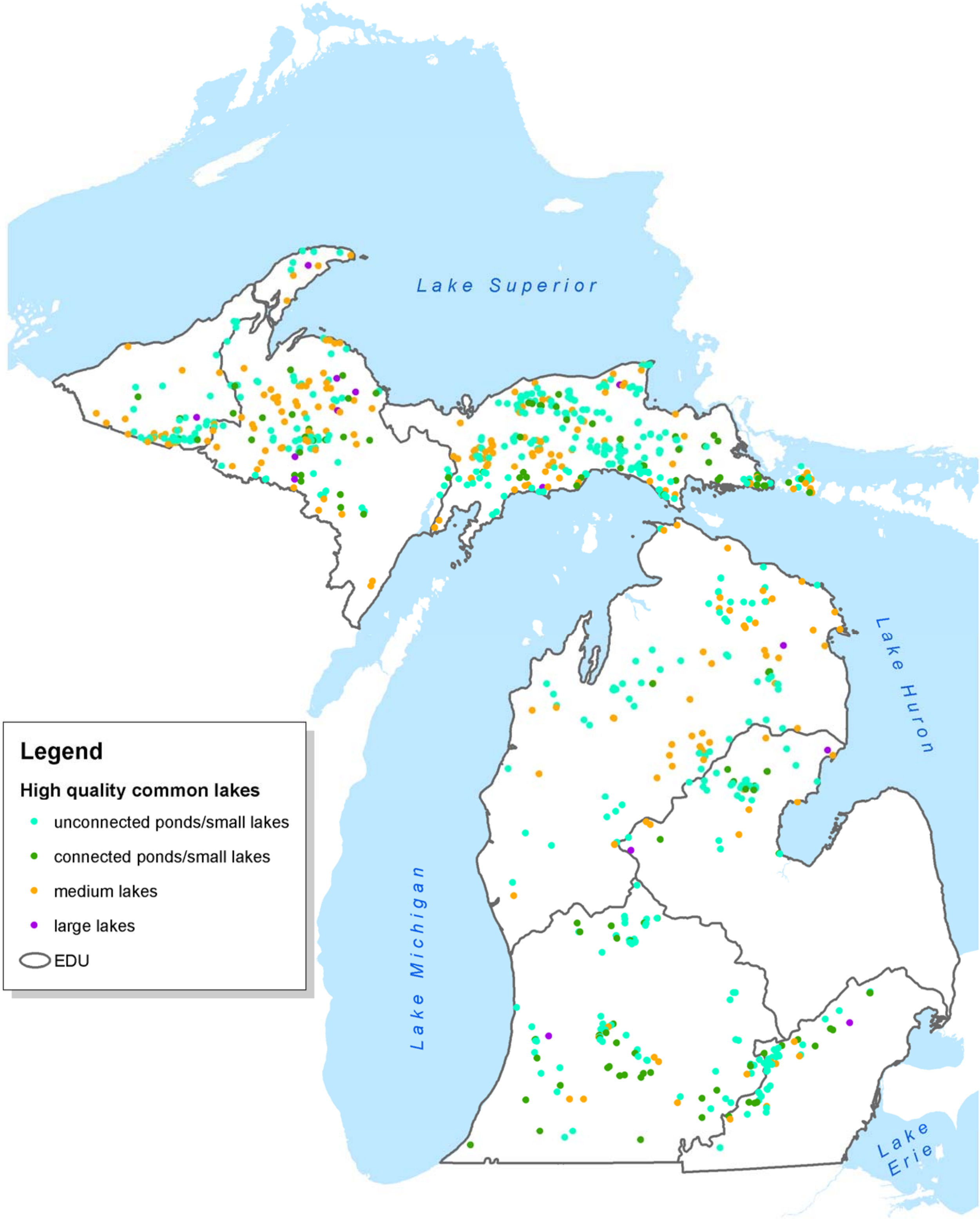


Figure 38. High quality lakes by EDU.

Land cover analysis

Description:

The land cover analysis was based on a combination of natural land cover for the entire catchment and within the riparian zones. All natural vegetation types identified by the IFMAP land coverage were combined together to form a new all natural vegetation data layer. Natural vegetation included grassland/herbaceous, shrubland, forest, and wetland. The percent of sub-watershed with natural land cover was determined and placed in one of 5 classes based on quartiles. Additionally, all rivers and lakes were buffered outward by 60 m to create the riparian zone for analysis. The percent of natural land cover within riparian zones was determined and placed in one of 5 classes based on quartiles. These two analyses were added together and divided by 2 to determine the overall class (1-5) for each sub-watershed.

Use:

This analysis was used to rank sub-watersheds in terms of natural cover, and was one component of the functional watershed analysis.

Limitations:

IFMAP land coverage is limited in accuracy. In addition, the IFMAP land cover was documented from satellite imagery taken between 1999 and 2001. Some areas of land have been altered since that time period rendering the land cover outdated for those areas.

File names:

pctNat_subwatershed.shp

pctNat_Riparian_subwatershed.shp

Data source:

Michigan Department of Natural Resources. 2003. Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Lower Peninsula and Upper Peninsula) GIS data layer, version 1 (2003). lu2000_f. Forest, Minerals and Fire Management Division, Michigan Department of Natural Resources (MDNR), Lansing, Michigan.

Results:

The percent natural land cover in sub-watersheds showed the expected; sub-watersheds in the northern Lower Peninsula and Upper Peninsula have more natural land cover (Figure 40). However, when only riparian land cover was considered, more sub-watersheds in the southern Lower Peninsula have relatively good natural riparian buffers (Figure 41), and more sub-watersheds in the northern Lower Peninsula and Upper Peninsula have poor riparian cover relative to the overall sub-watershed land cover. Many of the sub-watersheds with poor riparian cover are located in more urban environments (exp. Alpena, Escanaba, Sault St. Marie). When both natural land cover in the entire sub-watershed and within the riparian buffer were combined, the map shows something in between the two analyses (Figure 42).

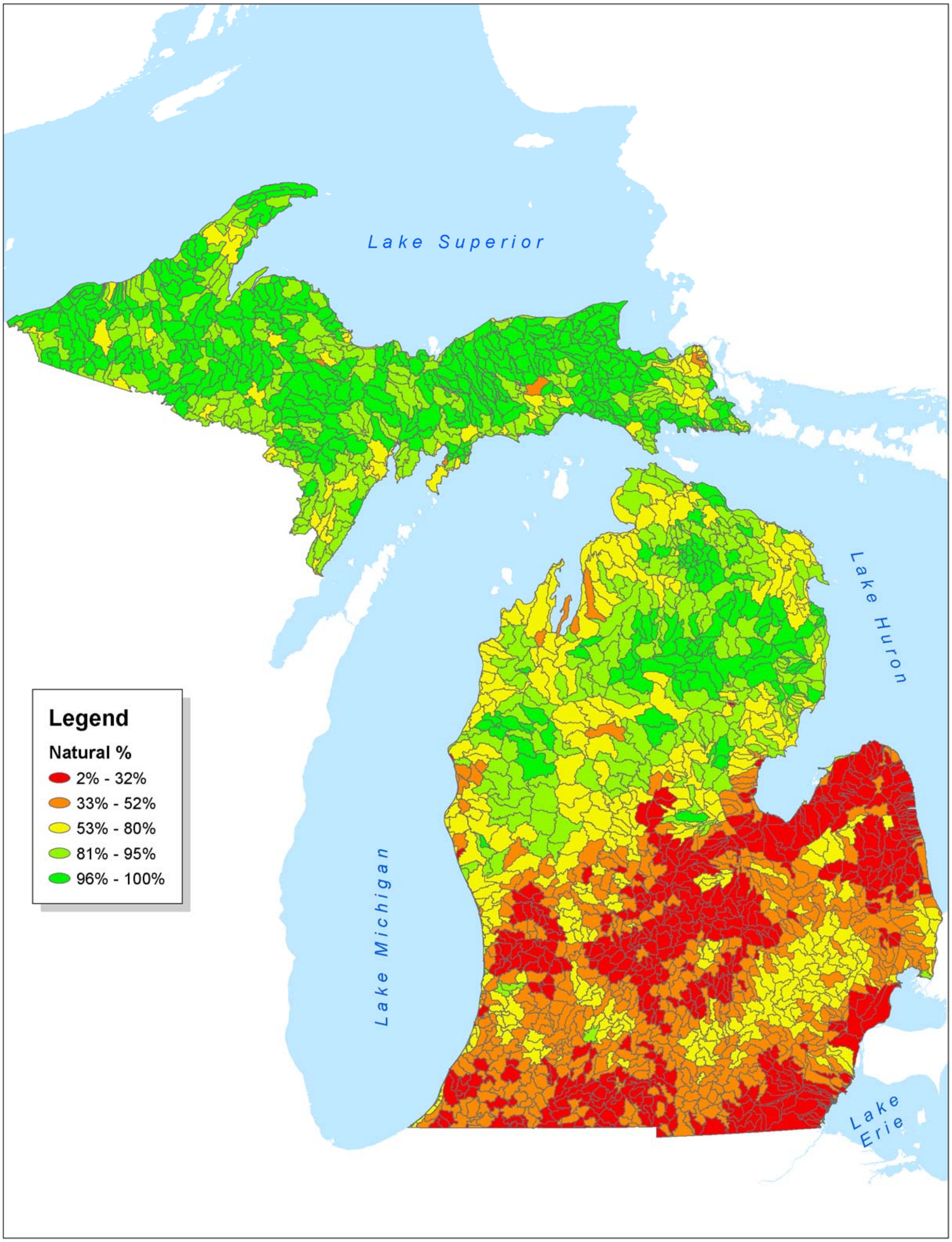


Figure 39. Percent natural land cover by sub-watershed.

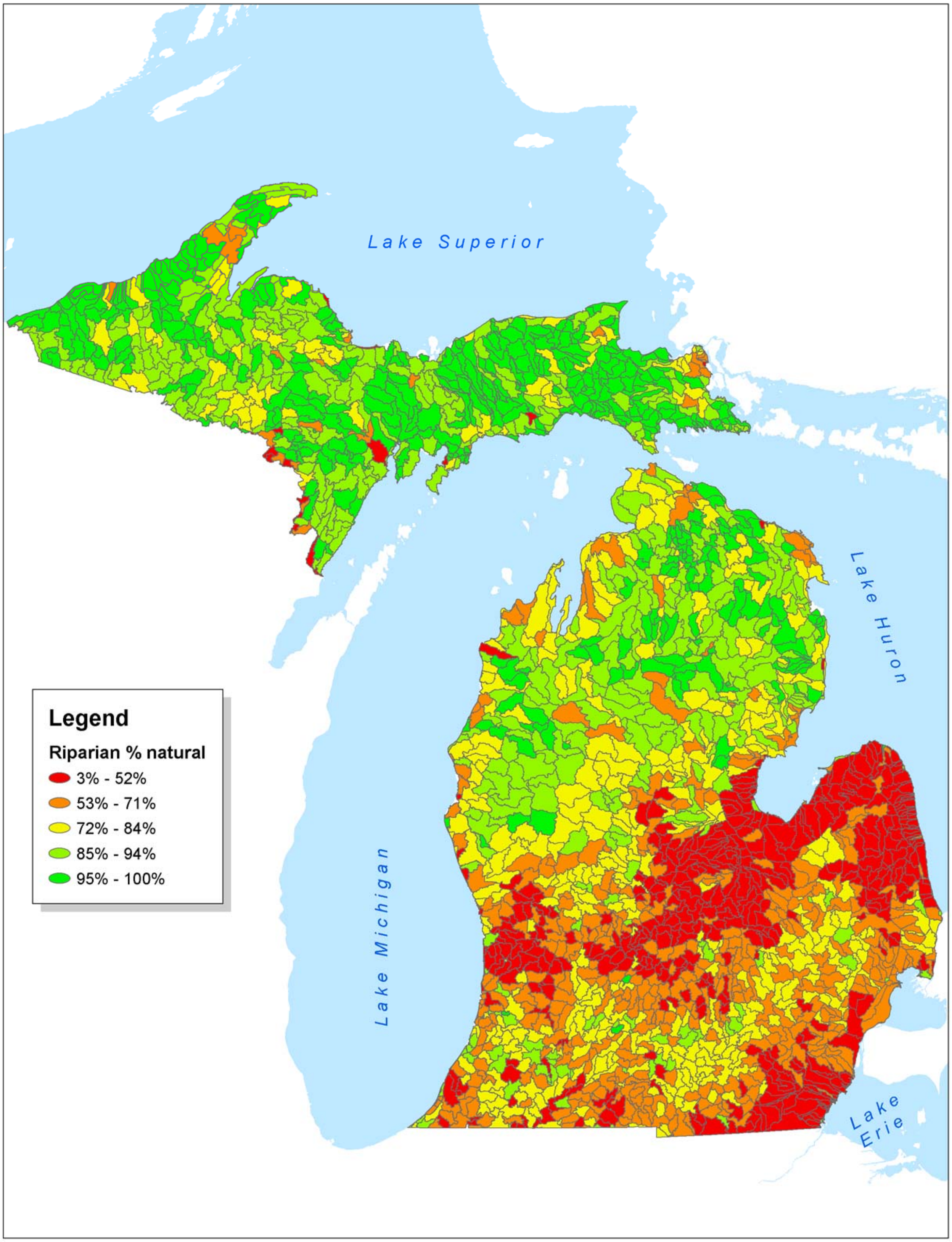


Figure 40. Percent natural land cover in riparian areas by subwatershed.

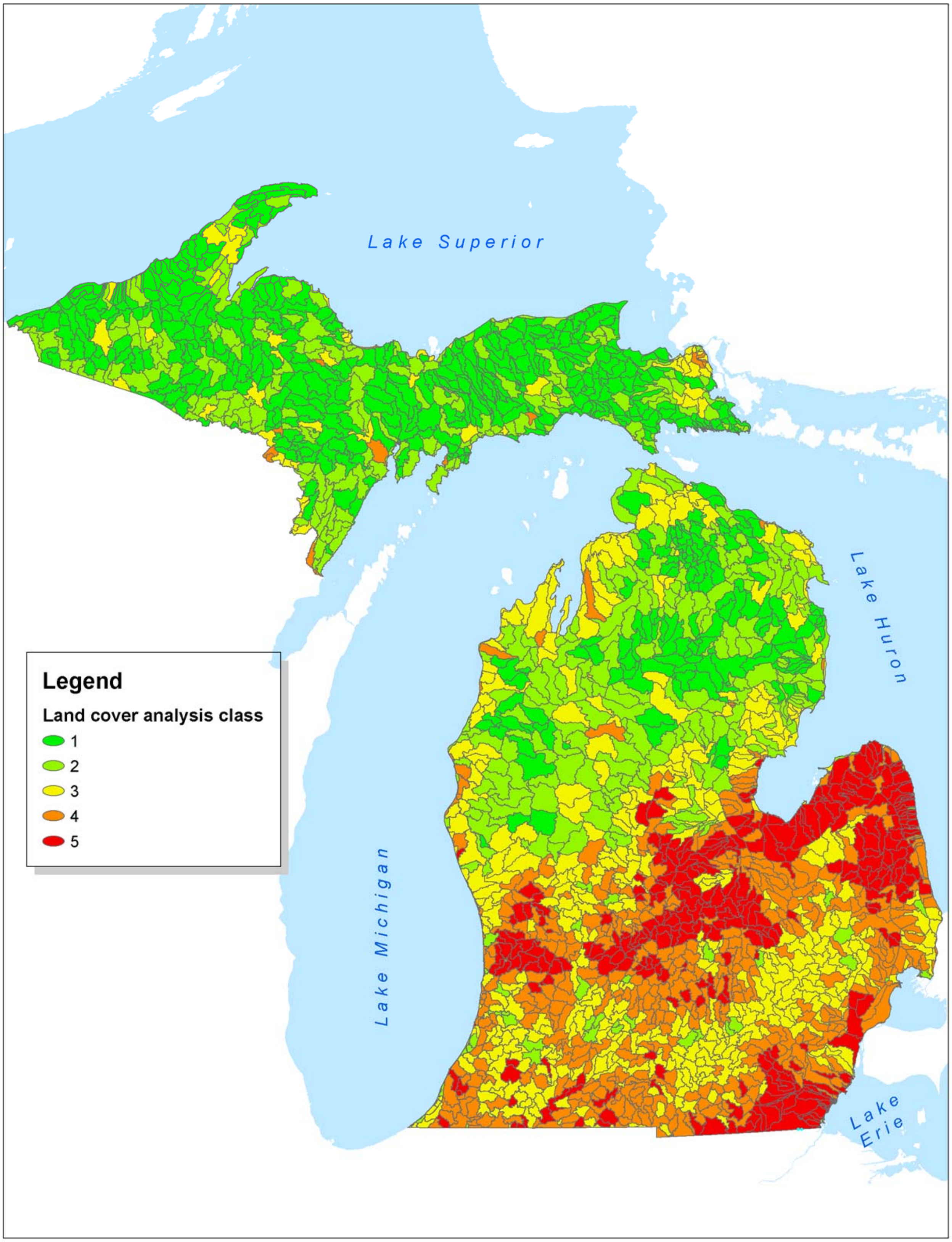


Figure 41. Land cover analysis by subwatershed.

Fragmentation analysis

Description:

This analysis provides information on the level of fragmentation of the rivers in each sub-watershed. There are two major fragmentation factors for rivers that can be easily gleaned from GIS data: dams and road crossings. Both can alter hydrologic flows, sediment exchange, and disrupt fish and mussel movements and population exchanges. Not all road and stream crossings fragment aquatic habitats, but if improperly installed and maintained they can. Because the quality of road crossing cannot be determined using available data, we treated all crossings as a level of fragmentation. In this analysis, the number of dams per river mile and the number of road and stream crossings per river mile in each sub-watershed were calculated, ranked within each watershed, and placed in one of 5 classes based on quartiles. These two analyses were added together and then divided by 2 to determine the overall class (1-5) for each sub-watershed.

Use:

This analysis provides information on which sub-watersheds have the least fragmentation, and was used to calculate the overall functional score of each sub-watershed.

Limitations:

Sub-watersheds with <0.1 miles of river were eliminated from the analysis. The data used in this analysis are static and hence may be outdated for some areas. Additionally, these are not the only factors that create fragmentation in aquatic ecosystems, however they are the easiest to determine given the available data. Even if sub-watersheds have no dams and few road crossings, they still can be substantially impacted by fragmentation upstream or downstream from the sub-watershed boundaries.

File names:

damCount_subwatershed.shp
rdxStrCount_subwatershed.shp
fragementation_subwatershed.shp

Data sources:

dams.shp from MDEQ

Michigan Center for Geographic Information. 2006. Michigan Geographic Framework v6b. roads_only_6b.shp.

Institute for Fisheries Research, Michigan Department of Natural Resources. mi_nhd_gap.shp. Date unknown. Produced and supplied by the University of Michigan and Michigan Department of Natural Resources, Institute for Fisheries Research, Ann Arbor, Michigan, USA, (September, 2005).

Results:

Some sub-watersheds, according to the available data, have very small sections of river, which can create high numbers of dams and stream crossings per river mile. For example, the sub-watershed with the highest number of dams (9) per river mile. This sub-watershed actually had 5 dams in 0.54 miles of river. The sub-watershed with the highest number of road crossings (22), resulted from a sub-watershed with 0.18 miles of river and 4 stream crossings.

Road crossings are a larger fragmentation issue in the southern Lower Peninsula, whereas dams are a bigger issue in the northern Lower Peninsula and the Upper Peninsula (Figure 42, 43). Figure 44 suggests that fragmentation is a major issue for aquatic ecosystems in Michigan across the state; there are few areas where fragmentation is not an issue.

Pollution analysis

Description:
This analysis provides an overall pollution score to each sub-watershed. This metric includes a variety of variables to target both point and non-point source pollution. The number of DEQ permitted point source facilities and active mining operations was calculated. In addition, the percent impervious surface for each sub-watershed was calculated. As in the previous analyses, each was placed in one of 5 classes (1-5) within a sub-watershed based on quartiles. The overall pollution metric was calculated by adding together each individual rank and divided by 3. This resultant metric ranged from 1 to 5, with 1 being the least polluted and 5 being the most polluted.

Use:
This analysis provides a broad look at both point and non-point source pollution within sub-watersheds. Those sub-watersheds with the least pollution threats were identified. The overall metric was used to calculate the overall functional score for each sub-watershed.

Limitations:
The point source and toxic release site data used in this analysis is static and may be outdated for some areas. IFMAP land coverage is limited in accuracy. In addition, the IFMAP land cover was documented from satellite imagery taken between 1999 and 2001. Some areas of land have been altered since that time period rendering the land cover outdated for those areas.

File names:
imperv_subwatershed.shp
npdesCount_subwatershed.shp
mineCount_subwatershed.shp
pollution_subwatershed.shp

Data sources:
U.S. Geological Survey (USGS) Active Mines and Mineral Processing Plants in the United States in 2003. http://mrdata.usgs.gov. mineplant_mi_georef.shp. Published 2005. USGS, Reston, VA.

Michigan Department of Environmental Quality (DEQ), Non-point source data, npdes_gw_permits1_georef.shp.

Michigan Department of Natural Resources. 2003. Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Lower Peninsula and Upper Peninsula) GIS data layer, version 1 (2003). G:\gis\landu\lu2000_f. Forest, Minerals and Fire Management Division, Michigan Department of Natural Resources (MDNR), Lansing, Michigan.

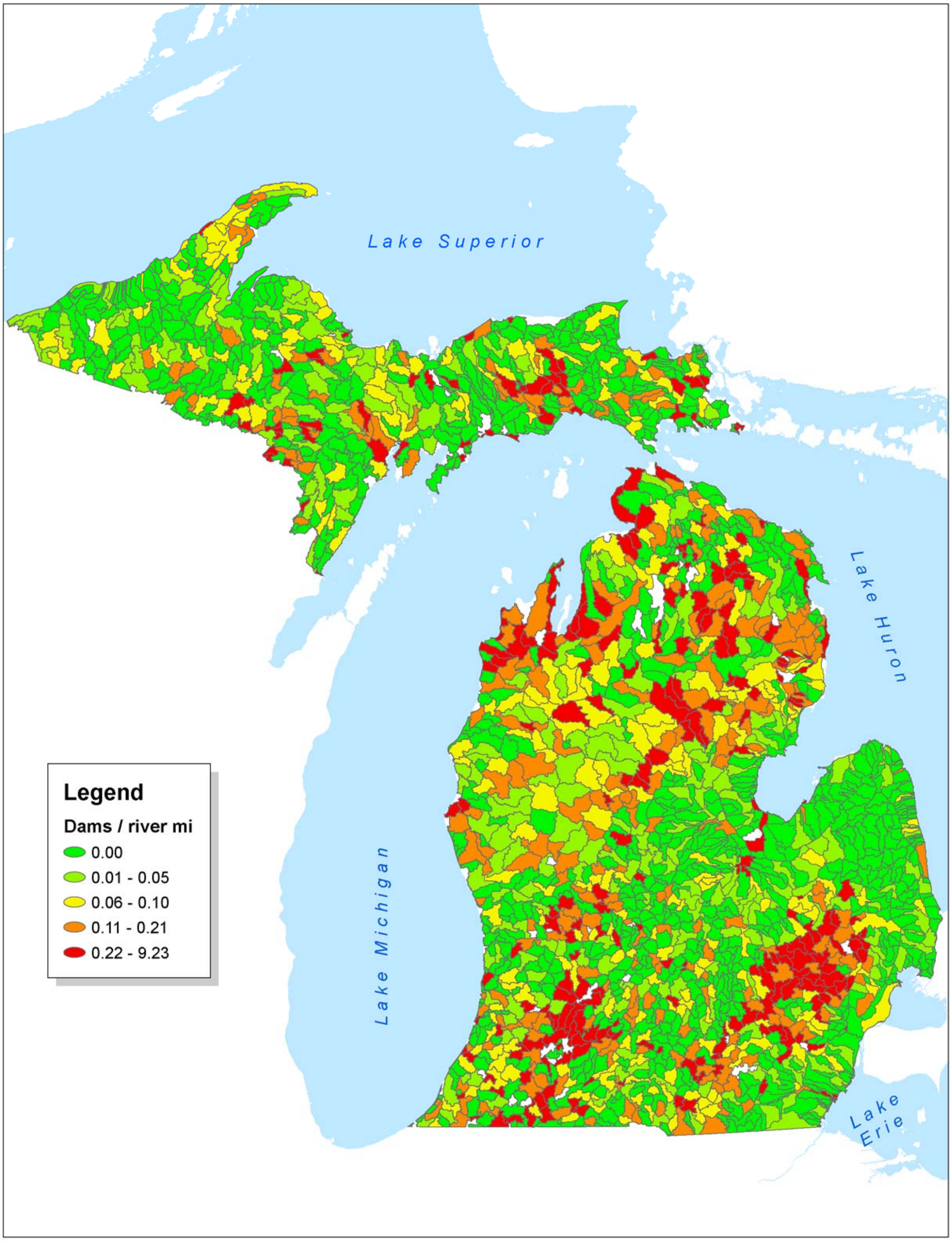


Figure 42. Number of dams per river mile in sub-watersheds.

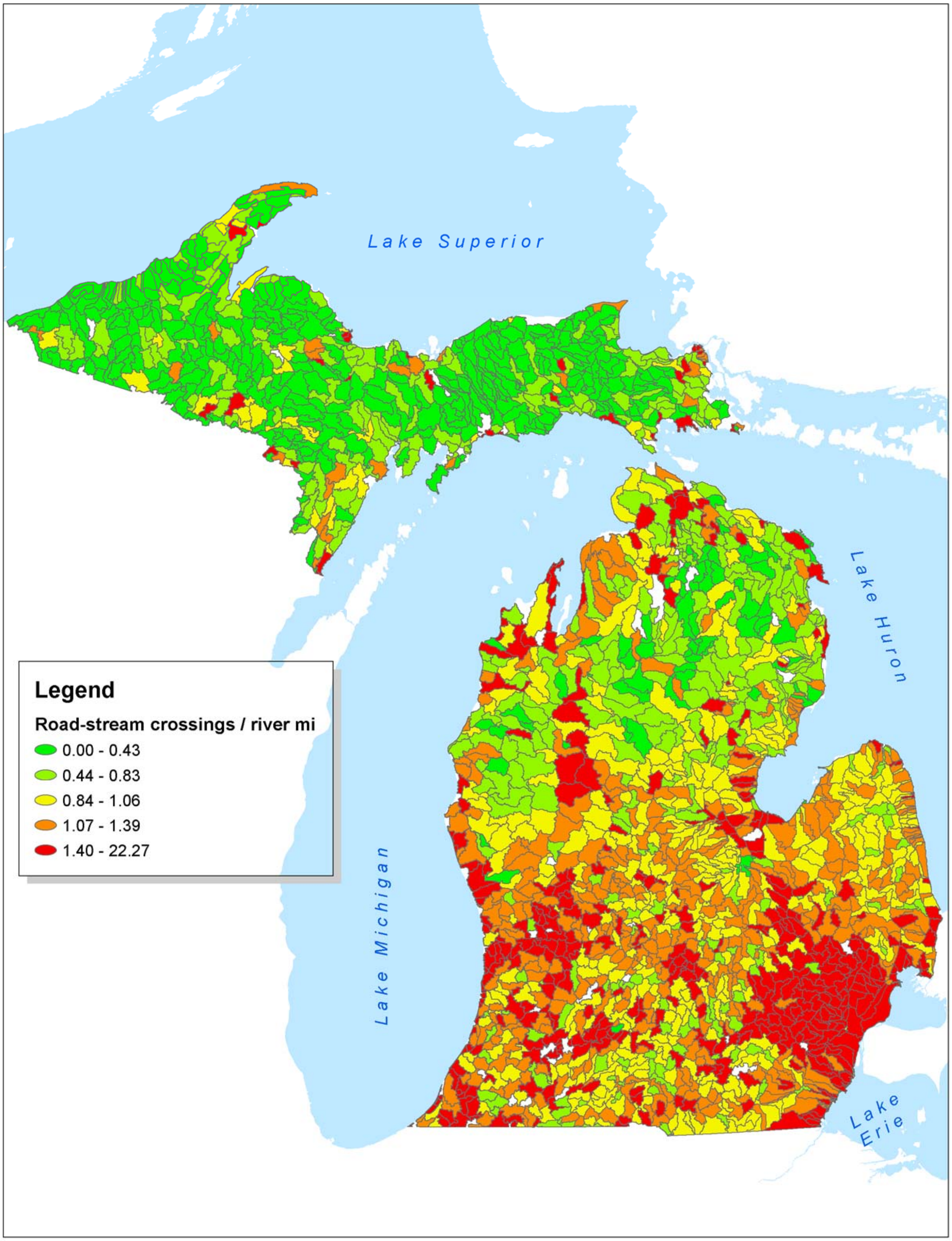


Figure 43. Number of road crossings per river mile in sub-watersheds.

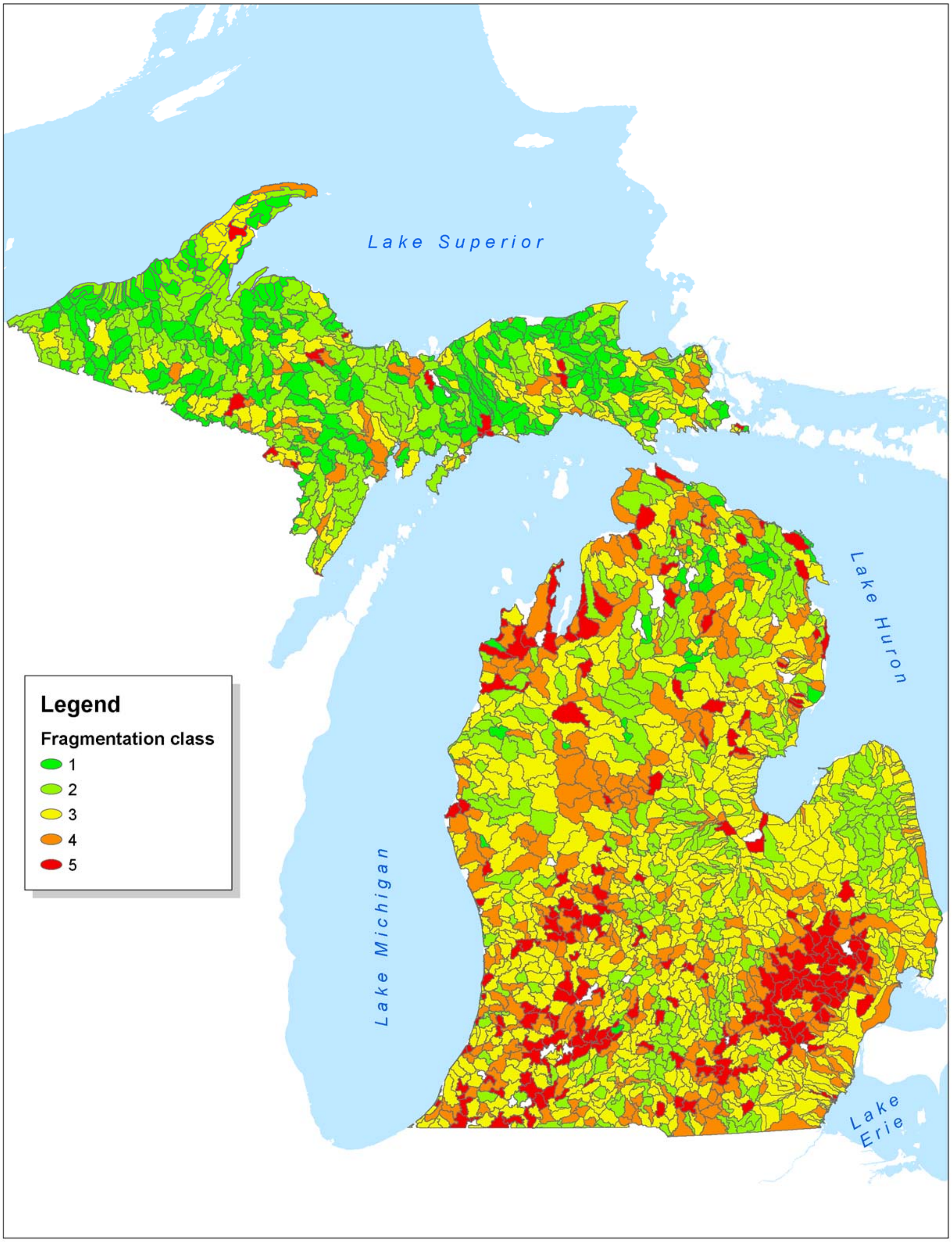


Figure 44. Fragmentation analysis by sub-watersheds.

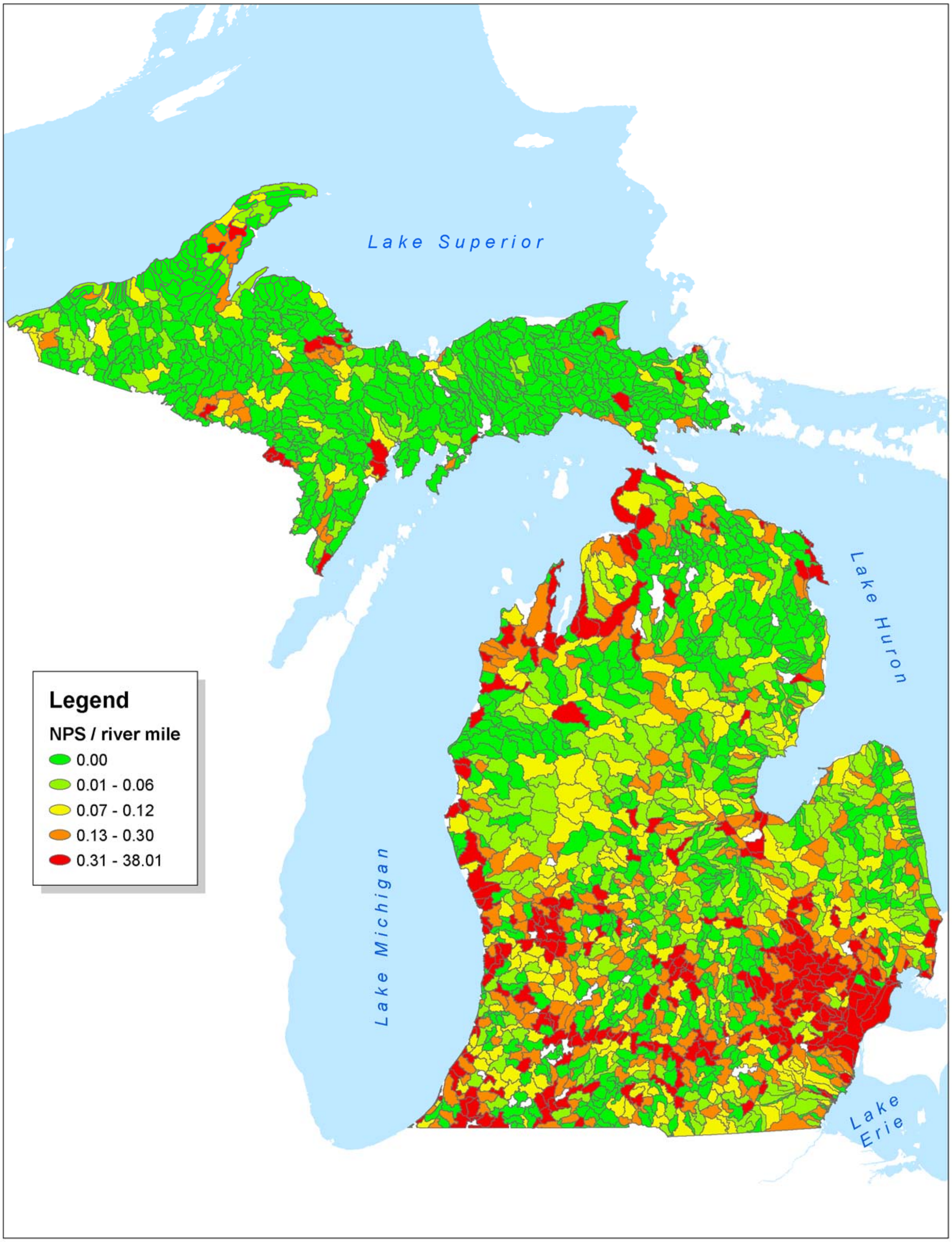


Figure 45. Number of DEQ non-point source pollution permits per river mile in sub-watersheds.

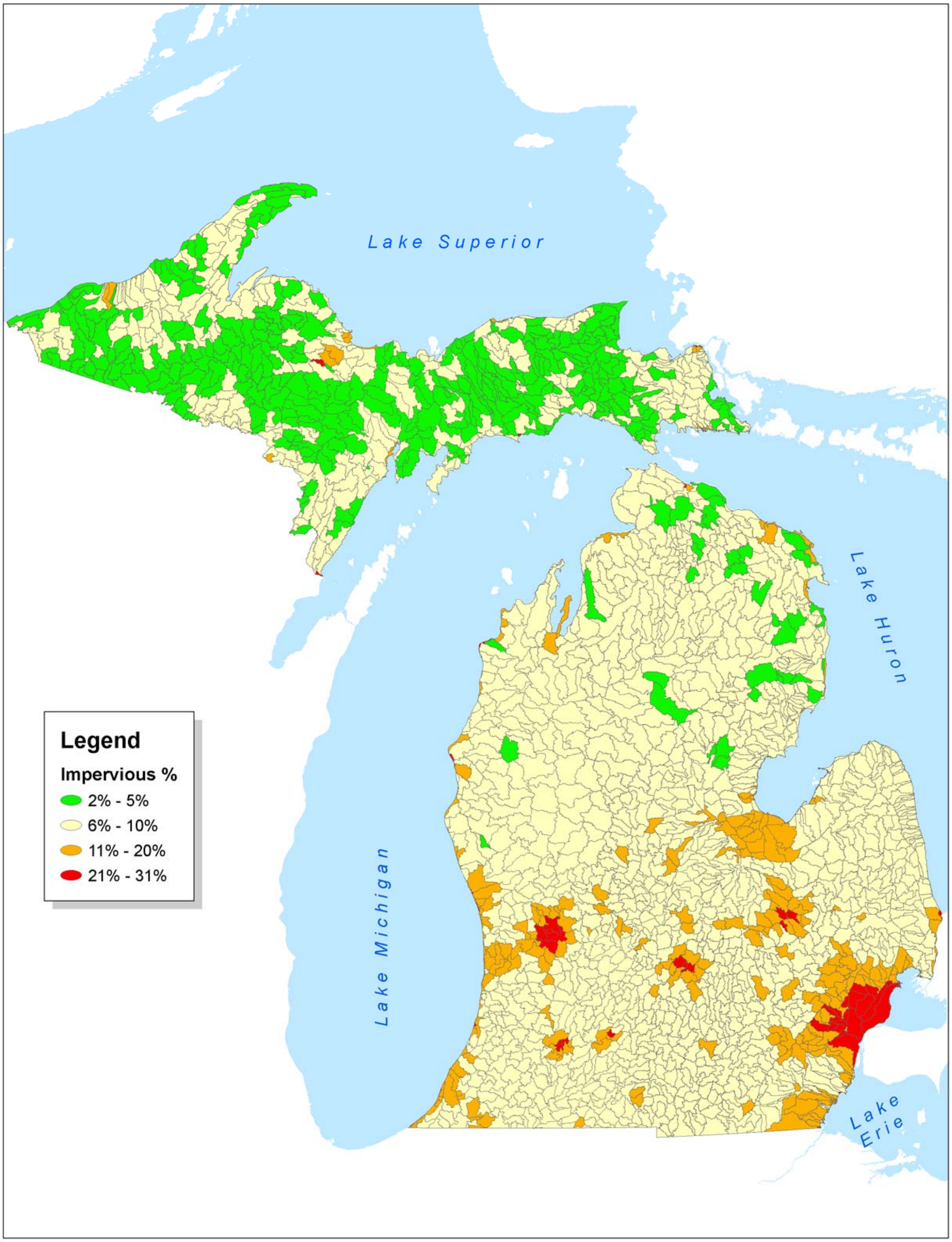


Figure 46. Percent impervious surface in sub-watersheds.

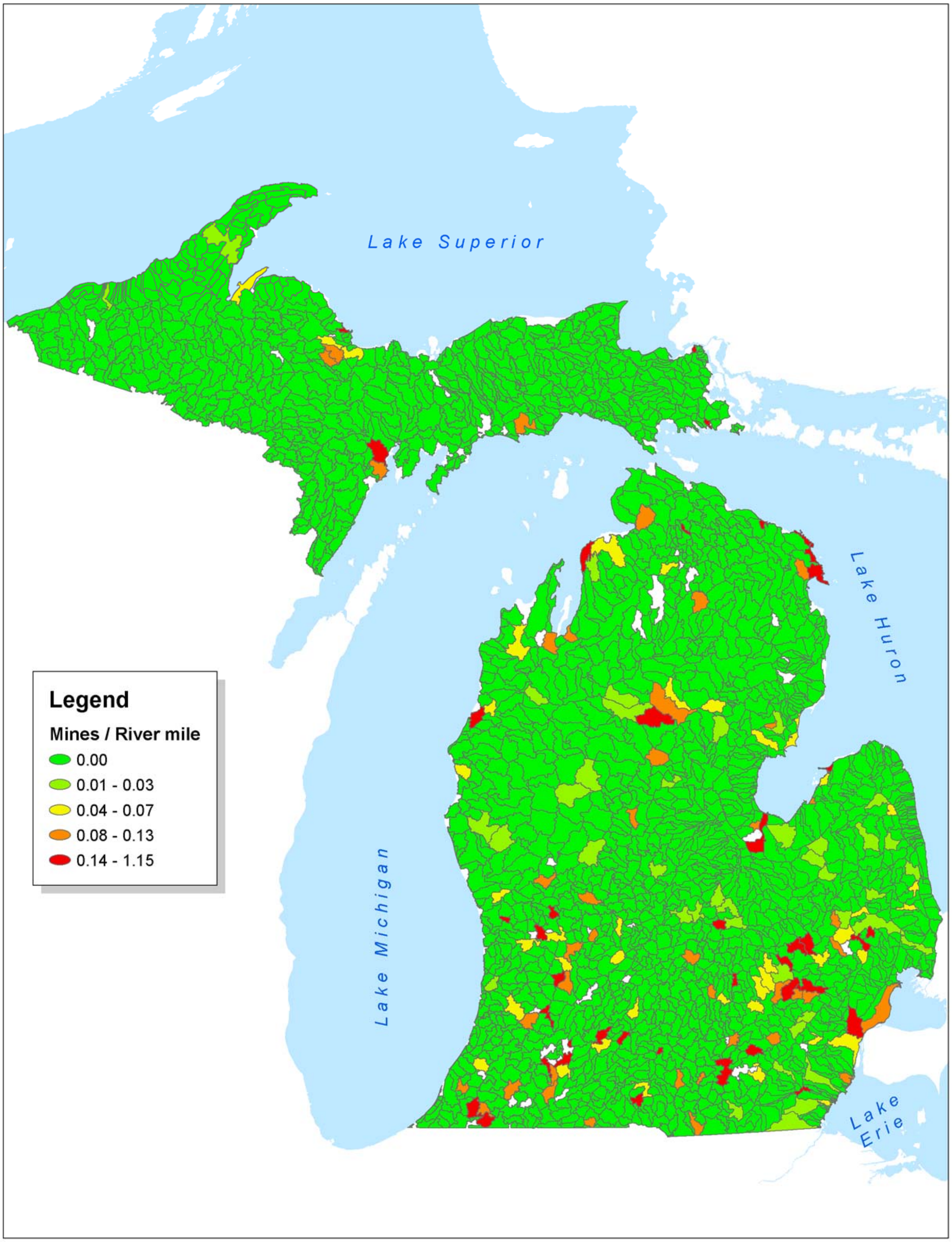


Figure 47. Number of active mines per river mile in sub-watersheds.

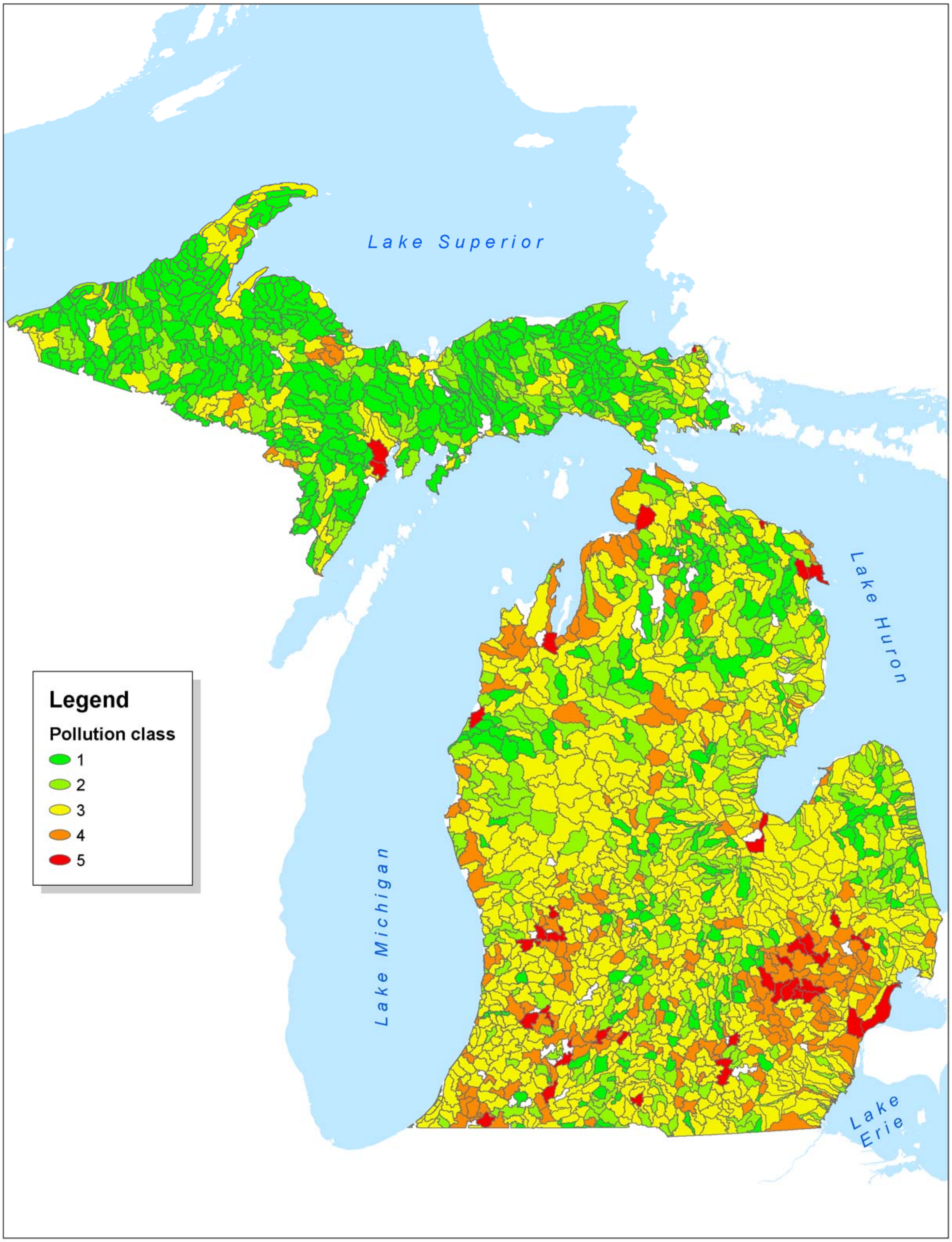


Figure 48. Pollution analysis by sub-watersheds.

Results:
The non-point source pollution (Figure 45) indicator shows a similar pattern as the impervious surface pollution indicator (Figure 46); they closely follow locations of cities or major towns. Active mines (Figure 47) are more limited in area as a pollution threat. The overall pollution analysis (Figure 48) shows that most of the Lower Peninsula of Michigan has moderate to high pollution threats.

Many studies have shown that watersheds with as little as 10 to 20% impervious surfaces are heavily degraded (Paul and Meyer 2001). Yet, for much of Michigan impervious surfaces range between 6 and 10% suggesting that most of Michigan's streams still have the potential for healthy natural processes to exist.

Overall Functional Sub-Watershed Results:

File name:
functional_subwatersheds.shp

As expected, the Upper Peninsula had the most sub-watersheds that were classified as least modified, and the southern Lower Peninsula had the most sub-watersheds classified as most modified (Figure 49). The sub-watersheds with the lowest score within each EDU occurred along the coast or at the border between Michigan and Indiana. This is likely an artifact of the small size of these sub-watersheds and lack of rivers in these areas.

Overall, the Lower Peninsula had very few sub-watersheds that scored a 1 (least-modified). In the Upper Peninsula between 13 and 26% of sub-watersheds scored a 1. When the top two least-modified scores (1 and 2) are combined, greater than 70% of sub-watersheds are in good functioning condition (Table 31). The Northern Lake Michigan, Lake Huron, and Straits of Mackinac (5) EDU had the next group of most functional sub-watersheds. The Saginaw Bay (4) and Southeast Lake Michigan (3) EDUs were ranked fairly similarly with most sub-watersheds having moderate amounts of modification. The Southeast Michigan Interlobate and Lake Plain (16+2) EDU, as expected, contained the most-modified (or least functional) sub-watersheds in the State.

There were 145 sub-watersheds that were classified as highly functional with a score of 1. In the Northern Lake Michigan, Lake Huron, and Straits of Mackinac (5) EDU these sub-watersheds occurred in Black, Cheboygan, Lone Lake – Ocqueoc, Manistee, and Pere Marquete – White watersheds. In the Eastern Upper Peninsula (7) EDU they occurred in the Betsy – Chocolay, Brevoort – Millecoquin, Carp – Pine, Fishdam – Sturgeon, Manistique, St. Marys, Tahquamenon, and Waiska watersheds. In the Central Upper Peninsula (8) EDU they occurred in the Brule, Cedar – Ford, Dead – Kelsey, Escanaba, Menominee, Ontonagon, and Sturgeon watersheds. And in the Western Upper Peninsula and Keweenaw Peninsula (6+12) EDU they occurred in the Black – Presque Isle, Dead – Kelsey, Keweenaw Peninsula, and Ontonagon watersheds. The most functional sub-watersheds, with a score of 2, for the other EDUs are following: In the Saginaw Bay (4) EDU occurred in the Au Gres – Riffle, Flint, Kawkawlin – Pine, Pine, Shiawassee, Tittabawassee, and Upper Grand watersheds. In the Southeast Lake Michigan (3) EDU they occurred in the Black – Macatawa, Kalamazoo, Muskegon, Pine, Shiawassee, St. Joseph, and Upper Grand watersheds. And in the Southeast Michigan Interlobate and Lake Plain (16+2) EDU they occurred in the Flint, Huron, and St. Joseph watersheds.

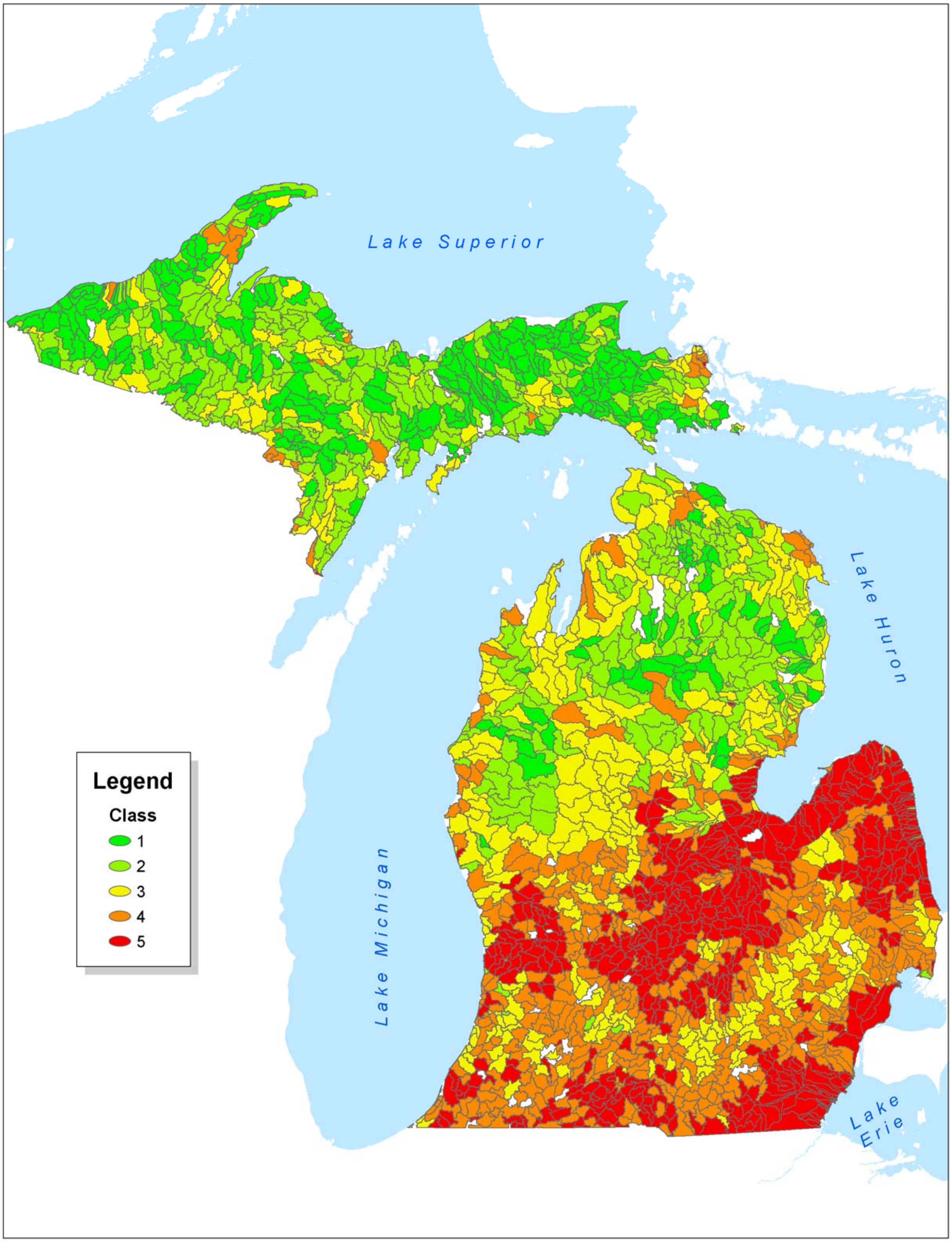


Figure 49. Sub-watersheds in Michigan scored from least-modified to most-modified.

Table 31. Percent of sub-watersheds in each EDU in each score category of the functional analysis. Scores of 1 are the least modified sub-watersheds and scores of 5 are the most modified sub-watersheds.

Score	16+2	3	4	5	7	8	6+12
1	0	0	0	3	**23**	**13**	**26**
2	1	3	5	**37**	**49**	**61**	**58**
3	**32**	**45**	**55**	**44**	25	22	14
4	**58**	**46**	**37**	14	3	4	2
5	10	7	3	2	0	1	0

Fine-Filter: Element Occurrence Data

Description:

The Michigan Natural Features Inventory has been inventorying and tracking Michigan's threatened, endangered, and special concern species and high quality natural communities since 1979. As of September, 2006, MNFI tracked 417 plant species, 248 animal species, and 74 natural community types. In addition to species and natural communities, MNFI also tracks other natural features such as colonial bird nesting colonies and significant geological features. The tracked species include those with Federal and State legal protection and special concern species which have no legal protection. Like the special concern species, natural communities also have no legal protection status. As of September, 2006, The MNFI database contained approximately 14,532 records of these natural features (plants, animals, and natural communities). Data sources include museum and herbarium collections, published reports, MNFI field surveys, and information from cooperators. Database records span a range from historic information to very current information from the latest field season. The data in the MNFI database are based on ground-truthed observations by reliable experts and are continually updated. The MNFI database is the most complete record of Michigan's sensitive species and natural features.

The MNFI database is a Natural Heritage database and utilizes Natural Heritage methodology and data standards originally designed by The Nature Conservancy and now maintained by Natureserve (www.natureserve.org). The MNFI database is more than a presence/absence database. Among other information, it contains dates of sightings, global and state imperilment rankings for species, and a quality (or viability) ranking for individual occurrences. Definitions of the global and state (or sub-national) rankings can be found in appendix A. The quality ranking is an A – D scale with A being the highest quality. Other codes such as E for extant, H for historic, and X for extirpated are also used. The standards for applying a quality rank to an occurrence vary by species and community, but generally fall into three main categories: size, condition, and context.

Approximately 50% of the mussels tracked by MNFI are considered globally critically imperiled (G1), imperiled (G2), or vulnerable (G3). This represents approximately 20% of all native mussels found in Michigan. In addition, 40% of the reptiles and 32% of the insects tracked in the MNFI database have a global rank of G1 – G3 some of which rely on aquatic ecosystems. For a list of aquatic species used in these analyses see Appendix D.

Limitations:

The primary limitations to MNFI's element occurrence database are 1) it contains static information – each element occurrence is updated infrequently, 2) lack of a statewide systematic survey, and 3) in some cases, very old and/or general (non location specific) records. Biological information from the field is collected annually from MNFI staff and other reliable contributors. Once this information is entered into the database, it may be decades before it gets updated. For example, approximately 36 % of the records in the database are over 20 years old. More significantly, there has never been a systematic survey of element occurrences in the state. This means that something can be said about the biological significance of an area containing element occurrence records, however nothing can be said definitively about the biological significance of areas with no known element occurrence records. This is where the quote "absence of evidence is not evidence of absence" comes into play. Related to this, is that there have been small areas of the state that have been systematically surveyed; however they are predominantly owned by public agencies or non-governmental organizations such as The Nature Conservancy.

Fine-Filter: Element Occurrence Data Analysis

EO Frequency Count

Description:
The EO frequency count is a count of all element occurrences that fall within a given public land survey system (PLSS) section. The model utilizes a statewide GIS data layer (Environmental Systems Research Institution (ESRI) shapefile) of the PLSS sections. A numeric count field is added to the section shapefile theme table. Each section shape is selected in turn and intersected with the MNFI GIS database. The number of aquatic occurrences intersecting each section shape is counted and that value is calculated into the count field in the section shapefile theme table. A cutoff date of September 1, 2006 was used to create the EO frequency datasets. All records added to the Michigan Natural Features database after this date are not included in this analysis.

This analysis is based on terrestrial boundaries (1 mile blocks) to allow for this analysis to be easily combined or overlaid with the terrestrial analysis.

Use:
The EO frequency count is a relatively simple representation of the MNFI data. It is designed to show users where there are concentrations of known species or natural community occurrences in the MNFI database. While the EO frequency count provides limited information, it does fulfill its intended purpose. Users can see if there are known occurrences in the vicinity of a proposed project or delineate those areas where there are concentrations of occurrences. All species information is removed so locations of particularly sensitive species cannot be determined from the model.

Limitations:
The primary disadvantage is that it provides very limited information. The user only knows that the known boundary of an occurrence overlaps the boundary of the area of interest. No allowance is made for the age of the record, relative importance of the species, or the extent of potential habitat within the occurrence boundary.

File name:
Aq_EO_trs_0906.shp

Data source:
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:
As the map shows (Figure 50), there are limited concentrations of rare aquatic species across the state. In the Upper Peninsula and the northern Lower Peninsula the high frequency counts are driven by common loon occurrences (Table 32), whereas, in the southern portion of the Lower Peninsula the high concentrations are driven by fully aquatic species, fish and mussels (Figure 51). The areas with the highest frequency counts of aquatic rare species are found in the Lower Grand River watershed, the St. Joseph River of the Maumee, the River Raisin, and the Black River in the St. Clair river watershed. This is not surprising since the Lake Erie basin and portions of the Southeast Lake Michigan (3) EDU have the most diverse aquatic species assemblages due to species range distributions.

Table 32. Frequency of element occurrences (with and without loons) and number of species occurring in EDUs.

	Frequency (all aquatic sp)	Frequency (no Loons)	Species Count
3	384	**376**	30
4	273	222	26
5	**438**	196	25
6+12	157	38	13
7	172	53	10
8	181	53	16
2+16	**524**	**523**	35

EO Likelihood

Description:
The likelihood modeling process consists of grouping species into habitat guilds, creating a habitat layer for each guild, using the habitat layer to redefine the spatial extent of the corresponding occurrences, and intersecting the spatially redefined occurrences with political boundaries such as Public Land Survey System (PLSS) units. Each political unit is then assigned the “highest” likelihood value for all occurrences that fall within it’s boundary.

Aquatic species’ habitat layers were created from either stream lines, the water class in the current land cover layer, or a combination of the two. The habitat layers are then used to redefine the spatial extent of the occurrences. The spatial extent of each occurrence is replaced by the spatial extent of the habitat within.

After the overlay process, each occurrence still retains all database attribute values, including the date of the last observation. A value is assigned based on this field and is used to represent the likelihood that the occurrence still exists. Occurrences with a last observed date of no later than 1982 are assigned a value of one, occurrences between 1970 and 1982 are assigned a value of 0.5, and occurrences prior to 1972 are assigned a value of 0.25.

These likelihood values are then aggregated up to a PLSS data set. First all records in the PLSS data set are selected and assigned a No Status value. Next the records in the occurrence layer with the lowest likelihood of still existing (value = 0.25) are selected. The PLSS data set is intersected with the occurrence layer and the selected PLSS records are assigned a value of “Low”. Next those records with a moderate likelihood of still existing are selected (value = 0.5). The PLSS data set is intersected with the occurrence layer and the selected PLSS records are assigned a value of “Moderate”. Finally

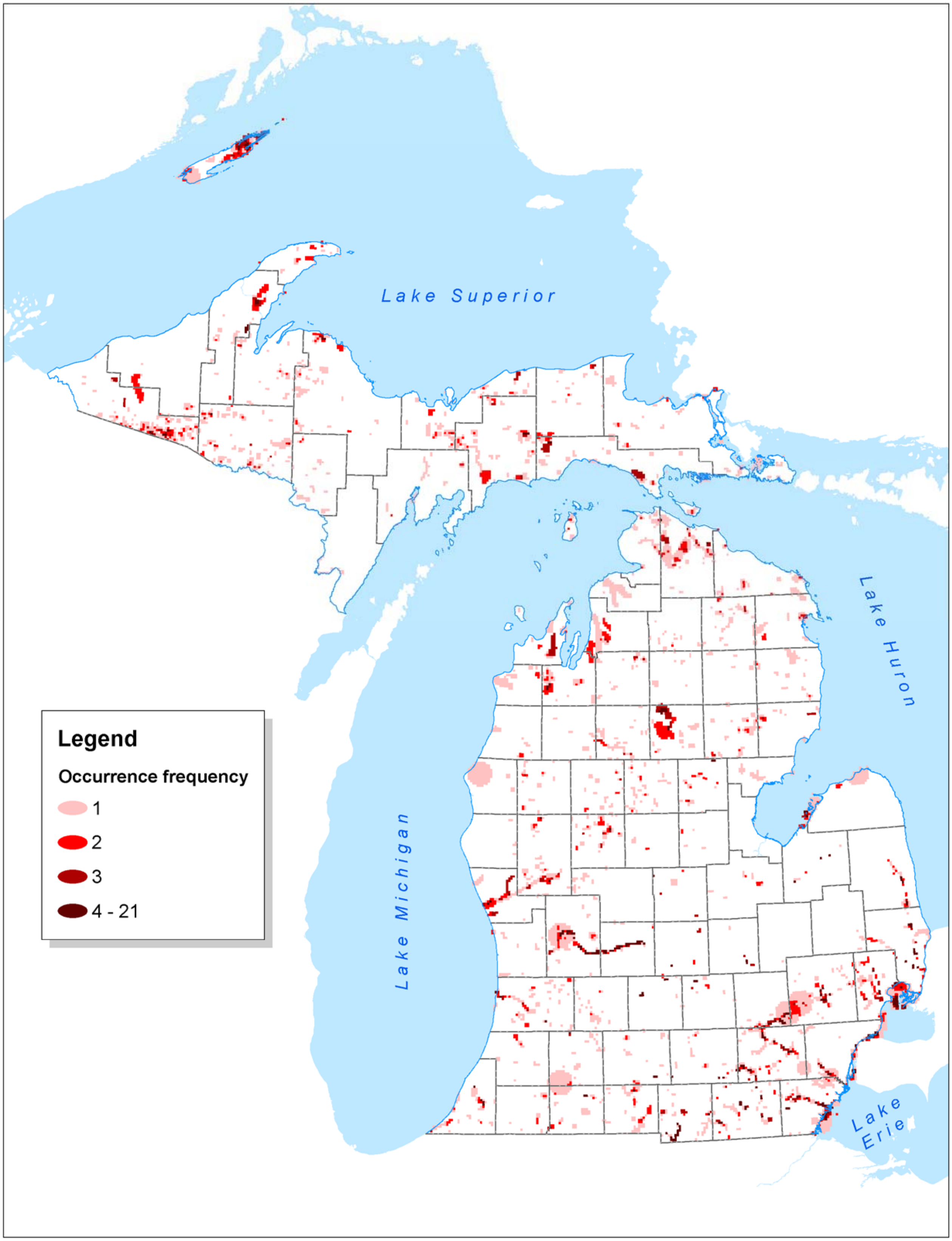


Figure 50. Frequency counts of aquatic element occurrences by PLSS.

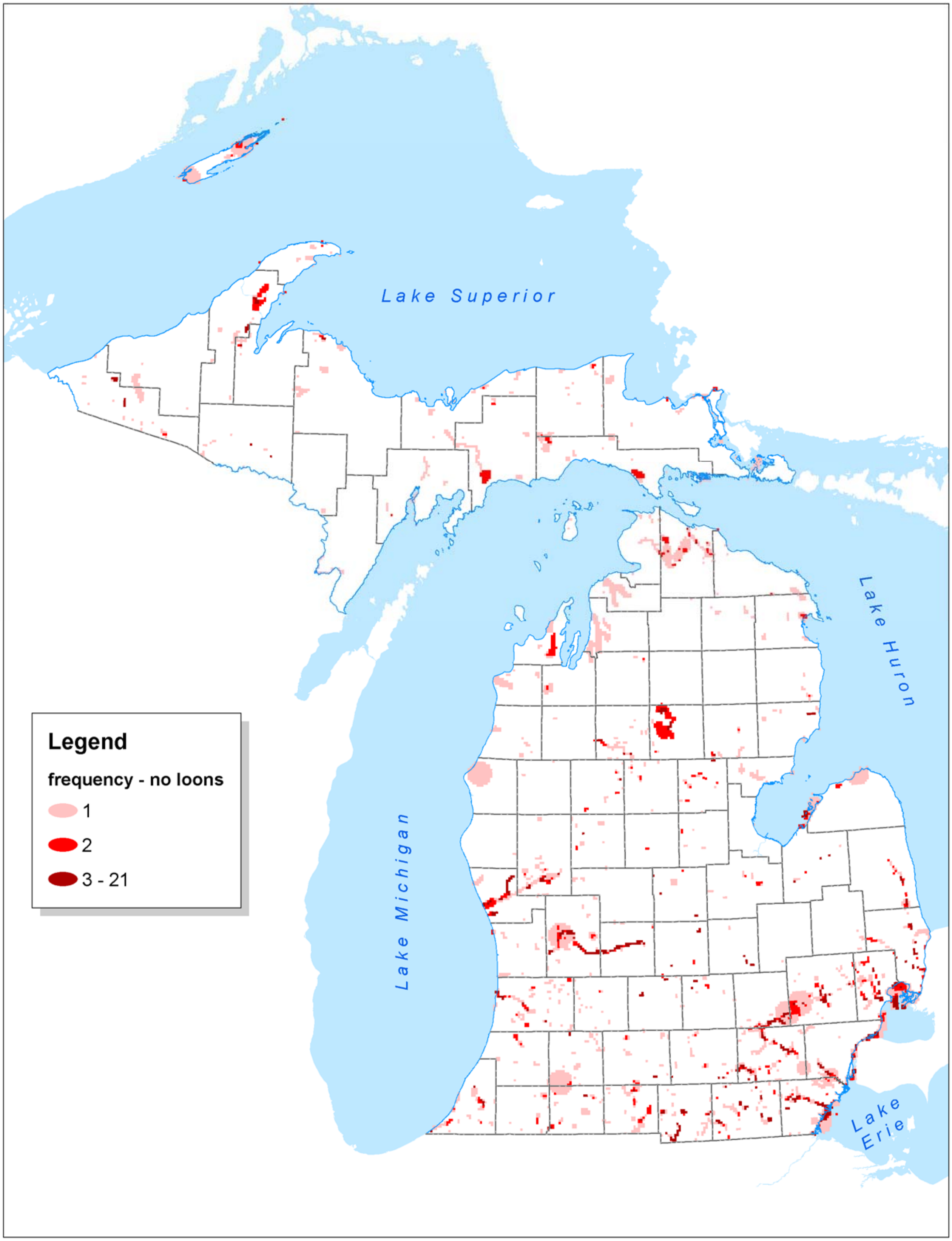


Figure 51. Frequency counts of aquatic element occurrences without loon EOs by PLSS.

the occurrences with the highest likelihood of still existing (value = 1) are selected. The PLSS data set is intersected with the selected occurrence features and the selected PLSS records are assigned a value of "High". Performing the selections and intersections in this order insures that a higher likelihood value in any PLSS feature will override a lower likelihood value.

The element occurrence database for this model was accessed September 1, 2006. Any records added to the Michigan Natural Features database after this date are not included in this analysis. This analysis is aggregated to terrestrial boundaries (1 mile blocks) to allow for merging or overlay with the terrestrial analysis.

This analysis is based on terrestrial boundaries (1 mile blocks) to allow for this analysis to be easily combined or overlaid with the terrestrial analysis.

Use:
The EO likelihood model is designed to help protect biodiversity and minimize potential regulatory problems by directing development away from those areas with a high likelihood of encountering a sensitive species. Because no specific species information is presented, the model reduces the sensitivity of the underlying MNFI data. A high probability indicates that the area of interest contains the spatial extent of an occurrence, there is potential habitat within the area, and the occurrence has been observed in the recent past. A low probability indicates that the area contains the spatial extent of an historic species occurrence and there is potential habitat within the area. While the low likelihood indicates that the underlying occurrences are historic, there is still a possibility that the species persists in appropriate habitat. In the recent past, MNFI botanists have reconfirmed three 100 year old plant records. A moderate likelihood indicates, by default, something between the other two values.

The EO likelihood model provides users with a higher level of information than the simple EO frequency count. Unlike the EO frequency count, which only implies that the extent of an occurrence lies within an area of interest, the EO likelihood model delineates those areas where there is a higher likelihood of encountering a sensitive species or natural community. Also, by utilizing potential habitat within the known extent of the occurrences, areas without potential habitat are eliminated from consideration.

The EO likelihood model can be used in the context of both land use planning efforts and conservation planning efforts. By delineating areas with high likelihood of encountering sensitive species or natural communities, the model can be used to direct development away from those areas, or to identify areas worthy of conservation efforts.

Limitations:
One shortcoming of the EO likelihood model is that all high likelihood areas are treated the same. Whether there is one recent occurrence in the area or thirty recent occurrences, the same high likelihood value is assigned to the area. There is also no allowance for the relative imperilment of the species found in any unit of interest, and there is no numeric value assigned to any of the units of interest that allow them to be compared to each other.

File name:
Aq_EO_trs_0906.shp

Data source:
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:
The results of this analysis did not provide significant additional information than the EO frequency count for the aquatic species (Figure 52). This is due to two main issues. The first is the coarseness of the available aquatic habitat data used. The habitat information was taken from IFMAP, and there is only one category for aquatic habitats (water body), whereas the terrestrial habitat was able to be broken up into more categories and hence provide more information. Second, many of the aquatic EOs are relatively old records. Little work has been conducted over the last 10 years on rare fish, macroinvertebrates, and macrophytes.

Bio-rarity Score

Description:
In addition to the EO likelihood value described above, each element occurrence is also assigned three other values, one based on the species global status, one based on the species state status, and one based on the occurrence viability rank. The greater the threat of imperilment to the species, the higher the value assigned to the occurrence. In a similar manner, the higher the quality or viability of each occurrence, the higher the value assigned to it. The biodiversity value of each occurrence is then calculated by adding the values for the global status, state status, and the quality ranking, then multiplying the sum by the EO likelihood value described above. To calculate the biodiversity value of a given PLSS feature, each feature in the PLSS theme is selected in sequence. Next, all the species occurrences intersecting the PLSS feature are selected. Then the biodiversity values of the selected species occurrences are summed and assigned to the PLSS feature. The result is a value for each PLSS unit that is the sum of the biodiversity values of all occurrences falling within the PLSS unit. A cutoff date of September 1, 2006 was used to create the bio-rarity datasets. All records added to the Michigan Natural Features database after this date are not included in this analysis.

This analysis is based on terrestrial boundaries (1 mile blocks) to allow for this analysis to be easily combined or overlaid with the terrestrial analysis.

Use:
Unlike the EO likelihood model, the bio-rarity score allows similar areas to be compared to each other to determine their relative contributions to biodiversity. Because resources for conservation are generally limited, the bio-rarity score can help direct limited resources to those areas where the resources will have the greatest conservation impact.

Limitations:
As with other element occurrence based information, this data layer is limited by: 1) static information, which is updated infrequently, 2) incomplete data, and 3) old and/or general (non location specific) records.

File name:
Aq_EO_trs_0906.shp

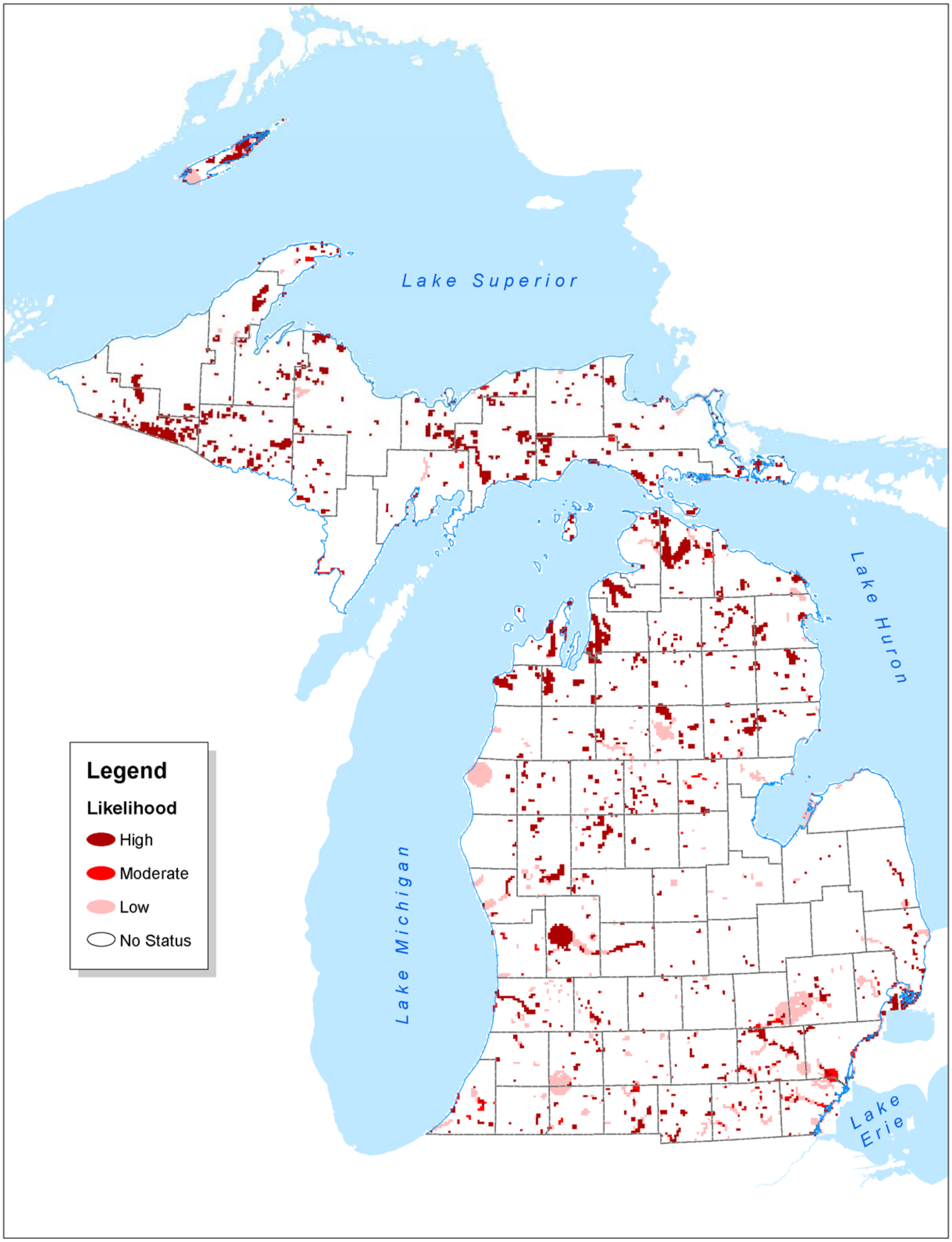


Figure 52. Aquatic element occurrence likelihood map by PLSS.

Figure 53. Aquatic element occurrence biological rarity by PLSS.

Data source:
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:
This analysis did provide some additional information to the EO frequency analysis (Figure 53), but it is likely less informative than the terrestrial analysis. More individual or small clumps of PLSS units are highlighted as important likely due to the status of the EO (S and G rank). This analysis is not as informative because of the limitations with the EO likelihood analysis and the EO rank. For most aquatic species the EO rank is simply extant. We do not have enough information for most aquatic EOs to determine viability of occurrences.

Rare Species Richness

Description:
This analysis counts the number of rare (state-listed and special concern) aquatic plant and animal species that fall within a given sub-watershed. The model utilizes a statewide GIS data layer (Environmental Systems Research Institution (ESRI) shapefile) of sub-watersheds and normalizes the data by river miles (Table 33). River miles are used because the majority of aquatic rare species use riverine habitats. One hundred twenty-five sub-watersheds did not contain a river, based on the NHD hydrology layer. An additional 19 sub-watersheds contained less than 0.1 miles of river, probably due to the inherent geometric inaccuracy of the spatial data layers (Table 34). These 146 sub-watersheds were removed from the analysis. A numeric count field was added to the sub-watershed shapefile theme table and the total number of species based on the MNFI Biotics database was determined. The count was then divided by sub-watershed river miles and then placed in categories based on quartiles.

Use:
Species richness is another relatively simple representation of the MNFI data. It is designed to show users where there are known rare species rich areas. While the species richness analysis provides limited information, it does fulfill its intended purpose.

Limitations:
As with the other element occurrence based information, this data layer is limited by: 1) static information, which is updated infrequently, 2) incomplete data, and 3) old and/or general (non location specific) records.

File name:
aq_EO_richness_subwatershed.shp

Data sources:
Institute for Fisheries Research, Michigan Department of Natural Resources.
mi_epastar_nhd_stresref.shp
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:
The results of this analysis generally follow the EO frequency count analysis (Figure 54). Listed-species richness ranged from 0 to 13 species per sub-watershed. Only four sub-watersheds, three within the River Raisin watershed and one draining directly to Lake St. Clair, had 10 or more listed-species. Thirty-four sub-watersheds had greater than 5 listed-species; these occurred in the Dead (1

sub-watershed), Muskegon (2), Lower Grand (2), St. Joseph (2), St. Joseph of the Maumee (2), Tiffin (1), Raisin (10), Huron (8), Lake St. Clair (4), and Clinton (2) watersheds. When the data was standardize the results are slightly altered. The number of listed-species per river mile ranged from 0 to 6.5. Thirteen sub-watersheds had greater than 2 listed-species per river mile, including: 2 sub-watersheds in the Huron watershed with 6.5 and 2.9 listed-species per river mile, four sub-watersheds in the St. Joseph watershed with between 4.4 and 5.6 listed-species per river mile, two sub-watersheds in the Upper Grand watershed with 4.07 listed-species per river mile in each, and one sub-watershed in the Huron, Lower Grand, Betsie-Platte, Black, Ottawa-Stony, and Manistique watersheds with 2.9, 2.7, 2.5, 2.4, 5.7, and 2.1 listed-species per river mile, respectively. The Southeast Michigan Interlobate and Lake Plain (16+2) EDU had the greatest aquatic species richness and the Saginaw Bay (4) EDU had the least (Table 35).

Table 33. Summary statistics on river miles per sub-watershed.

Count	2,319
Minimum	0
Maximum	331.55
Mean	19.93
Std Deviation	19.05

Table 34. Summary statistics of 19 sub-watersheds that had <0.1 mi of river.

Minimum	0
Maximum	6.5
Mean	0.08
Median	0
Standard Deviation	0.33

Table 35. Species richness per river mile by EDU.

EDU	Richness/river mi (x1000)
3	3.287
4	1.986
5	3.371
6+12	3.754
7	3.296
8	3.51
16+2	7.53

Species of Greatest Conservation Need Richness

Description:

This analysis counts the number of aquatic animal species of greatest conservation need (SGCN), as listed in Michigan's Wildlife Action Plan (Eagle et al. 2005), that fall within a given sub-watershed. The model utilizes a statewide GIS data layer (Environmental Systems Research Institution (ESRI) shapefile) of sub-watersheds and normalizes the data by river miles. River miles are used because the majority of aquatic rare species use riverine habitats. A numeric count field is added to the sub-watershed shapefile theme table. Each sub-watershed shape is selected in turn and intersected with the available SGCN GIS data. Species richness intersecting each sub-watershed shape is counted and that value is calculated into the count field in the sub-watershed shapefile theme table and then placed in categories based on quantiles.

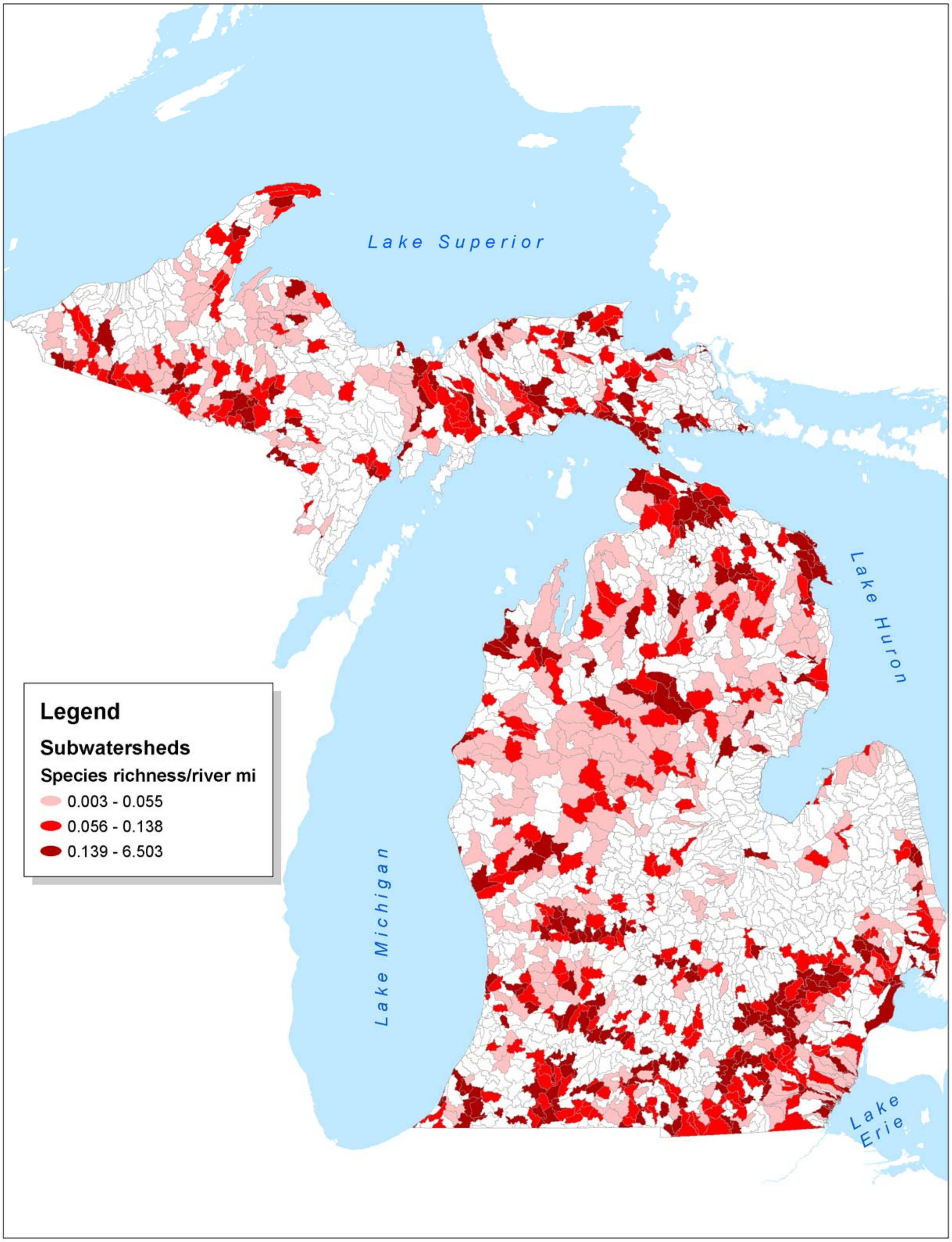


Figure 54. Aquatic rare species richness per river mile in sub-watersheds. Categories are based on quantiles.

In addition to the state-listed aquatic animal species, the following SGCN have available point location data:

> Mussels: pimpleback (*Quadrula pustulosa*), cylindrical papershell (*Anodontoides ferussacianus*), creek heelsplitter (*Lasmignona compressa*), black sandshell (*Ligumia recta*), threehorn wartyback (*Obliquaria reflexa*), and kidneyshell (*Ptychobranchus fasciolaris*).
>
> Amphibians (fully aquatic only): mudpuppy (*Necturus maculosus maculosus*) and western lesser siren (*Siren intermedia nettingi*).
>
> Fish (all SGCN fish have available point location data): brassy minnow (*Hybognathus hankinsoni*), striped shiner (*Luxilus chrysocephalus*), silver chub (*Macrhybopsis storeriana*), river chub (*Nocomis micropogon*), finescale dace (*Phoxinus neogaeus*), lake chubsucker (*Erimyzon sucetta*), spotted sucker (*Minytrema melanops*), black redhorse (*Moxostoma duquesnei*), golden redhorse (*Moxostoma erythrurum*), brown bullhead (*Ameiurus nebulosus*), stonecat (*Noturus flavus*), tadpole madtom (*Noturus gyrinus*), grass pickerel (*Esox americanus*), pirate perch (*Aphredoderus sayanus*), slimy sculpin (*Cottus cognatus*), fantail darter (*Etheostoma flabellare*), and least darter (*Etheostoma microperca*).

Use:
The species of greatest conservation need richness count is another relatively simple representation of known areas important to species biodiversity. While the species richness count provides limited information, it does fulfill its intended purpose.

Limitations:
As with the other species based information, this data layer is limited by: 1) static information, which is updated infrequently and 2) incomplete data because field sampling is limited, especially for particular species.

File name:
aq_SGCN_richness_subwatershed.shp

Data sources:
Institute for Fisheries Research, Michigan Department of Natural Resources
mi_epastar_nhd_stresref.shp

The Nature Conservancy – Great Lakes Program, Higgins et al. 1998
milakes_w_attributes.shp

Digital Water Atlas v1, Fish Atlas 03, Institute for Fisheries Research, MI DNR Fisheries Division
Mussel data from University of Michigan Museum of Zoology, created September 27, 2007
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Results:
This analysis highlighted different sub-watersheds (Figure 55) than the previous analysis. Thirteen sub-watersheds had greater than 15 SGCN located within their borders: 6 sub-watersheds were in the River Raisin watershed, 4 were in the Huron watershed, 2 in the Muskegon watershed, and 1 in the Clinton watershed. Fifty-three sub-watersheds had greater than 10 SGCN within their borders and 1,137 sub-watersheds had no aquatic SGCN reported. However, once the data was standardized by river miles the location of “hot spots” changed. Six sub-watersheds had greater than 5 SGCN per river mile including: 1 sub-watershed in the St. Joseph watershed (Lake Michigan Basin) with 26.6 SGCN per river mile, 2 sub-watersheds in the Huron watershed with 8.7 and 7 SGCN per river mile, one sub-watershed in the Upper Grand watershed with 5.4 SGCN per river mile, and one sub-watershed in the Ottawa-Stony and the Betsie-Platte watershed, with 17 and 9.8 SGCN per river mile, respectively.

There were 2,617 sub-watersheds with less than 1 SGCN per river mile. The sub-watersheds with high SGCN richness did not always coincide with high listed-species richness due to the plant species that were included in the listed-species list but not in the SGCN list. The Southeast Lake Michigan (3) and the Southeast Michigan Interlobate and Lake Plain (16+2) were the richest EDUs for SGCN. Whereas, the Saginaw Bay (4) and the Western Upper Peninsula and Keweenaw Peninsula (6+12) were the least rich EDUs (Table 36).

Table 36. Average species of greatest conservation need (SGCN) richness per river mile by EDU.

EDU	Average SGCN richness per river mile
3	0.29
4	0.06
5	0.18
6+12	0.06
7	0.14
8	0.08
16+2	0.44

Best Two Occurrences of Each Element by Watershed

Description:
The two highest ranking occurrences of each rare aquatic species tracked by MNFI were identified for each watershed and, when possible, at least 10 occurrences across the state were represented. There are a total of 19 aquatic plants (appendix C) and 74 animals (appendix D) currently tracked by MNFI. For this analysis, aquatic plants were strictly defined as plants that are floating or submerged. The ranking of occurrences used viability ranking in EO data, year EO was last observed, and landscape context. Again, there is often little available data to provide an accurate viability ranking, since most animal EOs received an extant ranking. Thus, the other two ranking factors were more important. The most recent EOs are ranked higher. Landscape context for river EOs was accessed using the analysis conducted by Wang et al. (2006), which classifies river reaches across a disturbance gradient (reference to disturbed). Landscape context for lakes was determined by analyzing land use and road density within a 500m buffer around the lakes. Land use is known to affect the quality of aquatic ecosystems and species (Allen 2004). We added road density as part of our landscape context analysis because we felt true land use may be masked in the IFMAP data because often natural vegetation buffers surround lakes, even if housing density is high since many roads are not at a scale that is detectable on Landsat satellite imagery. For those cases where EO viability, last observed date, and landscape quality was a tie, all occurrences were included.

Use:
In some cases, important element occurrences may be located outside areas deemed significant due to other natural assets such as size, intactness, connectivity, and quality. Identifying areas with high quality EOs regardless of landscape context can be important for ensuring adequate biological representation, and in turn protecting potential genetic variability.

Limitations:
As with the other element occurrence based information, this data layer is limited by: 1) static information, which is updated infrequently, 2) incomplete data, and 3) old and/or general (non location specific) records.

File name:
best2_aq_watershed_0906.shp

Data sources:
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Institute for Fisheries Research, Michigan Department of Natural Resources
mi_epastar_nhd_stresref.shp

The Nature Conservancy – Great Lakes Program, Higgins et al. 1998
milakes_w_attributes.shp

Results:
A total of 977 EOs were selected to represent the best 2 aquatic EOs within each watershed. The majority of EOs selected for riverine plants occurred in the Erie Basin and the northern tip of the Lower Peninsula, while the majority of EOs selected for lake plants occurred in the western Lower Peninsula and the Upper Peninsula (Figure 56). For riverine fish, the majority of EOs selected were located in the southern lower peninsula, and for lake fish the majority of EOs selected occurred throughout the state. Invertebrate EOs selected, including mussels, were mainly located in the Lower Peninsula. The Raisin, St. Joseph (Lake Michigan Basin), and Huron watersheds had the most EOs selected, partly due to species distributions and sampling effort.

Discussion

The methodology outlined here provides a key first step in assessing Michigan's aquatic biodiversity statewide. However due to the nature of the data used in this assessment, we can only point to areas with *potential* importance to Michigan's biodiversity. There has been no comprehensive statewide systematic survey to identify locations or habitat types for rare species in Michigan. Currently, we can only provide information based on available known data which has been inconsistently collected. This is not sufficient for understanding what these species need and how best to manage and protect them. As classification frameworks for aquatic habitats become available and finalized in Michigan, we will be able to design systematic surveys to search for rare aquatic species as well as unique ecosystems. This next step will allow us to begin truly quantifying Michigan's aquatic biodiversity.

As stated previously, the methodology developed for this project is a good first step. However, due to the nature of the project and available funding we were unable to conduct a detailed field-expert review. We view this as a critical next step to a robust statewide assessment. Due to the coarseness of some of the data and the emphasis on modeling, we need to begin scrutinizing the results to ensure that we are targeting what is important to Michigan's biodiversity (species and ecosystems). We also need to ensure that we do not miss key components of Michigan's biodiversity. In the future we hope to bring together a variety of experts to begin reviewing the results of this project.

Additionally, we want to tie this work with other aquatic efforts in the state and continue to develop a more robust statewide assessment of biodiversity. As aquatic habitat classifications become more refined in Michigan, we would like to update our analyses to ensure they provide the most current state of knowledge. We also want to look at this work in the context of The Nature Conservancy's conservation priority areas and the Wildlife Divisions (DNR) protected lands. The Great Lakes GAP analysis, when completed, will provide more detailed information on important habitats to the diversity of fish in Michigan and will provide information about important Great Lakes' habitats. Additionally, there are some datasets that we were unable to incorporate but would like to in the future, such as riparian ecosystems of the Lower Peninsula of Michigan (Baker) and Great Lakes ecosystems (in progress – Rutherford and Geddes, Aquatic GAP). By assessing this work in the context of how it fits in with other efforts in the state and a field-based expert review, we will be able to develop a more accurate assessment of Michigan's aquatic biodiversity.

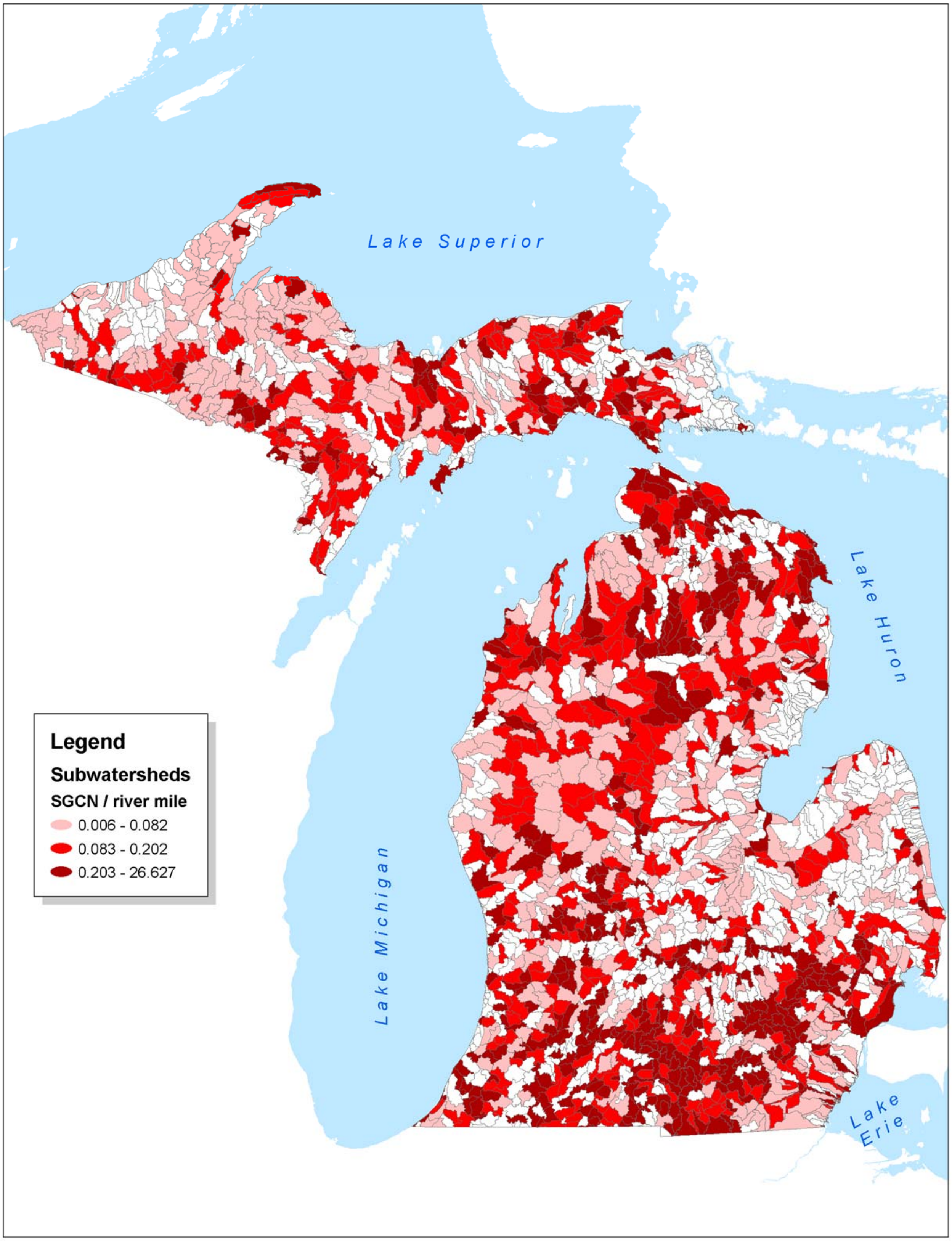


Figure 55. Aquatic species of greatest conservation need richness. Categories are based on quantiles.

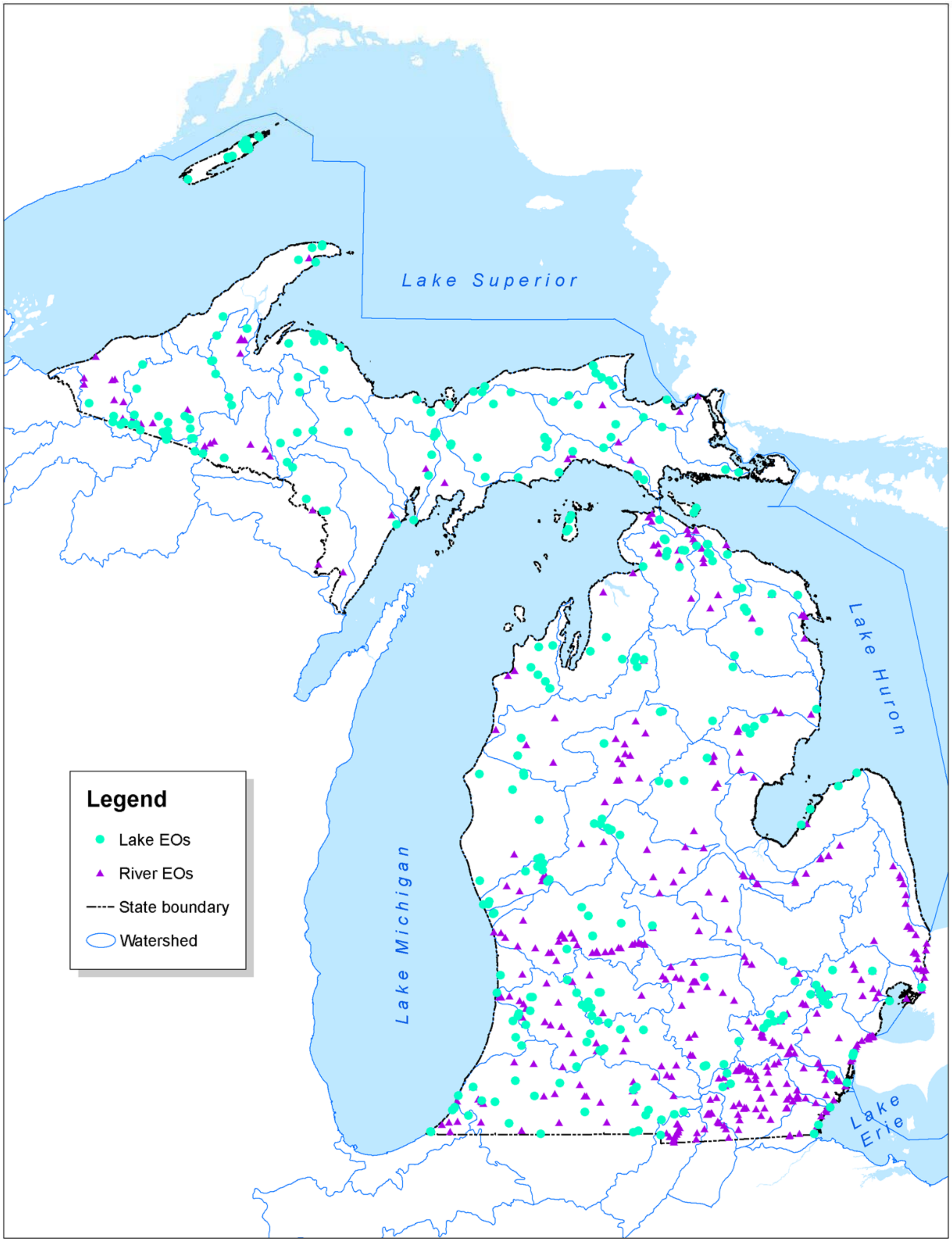


Figure 56. Locations of the best occurrences for each element by watershed.

Looking for Patterns: Integrating the Data Layers Together

Introduction

As stated earlier in the report, it was decided that the best way to address the various needs of potential end users was to develop a series of data layers that could be used individually or in combination with each other. The previous two chapters addressed the different data layers that were developed for both terrestrial and aquatic biodiversity; however, we haven't addressed how these data layers may be combined to identify important biodiversity areas based on several variables. From the authors' perspective, there are two major methods to combining the data layers; merging and prioritizing.

Merging is when several data layers containing different datasets are combined together to form an aggregate, and all areas identified are given the same priority. Areas where there is overlap between two or more data layers are not given a higher priority over an area with just one data layer. Data layers that seemed important to incorporate into the identification of core terrestrial biodiversity areas included: 1) bio-rarity hotspots, 2) natural vegetation core areas, 3) high quality natural communities, and 4) potentially unchanged natural vegetation core areas (Table 37).

Table 37. Important terrestrial biodiversity area data layers.

Data Layer	Description
Bio-rarity Hotspots	Only terrestrial species tracked in MNFI database; only top 10% of scores
Natural Vegetation Core Areas	All natural vegetation patches that meet a minimum size threshold determined by ecoregion, split by major roads and buffered 210 meters from roads and non-natural land cover
High Quality Natural Communities	All natural communities with an EO rank of A-B/C
Potentially unchanged natural vegetation core areas - by ecoregion	All potentially unchanged natural vegetation patches that meet a minimum size threshold determined by ecoregion; split by major roads; no buffer.

Prioritizing involves the same steps as merging. The difference is that areas which overlap are given a higher priority. The assumption is that areas containing several components of biodiversity have a higher value than areas that only contain one, and therefore are more valuable. Another way to view this is from an economic perspective. If two areas of approximately the same size contain different values, it makes sense to apply limited resources to the area with more value. Data layers incorporated into the identification of prioritized core terrestrial biodiversity areas included: 1) bio-rarity hotspots, 2) natural vegetation core areas, 3) high quality natural communities, and 4) potentially unchanged natural vegetation core areas. The resulting data layer is displayed as pixels with a score ranging from 0 (no data layers) to 4 (all four data layers) (Table 38). Note that a score of 3 or 4 requires the occurrence of a high quality natural community and/or high biorarity score. Both of these data layers are based on field observations that are biased towards certain species and natural communties, as well as certain areas of the state. One way to interpret this analysis is that: 1) all areas receiving a score of one or greater are important, 2) areas recieving a score of three or four may be the best places to focus on initially, and 3) a score of zero does not mean an area is unimportant to biodiversity conservation (could be due to lack of survey effort).

Table 38. Prioritized terrestrial biodiversity area descriptions.

Data Layers	Score	Existing Data type	Converted to:
Bio-rarity Hotspots	1	Grid	30m^2 pixel
Natural Vegetation Core Areas	1	30m^2 pixel	30m^2 pixel
High Quality Natural Communities	1	polygon	30m^2 pixel
Potentially Unchanged Natural Vegetation Core Areas – by ecoregion	1	30m^2 pixel	30m^2 pixel

In addition to the prioritized biodiversity areas, since many of these areas are small and/or isolated, it seemed important to incorporate those lands that may support these core biodiversity areas. This is called the supporting natural landscape, a term borrowed from the Massachusetts BioMap project. The supporting natural landscape was defined as all natural vegetation patches with no roads and no buffer that intersected with a core biodiversity area.

We also provided one example of prioritized core aquatic biodiversity areas in the state. We incorporated the two best classes of the functional sub-watersheds with the best two classes of the SGCN richness data layer. The resulting data layer displays sub-watersheds where the two data layers overlap (Figure 58).

Terrestrial Results:
A total of 12,609,097 acres fell into one of four categories of prioritized terrestrial biodiversity areas in the state. Using the criteria described above, these areas combined to represent approximately 35% of the total area of the state (not including inland water) (Table 39). Although the majority of these areas were located in the UP and NLP, the highest priority areas with scores of 3 and 4 were distributed across the state (Figure 57). High priority areas in the UP included: 1) Seney National Wildlife Refuge, 2) Grand Island National Recreation Area, 3) area just north of St. Ignace, 4) Lake Michigan shoreline in western Mackinac County and eastern Schoolcraft County, 5) Tahquamenon State Park, 6) Porcupine Mountains Wilderness State Park, 7) northern Marquette County, and 8) the north portion of the Keweenaw Peninsula. High priority areas in the NLP included: 1) Wilderness State Park, 2) Thompson's Harbor State Park, 3) eastern portion of Thunder Bay – east of Alpena, 4) large portions of the Au Sable watershed, 5) southeast Newaygo County, and 6) the Blue Lakes region of Oceana and Muskegon Counties. High priority areas in the SLP included: 1) Allegan State Game Area, 2) Fort Custer Recreation Area, 3) Pinckney-Waterloo Recreation Areas, and 4) St. Clair Flats.

Table 39. Summary of prioritized terrestrial biodiversity area scores.

Score	Total area in acres	% of State (not including water)
1	9,045,789	24.90%
2	3,371,944	9.28%
3	184,995	0.51%
4	6,369	0.02%
Total	12,609,097	34.71%

Aquatic Results:
A total of 78 sub-watersheds were selected as relatively functional and important to species of greatest conservation need. The selected sub-watersheds occurred in all EDUs but were most

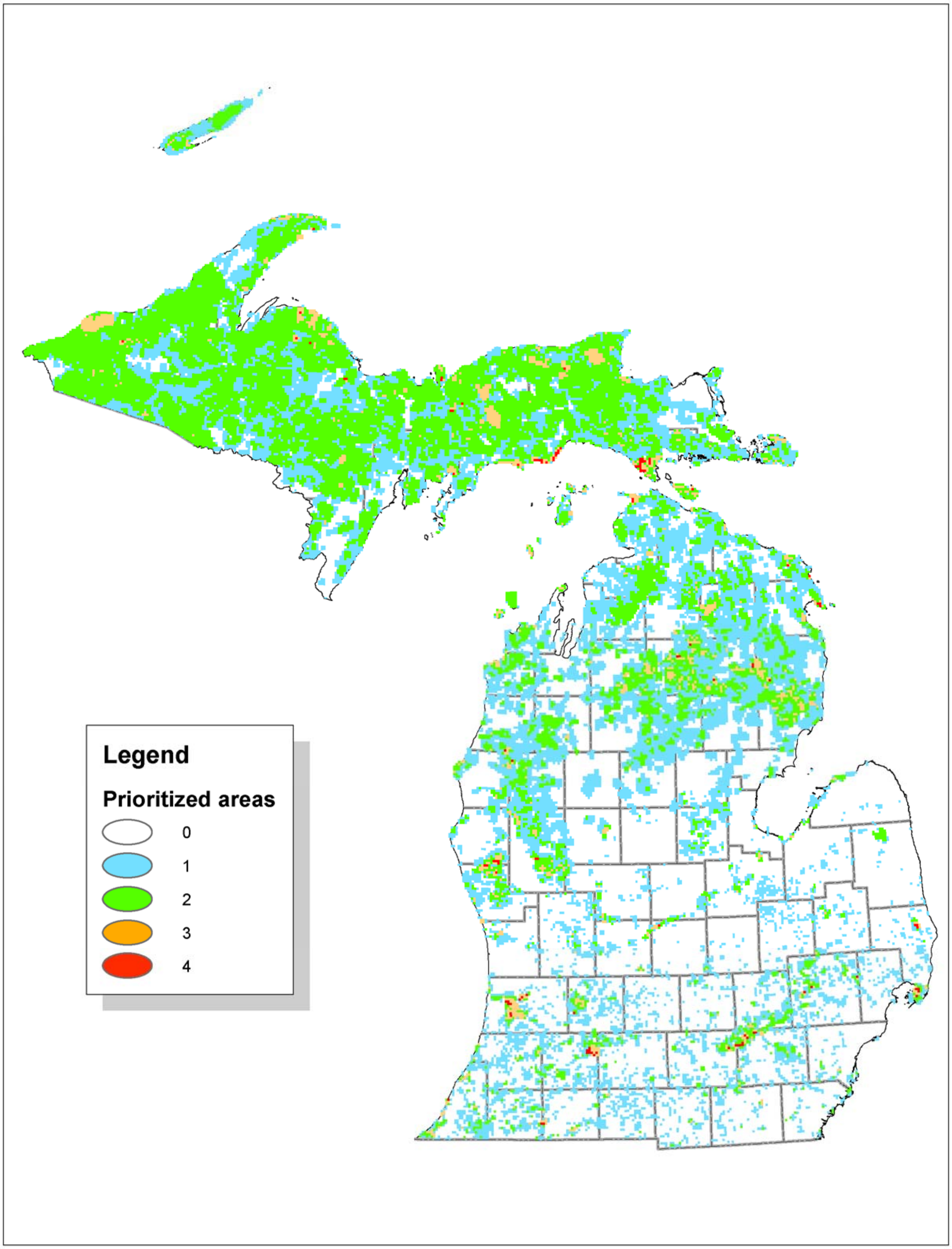


Figure 57. Prioritized terrestrial biodiversity areas displayed at a 1 mile^2 resolution.

prevalent in the Northern Lake Michigan, Lake Huron, and Straits of Mackinac and Easter Upper Peninsula EDUs, with 23 and 26 sub-watersheds selected, respectively. Five of the sub-watersheds occurred in the Southeast Michigan Interlobate and Lake Plain EDU (Bean Creek, the West Fork of the West Branch of the St. Joseph River, the River Raisin, and two are along the lake shore); the Southeast Lake Michigan (3) EDU had 6 sub-watersheds highlighted (Grand River, Looking Glass River, Battle Creek, South Branch of the Kalamazoo River, St. Joseph River, and Pigeon River); Saginaw Bay (4) EDU had 5 (South Branch of the Flint River, Shiawassee River, Molasses River, Black River, and one along the lake shore), Central Upper Peninsula (8) EDU had 9, and the Western Uppper Peninsula and Keweenaw Peninsula (6+12) EDU had 4 sub-watersheds (Tenderfoot Creek, West Branch of the Presque Isle River, and two watersheds that drain directly into Lake Superior) highlighted.

Additional ways to bring the data layers together

Aside from the example provided above to identify and prioritize potentially important biodiversity areas, there are many additional ways to analyze or overlay the different data layers described in this report to identify important natural resource areas in the state. The first example provided below focuses on identifying and prioritizing sites along the Great lakes shoreline. This analysis is important to conduct as a separate product due to the global and regional significance of the Great Lakes shoreline in Michigan. In addition, three other major categories of analysis that could be further explored include (but not limited to): 1) bio-rarity hotspots, 2) high quality natural communities, and 3) natural land cover types. Examples of a few analyses that could be conducted are listed under each of the headings. Lastly, it is important to identify gaps in protection by overlaying the data layer or layers you think are most important with the latest conservation lands or public lands data layer.

Great Lakes shoreline

An analysis was conducted to identify and prioritize sites along the Great Lakes shoreline which support concentrations of threatened and endangered species. The first step of the analysis involved selecting all natural community element occurrences, and all plant and animal occurrences from the MNFI database within a distance of 0.5 miles of the Michigan portion of the Great Lakes shoreline. Plant and animal occurrences greater than 20 years old were discarded. The shoreline layer was derived from the Michigan County layer, at 1:24,000 scale, and consists of a line delineating the entire Great Lakes shoreline of Michigan. The resulting features were buffered by 0.5 kilometers, and the boundaries between overlapping buffers were dissolved to create a new layer of shoreline sites.

The newly created sites were then scored using specific criteria outlined in the biological rarity score. The biological rarity model is generated by assigning each element occurrence a value based on the age of the record. This value is used to represent the probability that the occurrence still exist. Each element occurrence is also assigned three other values, one based on the species global status, one based on the species State status, and one based on the element occurrence quality rank. The greater the threat of imperilment to the species and the higher the quality of each occurrence, the higher the value assigned to the occurrence. Sites were then ranked based on the summed biological rarity scores.

File name:
GL shoreline sites\sites.shp

Data source:
Biot_p – Biotics polygon database created directly from Biotics from version created September 1, 2006.

Figure 58. Prioritized aquatic biodiversity areas based on species of greatest conservation concern and functional sub-watersheds.

Results:
A total of 1,960 element occurrences (all natural communities and only plant and animal occurrences observed within the last 20 years) were located within .5 miles of one of the Great Lakes. This represents 13% of the database. Once these occurrences were buffered by 0.5 kilometers and merged together, a total of 461 distinct sites were identified along the Great Lakes shoreline. Bio-rarity scores ranged from a low of 4 to a high of 1,957. The five sites with the highest scores were: 1) north half of Isle Royale, 2) Schoolcraft County shoreline, 3) Wilderness State Park, 4) Seiner's Point to Big Knob Campground, and 5) Drummond Island-Maxton Plains (Figure 59).

Bio-rarity hotspots

High terrestrial species bio-rarity score. Purpose is to identify areas with high unique natural features value regardless of patch or landscape integrity.

[High terrestrial species bio-rarity score] intersected with [all natural vegetation – all roads – 210m buffer]. Purpose is to identify areas with high unique natural features value located within landscapes of high ecological integrity. These sites are important because they contain a concentration of high quality natural features that have the best opportunity for long-term viability.

[High terrestrial species bio-rarity score] intersected with [matrix – all roads – 210m buffer]. Purpose is to identify areas with high unique natural features value located within landscapes of high ecological integrity. These sites are important because they contain a concentration of high quality natural features that have the best opportunity for long-term viability.

High quality natural communities

[High quality natural communities] intersected with [all natural vegetation – all roads - 210m buffer] – Identify high quality natural communities located within landscapes of high integrity.

[High quality natural communities] intersected with [matrix – all roads – 210m buffer] - Identify high quality natural communities located within landscapes of high integrity.

Natural landcover types

[natural vegetation types – all roads – 210m buffer]. Purpose is to identify areas with high patch integrity regardless of landscape integrity.

[natural vegetation types – all roads – 210m buffer] intersected with [all natural vegetation – all roads - 210m buffer]. Purpose is to identify areas with high patch and landscape integrity that have the potential to harbor a high diversity of plants and animals and/or rare species.

[natural vegetation types – all roads – 210m buffer] intersected with [matrix – all roads – 210m buffer] - Identify areas with high patch and landscape integrity that have the potential to harbor a high diversity of plants and animals and/or rare species.

Unique Aquatic ecosystems

[Unique river ecosystems] and [Unique lake ecosystems] intersected with [functional sub-watersheds] – Identify where there are higher concentrations of unique ecosystems within functional subwatersheds. This analysis could also help prioritize areas to survey for aquatic elements.

Unique river ecosystems] and [Unique lake ecosystems] intersected with [SGCN richness] – Identity sub-watersheds that may be key areas for overall aquatic biodiversity.

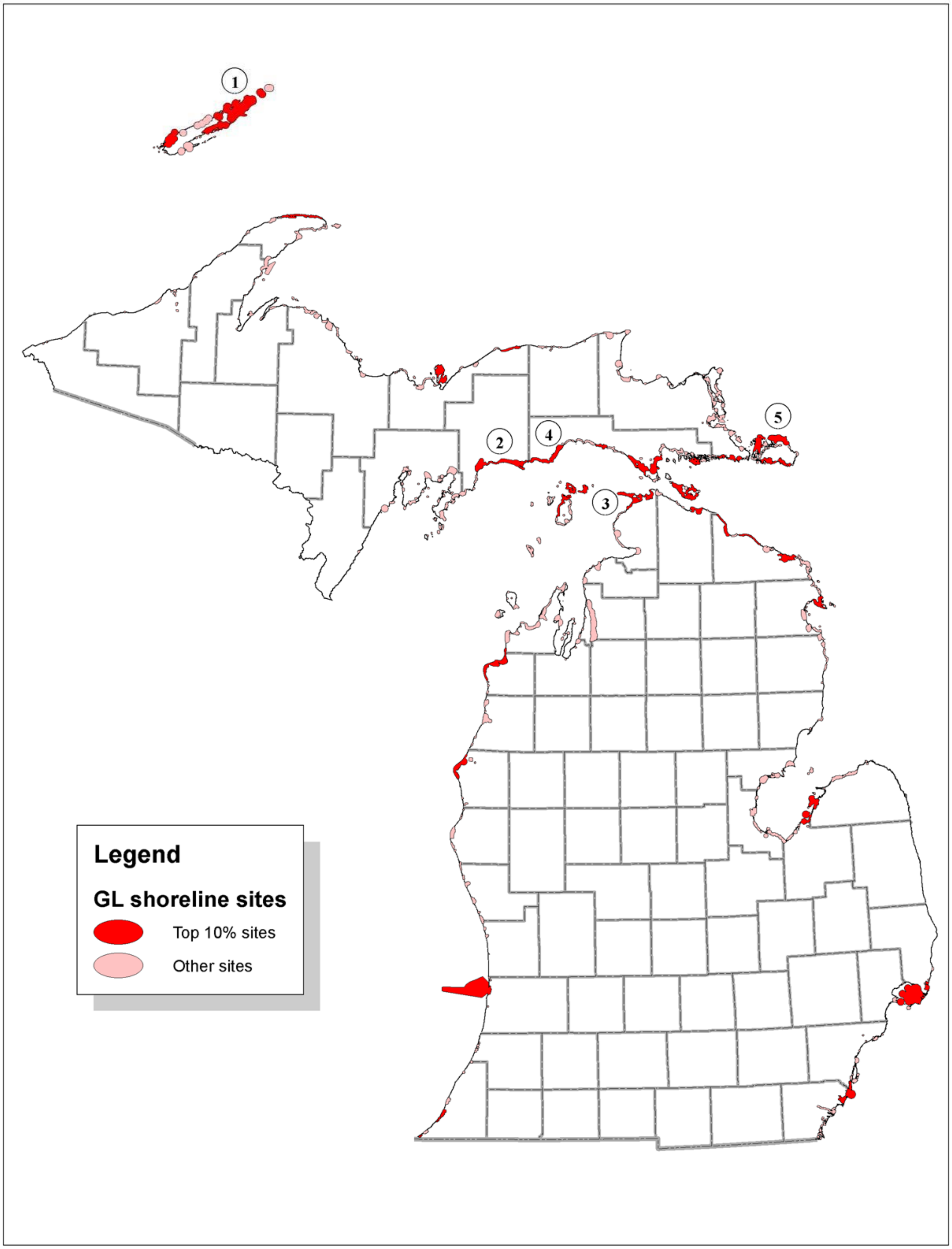


Figure 59. High priority great lakes shoreline sites.

Ownership Patterns

Lastly, it is important to also highlight important biodiversity lands that are under the highest degree of threat. The simplest way to accomplish this is to overlay the various data layers mentioned earlier with a public lands data layer. When using land ownership this way, we are assuming that the public lands shown on this data layer are at least somewhat protected from development or habitat destruction. From this perspective, the resulting maps will highlight private lands that fall within important biodiversity areas. Based on the most recent Conservation and Recreation Lands (CARL) database, developed by Ducks Unlimited and The Nature Conservancy, approximately 21% of the land in Michigan is under public ownership. However, these ownership patterns are not evenly distributed. The Eastern Upper Peninsula leads the state with 47% of the land in public ownership. This is followed by the western Upper Peninsula with 35%, the northern Lower Peninsula with 25%, and the southern Lower Peninsula with only 5%.

Next Steps

Assessing the state of Michigan's biodiversity and identifying important areas for conservation is far from complete. The primary focus of this initial effort was to gather, develop, and assess a series of data layers for both terrestrial and aquatic natural features that could be used for future conservation planning efforts at multiple scales. Given this basis of information, there are five categories of next steps: 1) gathering needed data, 2) conducting field-expert reviews, 3) examining this work in light of other efforts in the state (TNC's conservation priority areas, and the terrestrial and aquatic Michigan GAP projects), 4) updating models, and 5) setting conservation priorities.

First, this project helped crystallize that more data is needed to aid in more effective models and analyses. One element that is still missing and that plays a key role in conducting a critical assessment of Michigan's biodiversity is a comprehensive, systematic biological survey. Very few places in Michigan have had a systematic survey of its natural features. The vast majority of areas where surveys have been conducted are publicly owned, and our knowledge of the places that have been surveyed is incomplete. We need comprehensive statewide data, as well as more data on species viability. The majority of rare animal element occurrences in the MNFI database have an EO rank of E for extant. As a result, all of the data layers that utilize rare animal occurrence data, specifically the EO rank, are not as robust as they could be. Predictive models for species can help identify areas with potentially high species diversity or areas important for particular guilds of species, such as wading birds. As part of the Michigan GAP Project, predictive models were developed for 327 vertebrate terrestrial species. The Michigan Aquatic GAP analysis is still in progress. However, in order to obtain the level of confidence needed to effectively model where important natural features occur across the state of Michigan, we need field data that is more comprehensive, accurate, and complete.

Other data needs include:

- Biotic and abiotic surveys of significant sites identified through GIS models to determine if those sites truly are significant and/or unique.
- A scientifically defensible lakes classification system in Michigan.
- Defined riverine natural communities with associated species
- Improved methodology for identifying high quality natural land cover

Second, since this project relied on broad GIS data and modeling to conduct our analyses, a detailed field-expert review is needed to determine the accuracy and validity of our methods. Three key reasons to include regional experts in the review of our work are to: 1) gather data to fine tune the models; 2) set priorities for field surveys, and 3) expand ownership of the assessment. Although we were unable to include a large stakeholder or user group in the development of this project, we understand the importance of stakeholder input. We believe an expert review is an important next step.

Third, we need to tie our work to other statewide efforts in Michigan. Future aquatic classifications (lakes, Great Lakes) should be examined for their utility in an updated aquatic assessment. We would also like to examine how our results fit in with TNC's conservation priority areas for Michigan and the Great Lakes, as well as the terrestrial and aquatic Michigan GAP projects. Examining the variety of conservation and natural resource efforts in Michigan allows us to more accurately identify where there are gaps in knowledge.

Fourth, to begin setting conservation priorities for Michigan's biodiversity, we need to determine important areas for both terrestrial and aquatic biodiversity, and identify and design an interconnected network of conservation areas, including connecting corridors. Although the initial efforts for the aquatic and terrestrial assessment needed to be completed separately, we now need to determine the best way to bring these two different components together. By connecting these components in a scientifically defensible, efficient, and meaningful way, we can begin prioritizing areas across the state that are potentially important for both aquatic and terrestrial biodiversity. More than likely important areas will compliment each other, and GIS tools that evaluate adjacency and proximity will help identify where these areas of terrestrial and aquatic features converge on the landscape.

Fifth, this report provides examples of how the data could be used to spatially identify important areas on the landscape; however designing an interconnected network of conservation areas is a bit more complicated. One key element that still needs to be addressed is connecting corridors or linkages between important areas and sites. Corridors can be difficult to identify because: 1) their location and design are dependent on the specific requirements of the biotic and/or abiotic target(s), and 2) obstacles such as roads, development, dams, large scale intensive agricultural operations, railroads, and other non-natural land cover types fragment the landscape, restrict opportunities and lead to numerous design challenges. One way to address an interconnected network of conservation areas is by developing green infrastructure plans at multiple scales.

Green infrastructure plans essentially consist of three design elements: hubs, sites, and linkages. Hubs are large areas of natural land that act as anchors for a variety of natural processes, and provide an origin or destination for many species of wildlife. Hubs tend to have a wide diversity of habitats, and are resilient to natural disturbances such as fire, flooding, and wind throw. At the next finer scale, it is important to identify sites. Sites are smaller landscape areas that incorporate smaller-scale ecologically important features. They tend to be well defined, isolated places on the landscape, such as an isolated wetland, a sink hole, or a great blue heron rookery. Once these are identified, it is important to identify a suite a species that would benefit from a corridor or linkage between two or more hubs or sites. Again, multiple scales need to be considered. Wide ranging terrestrial species such as black bear, moose, elk, martin, or bobcat, or migrating fish might be good candidates for the design and incorporation of linkages at the 10^2 to 10^3 m scale. On a finer scale, smaller ranging species that require multiple habitat types for survival, such as many of Michigan’s snakes and turtles, or species whose populations are characterized as meta-populations, might be good candidates for the design of very site specific travel corridors at the 10^1 m scale. Determining effective and meaningful conservation areas is a difficult and complicated endeavor, but through this report we now have data to help Michigan’s resource agencies, conservation organizations, and concerned citizens begin the process.

This report provides the basis for the next steps in completing a comprehensive and robust assessment of Michigan’s biodiversity. Despite the several areas of improvement mentioned above, the data layers provided in this report reflect the best information currently available on Michigan’s biodiversity at the state and regional scales. Data layers that are particularly weak due to lack of empirical data are the unique lakes and streams analyses. However, the rest of the data layers provided in this report, particularly the terrestrial layers, should meet the majority of end user needs. The information and data on terrestrial and aquatic biodiversity can be used by: 1) government agencies to help develop conservation plans at multiple scales, 2) local units of government that are interested in creating green infrastructure plans or updating their parks and recreation plans, 3) watershed councils for watershed planning and protection, and 4) land conservancies for prioritizing lands for permanent protection. All of these efforts should include field visits to verify the modeling results.

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Appendix A - Rare terrestrial plant list

Species	Common name	Fed	State	Grank	Srank
Adlumia fungosa	Climbing fumitory		SC	G4	S3
Agalinis gattingeri	Gattinger's gerardia		E	G4	S1
Agalinis skinneriana	Skinner's gerardia		E	G3	S1
Agoseris glauca	Prairie or pale agoseris		T	G5	S2
Agrimonia rostellata	Beaked agrimony		SC	G5	S1S2
Agropyron spicatum	Bluebunch wheatgrass		X	G5	SX
Allium schoenoprasum	Wild chives		T	G5	S2
Amerorchis rotundifolia	Round-leaved orchis		E	G5	S1
Amorpha canescens	Leadplant		SC	G5	S3
Androsace occidentalis	Rock-jasmine		E	G5	SH
Angelica venenosa	Hairy angelica		SC	G5	S3
Antennaria parvifolia	Pussy-toes		SC	G5	S1
Antennaria rosea	Rosy pussytoes		T	G5	SH
Arabis missouriensis var. deamii	Missouri rock-cress		SC	G4G5QT3?Q	S2
Arabis perstellata sensu lato	Rock cress		T	G5	S1
Arenaria macrophylla	Big-leaf sandwort		T	G4	S1
Aristida dichotoma	Shinner's three-awned grass		X	G5	SX
Aristida longespica	Three-awned grass		T	G5	S2
Aristida tuberculosa	Beach three-awned grass		T	G5	S1
Aristolochia serpentaria	Virginia snakeroot		T	G4	S2
Arnica cordifolia	Heart-leaved arnica		E	G5	S1
Artemisia ludoviciana	Western mugwort		T	G5	S1
Asclepias hirtella	Tall green milkweed		T	G5	S2
Asclepias ovalifolia	Dwarf milkweed		E	G5?	S1
Asclepias purpurascens	Purple milkweed		SC	G5?	S3
Asclepias sullivantii	Sullivant's milkweed		T	G5	S2
Asplenium montanum	Mountain spleenwort		X	G5	SH
Asplenium rhizophyllum	Walking fern		T	G5	S2S3
Asplenium ruta-muraria	Wall-rue		E	G5	S1
Asplenium scolopendrium var. americanum	Hart's-tongue fern	LT	E	G4T3	S1
Asplenium trichomanes-ramosum	Green spleenwort		T	G4	S2S3
Aster furcatus	Forked aster		T	G3	S1
Aster modestus	Great northern aster		T	G5	S1
Aster praealtus	Willow aster		SC	G5	S3
Aster sericeus	Western silvery aster		T	G5	S2
Astragalus canadensis	Canadian milk-vetch		T	G5	S1S2
Astragalus neglectus	Cooper's milk-vetch		SC	G4	S3
Baptisia lactea	White or prairie false indigo		SC	G4Q	S3
Baptisia leucophaea	Cream wild indigo		E	G4G5T4T5	S1
Bartonia paniculata	Panicled screw-stem		T	G5	S2
Beckmannia syzigachne	Slough grass		T	G5	S2
Berula erecta	Cut-leaved water-parsnip		T	G4G5	S2
Besseya bullii	Kitten-tails		T	G3	S1S2
Betula murrayana	Murray birch		SC	G1Q	S1
Botrychium acuminatum	Acute-leaved moonwort		E	G1	S1
Botrychium campestre	Prairie moonwort		T	G3G4	S2
Botrychium hesperium	Western moonwort		T	G3G4	S2
Botrychium mormo	Goblin moonwort		T	G3	S2
Botrychium pallidum	pale moonwort		SC	G2G3	S3

Appendix A - Rare terrestrial plant list - continued

Species	Common name	Fed	State	Grank	Srank
Bouteloua curtipendula	Side-oats grama grass		T	G5	S1S2
Braya humilis	Low northern rock-cress		T	G5	S1
Bromus pumpellianus	Pumpelly's brome grass		T	G5T4	S2
Buchnera americana	Blue-hearts		X	G5?	SX
Cacalia plantaginea	Prairie indian-plantain		SC	G4G5	S3
Calamagrostis lacustris	Northern reedgrass		T	G3Q	S1
Calamagrostis stricta	Narrow-leaved reedgrass		T	G5	S1
Calypso bulbosa	Calypso or fairy-slipper		T	G5	S2
Camassia scilloides	Wild-hyacinth		T	G4G5	S2
Carex albolutescens	Greenish-white sedge		T	G5	S2
Carex assiniboinensis	Assiniboia sedge		T	G4G5	S2
Carex atratiformis	Sedge		T	G5	S2
Carex concinna	Beauty sedge		SC	G4G5	S3
Carex conjuncta	Sedge		T	G4G5	S1
Carex crus-corvi	Raven's-foot sedge		T	G5	SH
Carex davisii	Davis's sedge		SC	G4	S3
Carex decomposita	Log sedge		X	G3	SX
Carex festucacea	Fescue sedge		SC	G5	S1
Carex frankii	Frank's sedge		SC	G5	S2S3
Carex gravida	Sedge		X	G5	SX
Carex haydenii	Hayden's sedge		X	G5	SX
Carex heleonastes	Hudson bay sedge		E	G4	S1
Carex lupuliformis	False hop sedge		T	G4	S2
Carex media	Sedge		T	G5T5?	S2S3
Carex nigra	Black sedge		E	G5	S1
Carex novae-angliae	New england sedge		T	G5	S1
Carex oligocarpa	Eastern few-fruited sedge		T	G4	S2
Carex platyphylla	Broad-leaved sedge		T	G5	S1
Carex richardsonii	Richardson's sedge		SC	G4	S3S4
Carex rossii	Ross's sedge		T	G5	S2
Carex scirpoidea	Bulrush sedge		T	G5	S2
Carex seorsa	Sedge		T	G4	S2
Carex squarrosa	Sedge		SC	G4G5	S1
Carex straminea	Straw sedge		E	G5	SH
Carex tincta	Sedge		SC	G4G5	SNR
Carex trichocarpa	Hairy-fruited sedge		SC	G4	S2
Carex typhina	Cat-tail sedge		T	G5	S1
Carex wiegandii	Wiegand's sedge		T	G3	S2
Castanea dentata	American chestnut		E	G4	S1S2
Castilleja septentrionalis	Pale indian paintbrush		T	G5	S2S3
Ceanothus sanguineus	Redstem ceanothus		T	G4G5	S2
Celtis tenuifolia	Dwarf hackberry		SC	G5	S3
Chamaerhodos nuttallii var. keweenawensis	Keweenaw rock-rose		E	G5T1Q	S1
Chasmanthium latifolium	Wild-oats		T	G5	S1
Chelone obliqua	Purple turtlehead		E	G4	S1
Cirsium hillii	Hill's thistle		SC	G3	S3
Cirsium pitcheri	Pitcher's thistle	LT	T	G3	S3
Clematis occidentalis	Purple clematis		SC	G5	S3
Collinsia parviflora	Small blue-eyed mary		T	G5	S2

Species	Common name	Fed	State	Grank	Srank
Commelina erecta	Slender day-flower		X	G5	SX
Coreopsis palmata	Prairie coreopsis		T	G5	S2
Corydalis flavula	Yellow fumewort		T	G5	S2
Crataegus douglasii	Douglas's hawthorn		SC	G5	S3S4
Cryptogramma acrostichoides	American rock-brake		E	G5	S2
Cryptogramma stelleri	Slender cliff-brake		SC	G5	S3S4
Cuscuta campestris	Field dodder		SC	G5T5	SH
Cuscuta glomerata	Rope dodder		SC	G5	SH
Cuscuta indecora	Dodder		SC	G5	SH
Cuscuta pentagona	Dodder		SC	G5	SH
Cuscuta polygonorum	Knotweed dodder		SC	G5	S2
Cyperus acuminatus	Nut-grass		X	G5	SX
Cyperus flavescens	Yellow nut-grass		SC	G5	S2S3
Cypripedium arietinum	Ram's head lady's-slipper		SC	G3	S3
Cypripedium candidum	White lady-slipper		T	G4	S2
Cystopteris laurentiana	Laurentian fragile fern		SC	G3	S1S2
Dalea purpurea	Purple prairie-clover		X	G5	SX
Dalibarda repens	False-violet		T	G5	S1S2
Danthonia compressa	Flat oat grass		SC	G5	S1
Danthonia intermedia	Wild oat-grass		SC	G5	S1S2
Dasistoma macrophylla	Mullein foxglove		T	G4	S1S2
Dennstaedtia punctilobula	Hay-scented fern		X	G5	SNR
Dentaria maxima	Large toothwort		T	G5Q	S1S2
Diarrhena americana	Beak grass		T	G4?	S2
Digitaria filiformis	Slender finger-grass		X	G5	SX
Disporum hookeri	Fairy bells		E	G5	S1
Disporum maculatum	Nodding mandarin		X	G3G4	SX
Disporum trachycarpum	northern fairy bells		T	G5	S1
Dodecatheon meadia	Shooting-star		E	G5	S1
Draba arabisans	Rock whitlow-grass		SC	G4	S3
Draba cana	Ashy whitlow-grass		T	G5	S1
Draba glabella	Smooth whitlow-grass		E	G4G5	S1
Draba incana	Twisted whitlow-grass		T	G5	S1
Draba nemorosa	Whitlow-grass		X	G5	SX
Draba reptans	Creeping whitlow-grass		T	G5	S1
Drosera anglica	English sundew		SC	G5	S3
Dryopteris celsa	Log fern		T	G4	S2
Dryopteris filix-mas	Male fern		SC	G5	S3
Dryopteris fragrans	Fragrant cliff woodfern		SC	G5	S3
Echinacea purpurea	Purple coneflower		X	G4	SX
Echinodorus tenellus	Dwarf burhead		E	G5?	S1
Eleocharis atropurpurea	Purple spike-rush		E	G4G5	S1
Eleocharis caribaea	Spike-rush		T	G4G5	S1
Eleocharis compressa	Flattened spike-rush		T	G4	S2
Eleocharis engelmannii	Engelmann's spike-rush		SC	G4G5Q	S2S3
Eleocharis equisetoides	Horsetail spike-rush		SC	G4	S3
Eleocharis melanocarpa	Black-fruited spike-rush		SC	G4	S3
Eleocharis microcarpa	Small-fruited spike-rush		E	G5	S1
Eleocharis nitida	Slender spike-rush		E	G3G4	S1

Appendix A - Rare terrestrial plant list - continued

Species	Common name	Fed	State	Grank	Srank
Eleocharis parvula	Dwarf spike-rush		T	G5	S1
Eleocharis radicans	Spike-rush		X	G5	SX
Eleocharis tricostata	Three-ribbed spike-rush		T	G4	S2
Elymus glaucus	Blue wild-rye		SC	G5	S3
Elymus mollis	American dune wild-rye		SC	G5	S3
Empetrum nigrum	Black crowberry		T	G5	S2
Equisetum telmateia	Giant horsetail		X	G5	SX
Eragrostis capillaris	Love grass		SC	G5	SH
Eragrostis pilosa	Small love grass		SC	G4	SH
Erigeron acris	fleabane		SC	G5	SR
Erigeron hyssopifolius	Hyssop-leaved fleabane		T	G5	S1
Eryngium yuccifolium	Rattlesnake-master		T	G5	S2
Euonymus atropurpurea	Wahoo		SC	G5	S3
Eupatorium fistulosum	Hollow-stemmed joe-pye-weed		T	G5?	S1
Eupatorium sessilifolium	Upland boneset		T	G5	S1
Euphorbia commutata	Tinted spurge		T	G5	S1
Euphrasia hudsoniana	Eyebright		T	G5?	SNR
Euphrasia nemorosa	Common eyebright		T	G5	S1
Festuca scabrella	Rough fescue		T	G5	S2S3
Filipendula rubra	Queen-of-the-prairie		T	G4G5	S2
Fimbristylis puberula	Chestnut sedge		X	G5	SX
Fraxinus profunda	Pumpkin ash		T	G4	S2
Fuirena squarrosa	Umbrella-grass		T	G4G5	S2
Galearis spectabilis	Showy orchis		T	G5	S2
Galium kamtschaticum	Bedstraw		T	G5	S1
Gentiana flavida	White gentian		E	G4	S1
Gentiana linearis	Narrow-leaved gentian		T	G4G5	S2
Gentiana puberulenta	Downy gentian		E	G4G5	S1
Gentiana saponaria	Soapwort gentian		X	G5	SX
Gentianella quinquefolia	Stiff gentian		T	G5	S2
Geum triflorum	Prairie-smoke		T	G5	S2S3
Geum virginianum	Pale avens		SC	G5	S1S2
Gillenia trifoliata	Bowman's root		T	G4G5	S1
Glyceria acutiflora	Manna grass		X	G5	SX
Gnaphalium sylvaticum	Cudweed		T	G3G4	S1
Gratiola aurea	Hedge-hyssop		T	G5	S1S2
Gratiola virginiana	Round-fruited hedge hyssop		T	G5	S1
Gymnocarpium jessoense	Northern oak fern		E	G5	S1
Gymnocarpium robertianum	Limestone oak fern		T	G5	S2
Gymnocladus dioicus	Kentucky coffee-tree		SC	G5	S3S4
Hedyotis nigricans	Hedyotis		X	G5	SX
Hedysarum alpinum	Alpine sainfoin		E	G5	S1
Helianthus hirsutus	Whiskered sunflower		SC	G5	S3
Helianthus microcephalus	Small wood sunflower		X	G5	SX
Helianthus mollis	Downy sunflower		T	G4G5	S2
Hemicarpha micrantha	Dwarf-bulrush		SC	G5	S3
Hibiscus laevis	Smooth rose-mallow		SC	G5	SH
Hibiscus moscheutos	Swamp rose-mallow		SC	G5	S3S4
Hieracium paniculatum	Panicled hawkweed		SC	G5	S2

Appendix A - Rare terrestrial plant list - continued

Species	Common name	Fed	State	Grank	Srank
Houstonia caerulea	bluets		SC	G5	SNR
Huperzia appalachiana	mountain fir-moss		E	G4G5	S?
Huperzia selago	Fir clubmoss		SC	G5	S3
Hybanthus concolor	Green violet		SC	G5	S3
Hydrastis canadensis	Goldenseal		T	G4	S2
Hymenoxys herbacea	Lakeside daisy	LT	E	G2	S1
Hypericum gentianoides	Gentian-leaved st. john's-wort		SC	G5	S3
Hypericum sphaerocarpum	Round-fruited st. john's-wort		T	G5	S1
Ipomoea pandurata	Wild potato-vine		T	G5	S2
Iris lacustris	Dwarf lake iris	LT	T	G3	S3
Isoetes engelmannii	Appalachian quillwort		E	G4	S1
Isotria medeoloides	Smaller whorled pogonia	LT	E	G2	S1
Isotria verticillata	Whorled pogonia		T	G5	S2
Jeffersonia diphylla	Twinleaf		SC	G5	S3
Juncus brachycarpus	Short-fruited rush		T	G4G5	S1S2
Juncus militaris	Bayonet rush		T	G4	S1
Juncus scirpoides	Scirpus-like rush		T	G5	S2
Juncus stygius	Moor rush		T	G5	S1S2
Juncus vaseyi	Vasey's rush		T	G5?	S1S2
Justicia americana	Water-willow		T	G5	S2
Kuhnia eupatorioides	False boneset		SC	G5	S2
Lactuca floridana	Woodland lettuce		T	G5	S2
Lactuca pulchella	Blue lettuce		T	G5T5	SH
Lechea minor	Least pinweed		SC	G5	SH
Lechea pulchella	Leggett's pinweed		T	G5	S1S2
Lechea stricta	Erect pinweed		SC	G4?	S1
Lespedeza procumbens	Trailing bush-clover		X	G5	SX
Leucospora multifida	conobea		SC	G5	SNR
Liatris punctata	Dotted blazing-star		X	G5	SX
Liatris squarrosa	Blazing-star		X	G5	SX
Linum sulcatum	Furrowed flax		SC	G5	S2S3
Linum virginianum	Virginia flax		T	G4G5	S2
Liparis liliifolia	Purple twayblade		SC	G5	S3
Listera auriculata	Auricled twayblade		SC	G3	S2S3
Lithospermum incisum	Narrow-leaved puccoon		X	G5	SX
Lithospermum latifolium	Broad-leaved puccoon		SC	G4	S2
Littorella uniflora	American shore-grass		SC	G5	S2S3
Lonicera involucrata	Black twinberry		T	G4G5	S2
Ludwigia alternifolia	Seedbox		SC	G5	S3
Ludwigia sphaerocarpa	Globe-fruited seedbox		T	G5	S1
Luzula parviflora	Small-flowered woodrush		T	G5	S1
Lycopodiella margueriteae	northern prostrate clubmoss		T	G2	S2
Lycopodiella subappressa	Northern appressed clubmoss		SC	G2	S2
Lycopus virginicus	Virginia water-horehound		T	G5	S2
Lygodium palmatum	Climbing fern		E	G4	S1
Lysimachia hybrida	Swamp candles		SC	G5	S2
Mertensia virginica	Virginia bluebells		T	G5	S2
Mikania scandens	Mikania		X	G5	SX
Mimulus alatus	Wing-stemmed monkey-flower		X	G5	SX

Appendix A - Rare terrestrial plant list - continued

Species	Common name	Fed	State	Grank	Srank
Mimulus glabratus var. michiganensis	Michigan monkey-flower	LE	E	G5T1	S1
Mimulus guttatus	Western monkey-flower		SC	G5	S1
Monarda didyma	Oswego tea		X	G5	SX
Morus rubra	Red mulberry		T	G5	S2
Muhlenbergia cuspidata	Plains muhly		X	G4	SX
Muhlenbergia richardsonis	Mat muhly		T	G5	S2
Onosmodium molle	Marbleweed		X	G4G5	SX
Ophioglossum vulgatum	Southeastern adder's tongue		T	G5	S1
Oplopanax horridus	Devil's-club		T	G4	S2
Opuntia fragilis	Fragile prickly-pear		E	G4G5	S1
Orobanche fasciculata	Fascicled broom-rape		T	G4	S2
Oryzopsis canadensis	Canada rice-grass		T	G5	S2
Osmorhiza depauperata	Sweet cicely		T	G5	S2
Oxalis violacea	Violet wood-sorrel		T	G5	S1
Panax quinquefolius	Ginseng		T	G3G4	S2S3
Panicum leibergii	Leiberg's panic-grass		T	G5	S2
Panicum longifolium	Long-leaved panic-grass		T	G4	S2
Panicum microcarpon	Small-fruited panic-grass		SC	G5T5	S2
Panicum polyanthes	Round-seed panic grass		E	G5T5	S1
Panicum verrucosum	Warty panic-grass		T	G4	S1
Parnassia palustris	Marsh grass-of-parnassus		T	G5	S2
Paronychia fastigiata	Low-forked chickweed		SC	G5	SH
Pellaea atropurpurea	Purple cliff-brake		T	G5	S2
Penstemon calycosus	Smooth beard tongue		T	G5	S2
Penstemon gracilis	Slender beard-tongue		E	G5	S1
Penstemon pallidus	Pale beard tongue		SC	G5	S3
Petasites sagittatus	Sweet coltsfoot		T	G5	S1S2
Phacelia franklinii	Franklin's phacelia		T	G5	S1
Phaseolus polystachios	Wild bean		SC	G4	SH
Phleum alpinum	Mountain timothy		X	G5	SX
Phlox bifida	Cleft phlox		T	G5?	S1
Phlox maculata	Spotted phlox		T	G5	S1
Pinguicula vulgaris	Butterwort		SC	G5	S3
Piperia unalascensis	Alaska orchid		SC	G5	S2S3
Plantago cordata	Heart-leaved plantain		E	G4	S1
Platanthera ciliaris	Orange or yellow fringed orchid		T	G5	S2
Platanthera leucophaea	Prairie fringed orchid	LT	E	G2	S1
Poa alpina	Alpine bluegrass		T	G5	S1S2
Poa canbyi	Canby's bluegrass		E	G4G5	S1
Poa paludigena	Bog bluegrass		T	G3	S2
Polemonium reptans	Jacob's ladder or greek-valerian		T	G5	S2
Polygala cruciata	Cross-leaved milkwort		SC	G5	S3
Polygala incarnata	Pink milkwort		X	G5	SX
Polygonatum biflorum var. melleum	Honey-flowered solomon-seal		X	G5TH	SX
Polygonum careyi	Carey's smartweed		T	G4	S1S2
Polygonum viviparum	Alpine bistort		T	G5	S1S2
Polymnia uvedalia	Large-flowered leafcup		T	G4G5	S1
Polytaenia nuttallii	Prairie-parsley		X	G5	SX
Populus heterophylla	Swamp or black cottonwood		E	G5	S1

Species	Common name	Fed	State	Grank	Srank
Potentilla paradoxa	Sand cinquefoil		T	G5	SU
Potentilla pensylvanica	Prairie cinquefoil		T	G5	S1
Proserpinaca pectinata	Mermaid-weed		E	G5	S1
Prunus alleghaniensis var. davisii	Alleghany or sloe plum		SC	G4T3Q	S3
Psilocarya scirpoides	Bald-rush		T	G4	S2
Pterospora andromedea	Pine-drops		T	G5	S2
Pycnanthemum muticum	Mountain-mint		T	G5	S1
Pycnanthemum pilosum	Hairy mountain-mint		T	G5T5	S2
Pycnanthemum verticillatum	Whorled mountain-mint		SC	G5	S2
Quercus shumardii	Shumard's oak		SC	G5	S2
Ranunculus ambigens	Spearwort		T	G4	SH
Ranunculus cymbalaria	Seaside crowfoot		T	G5	S1
Ranunculus lapponicus	Lapland buttercup		T	G5	S1S2
Ranunculus macounii	Macoun's buttercup		T	G5	S1
Ranunculus rhomboideus	Prairie buttercup		T	G5	S2
Rhexia mariana var. mariana	Maryland meadow-beauty		T	G5T5	S1S2
Rhexia virginica	Meadow-beauty		SC	G5	S3
Rhynchospora globularis	Globe beak-rush		E	G5	S1
Rhynchospora macrostachya	Tall beak-rush		SC	G4	S3S4
Ribes oxyacanthoides	Northern gooseberry		SC	G5	S3
Rotala ramosior	Tooth-cup		SC	G5	S3
Rubus acaulis	Dwarf raspberry		E	G5	S1
Rudbeckia subtomentosa	Sweet coneflower		X	G5	S?
Ruellia humilis	Hairy ruellia		T	G5	S1
Ruellia strepens	Smooth ruellia		T	G4G5	S1
Rumex occidentalis	Western dock		E	G5	SNR
Sabatia angularis	Rose-pink		T	G5	S2
Sagina nodosa	Pearlwort		T	G5	S2
Sagittaria montevidensis	Arrowhead		T	G4G5	S1S2
Salix pellita	Satiny willow		SC	G5	S2
Salix planifolia	Tea-leaved willow		T	G5	SH
Sanguisorba canadensis	Canadian burnet		T	G5	S1
Sarracenia purpurea ssp. heterophylla	Yellow pitcher-plant		T	G5T1T2Q	S1
Saxifraga paniculata	Encrusted saxifrage		T	G5	S1
Saxifraga tricuspidata	Prickly saxifrage		T	G4G5	S2
Scirpus clintonii	Clinton's bulrush		SC	G4	S3
Scirpus hallii	Hall's bulrush		T	G2	S2
Scirpus olneyi	Olney's bulrush		T	G4Q	S1
Scirpus torreyi	Torrey's bulrush		SC	G5?	S2S3
Scleria pauciflora	Few-flowered nut-rush		E	G5	S1
Scleria reticularis	Netted nut-rush		T	G4	S2
Scleria triglomerata	Tall nut-rush		SC	G5	S3
Scutellaria elliptica	Hairy skullcap		SC	G5	S3
Scutellaria incana	Downy skullcap		X	G5	SX
Scutellaria nervosa	Skullcap		T	G5	S1
Scutellaria ovata	Heart-leaved skullcap		X	G5	SX
Scutellaria parvula	Small skullcap		T	G4	S2
Senecio congestus	Marsh-fleabane		X	G5	SX
Senecio indecorus	Rayless mountain ragwort		T	G5	S1

Appendix A - Rare terrestrial plant list - continued

Species	Common name	Fed	State	Grank	Srank
Silene stellata	Starry campion		T	G5	S2
Silene virginica	Fire pink		T	G5	S1
Silphium integrifolium	Rosinweed		T	G5	S2
Silphium laciniatum	Compass-plant		T	G5	S1S2
Silphium perfoliatum	Cup-plant		T	G5	S2
Sisyrinchium atlanticum	Atlantic blue-eyed-grass		T	G5	S2
Sisyrinchium farwellii	Farwell's blue-eyed-grass		X	GHQ	SX
Sisyrinchium hastile	Blue-eyed-grass		X	GUGHQ	SX
Sisyrinchium strictum	Blue-eyed-grass		SC	G2Q	S2
Smilax herbacea	Smooth carrion-flower		SC	G5	S3
Solidago bicolor	White goldenrod		SC	G5	S3
Solidago houghtonii	Houghton's goldenrod	LT	T	G3	S3
Solidago missouriensis	Missouri goldenrod		T	G5	SNR
Spiranthes ochroleuca	Yellow ladies'-tresses		SC	G4	S3
Spiranthes ovalis	Lesser ladies'-tresses		T	G5?	S1
Sporobolus clandestinus	Dropseed		SC	G5	S1
Sporobolus heterolepis	Prairie dropseed		SC	G5	S3
Stellaria crassifolia	Fleshy stitchwort		T	G5	S1S2
Stellaria longipes	Stitchwort		SC	G5	S2
Strophostyles helvula	Trailing wild bean		SC	G5	S3
Tanacetum huronense	Lake huron tansy		T	G5T4T5	S3
Thalictrum venulosum var. confine	Veiny meadow-rue		SC	G5T4?Q	S3
Tipularia discolor	Cranefly orchid		T	G4G5	S1
Tofieldia pusilla	False asphodel		T	G5	S2
Tomanthera auriculata	Eared false foxglove		X	G3	SX
Tradescantia bracteata	Long-bracted spiderwort		X	G5	SX
Tradescantia virginiana	Virginia spiderwort		SC	G5	S2
Trichostema brachiatum	False pennyroyal		T	G5	S1
Trichostema dichotomum	Bastard pennyroyal		T	G5	S2
Trillium nivale	Snow trillium		T	G4	S2
Trillium recurvatum	Prairie trillium		T	G5	S2S3
Trillium sessile	Toadshade		T	G4G5	S2S3
Trillium undulatum	Painted trillium		E	G5	S1S2
Trillium viride	Green trillium		X	G4G5	SX
Triphora trianthophora	Three-birds orchid		T	G3G4	S1
Triplasis purpurea	Sand grass		SC	G4G5	S2
Trisetum spicatum	Downy oat-grass		SC	G5	S2S3
Vaccinium cespitosum	Dwarf bilberry		T	G5	S1S2
Vaccinium uliginosum	Alpine blueberry		T	G5	S2
Vaccinium vitis-idaea	Mountain-cranberry		E	G5	S1
Valeriana edulis var. ciliata	Edible valerian		T	G5T3	S2
Valerianella chenopodiifolia	Goosefoot corn-salad		T	G5	S1
Valerianella umbilicata	Corn-salad		T	G3G5	S2
Viburnum edule	Squashberry or mooseberry		T	G5	S2S3
Viburnum prunifolium	Black haw		SC	G5	S3
Viola epipsila	Northern marsh violet		T	G4	SH
Viola novae-angliae	New england violet		T	G4Q	S2
Viola pedatifida	Prairie birdfoot violet		T	G5	S1
Vitis vulpina	Frost grape		T	G5	S1S2

Appendix A - Rare terrestrial plant list - continued

Species	Common name	Fed	State	Grank	Srank
Wisteria frutescens	Wisteria		T	G5	S1
Woodsia alpina	Northern woodsia		T	G4	S1
Woodsia obtusa	Blunt-lobed woodsia		T	G5	S1S2
Woodwardia areolata	Netted chain-fern		X	G5	SX
Zizania aquatica var. aquatica	Wild-rice		T	G5T5	S2S3
Zizia aptera	Prairie golden alexanders		T	G5	S1S2

Appendix B - Rare terrestrial animal list

Scientic Name	Common Name	Federal status	State status	Global rank	State rank
AMPHIBIANS					
Acris crepitans blanchardi	Blanchard's Cricket Frog		SC	G5T5	S2S3
Ambystoma opacum	Marbled Salamander		T	G5	S1
Ambystoma texanum	Smallmouth Salamander		E	G5	S1
Pseudacris triseriata maculata	Boreal Chorus Frog		SC	G5T5	S1
BIRDS					
Protonotaria citrea	Prothonotary Warbler		SC	G5	S3
Rallus elegans	King Rail		E	G4	S1
Seiurus motacilla	Louisiana Waterthrush		SC	G5	S2S3
Spiza americana	Dickcissel		SC	G5	S3
Sterna caspia	Caspian Tern		T	G5	S2
Sterna forsteri	Forster's Tern		SC	G5	S2
Sterna hirundo	Common Tern		T	G5	S2
Sturnella neglecta	Western Meadowlark		SC	G5	S4
Pandion haliaetus	Osprey		T	G5	S4
Phalaropus tricolor	Wilson's Phalarope		SC	G5	S2
Picoides arcticus	Black-backed Woodpecker		SC	G5	S2
Tympanuchus phasianellus	Sharp-tailed Grouse		SC	G4	S3S4
Tyto alba	Barn Owl		E	G5	S1
Wilsonia citrina	Hooded Warbler		SC	G5	S3
Xanthocephalus xanthocephalus	Yellow-headed Blackbird		SC	G5	S2
Ammodramus henslowii	Henslow's Sparrow		T	G4	S2S3
Ammodramus savannarum	Grasshopper Sparrow		SC	G5	S3S4
Asio flammeus	Short-eared Owl		E	G5	S1
Accipiter cooperii	Cooper's Hawk		SC	G5	S3S4
Accipiter gentilis	Northern Goshawk		SC	G5	S3
Botaurus lentiginosus	American Bittern		SC	G4	S3S4
Buteo lineatus	Red-shouldered Hawk		T	G5	S3S4
Asio otus	Long-eared Owl		T	G5	S2
Chondestes grammacus	Lark Sparrow		X	G5	SX
Circus cyaneus	Northern Harrier		SC	G5	S3
Cistothorus palustris	Marsh Wren		SC	G5	S3S4
Charadrius melodus	Piping Plover	LE	E	G3	S1
Chlidonias niger	Black Tern		SC	G4	S3
Cygnus buccinator	Trumpeter Swan		T	G4	S3
Dendroica cerulea	Cerulean Warbler		SC	G4	S3
Dendroica discolor	Prairie Warbler		E	G5	S1
Dendroica dominica	Yellow-throated Warbler		T	G5	S1
Dendroica kirtlandii	Kirtland's Warbler	LE	E	G1	S1
Coturnicops noveboracensis	Yellow Rail		T	G4	S1S2
Falcipennis canadensis	Spruce Grouse		SC	G5	S2S3
Falco columbarius	Merlin		T	G5	S1S2
Falco peregrinus	Peregrine Falcon		E	G4	S1
Gallinula chloropus	Common Moorhen		SC	G5	S3
Haliaeetus leucocephalus	Bald Eagle		T	G4	S4
Ixobrychus exilis	Least Bittern		T	G5	S2
Lanius ludovicianus migrans	Migrant Loggerhead Shrike		E	G4T3Q	S1

Appendix B - Rare terrestrial animal list - continued

Scientic Name	Common Name	Federal status	State status	Global rank	State rank
Nycticorax nycticorax	Black-crowned Night-heron		SC	G5	S2S3
Beetles					
Nicrophorus americanus	American Burying Beetle	LE	E	G2G3	SH
Dryobius sexnotatus	Six-banded Longhorn Beetle		SC	GNR	SH
Liodessus cantralli	Cantrall's Bog Beetle		SC	GNR	S1S3
Lordithon niger	Black Lordithon Rove Beetle		SC	GU	SH
Somatochlora hineana	Hine's Emerald	LE	E	G2G3	S1
Somatochlora incurvata	Incurvate Emerald		SC	G4	S1S2
Butterflies and Moths					
Lycaeides idas nabokovi	Northern Blue		T	G5TU	S2
Lycaeides melissa samuelis	Karner Blue	LE	T	G5T2	S2
Merolonche dolli	Doll's Merolonche		SC	G3G4	S1S2
Meropleon ambifusca	Newman's Brocade		SC	G3G4	S1S2
Oarisma poweshiek	Poweshiek Skipperling		T	G2G3	S1S2
Neonympha mitchellii mitchellii	Mitchell's Satyr	LE	E	G1G2T1T2	S1
Erebia discoidalis	Red-disked Alpine		SC	G5	S2S3
Euphyes dukesi	Dukes' Skipper		T	G3	S1
Euxoa aurulenta	Dune Cutworm		SC	G5	S1S2
Fixsenia favonius ontario	Northern Hairstreak		SC	G4T4	S1
Euchloe ausonides	Large Marble		SC	G5	S1S2
Incisalia henrici	Henry's Elfin		SC	G5	S2S3
Incisalia irus	Frosted Elfin		T	G3	S2S3
Hesperia ottoe	Ottoe Skipper		T	G3G4	S1S2
Heterocampa subrotata	Small Heterocampa		SC	G4G5	S1S2
Heteropacha rileyana	Riley's Lappet Moth		SC	G4	S1S2
Hemileuca maia	Barrens Buckmoth		SC	G5	S2S3
Eacles imperialis pini	Pine Imperial Moth		SC	G5T3T4	S2S3
Erora laeta	Early Hairstreak		SC	G3G4	S2S3
Erynnis baptisiae	Wild Indigo Duskywing		SC	G5	S2S3
Erynnis persius persius	Persius Duskywing		T	G5T1T3	S3
Chlosyne gorgone carlota	Gorgone Checkerspot		SC	G5T5	S2S3
Brachionycha borealis	Boreal Brachionyncha		SC	G4	S1S2
Atrytonopsis hianna	Dusted Skipper		T	G4G5	S2S3
Basilodes pepita	Gold Moth		SC	G4	S1S2
Battus philenor	Pipevine Swallowtail		SC	G5	S1S2
Boloria freija	Freija Fritillary		SC	G5	S3S4
Boloria frigga	Frigga Fritillary		SC	G5	S3S4
Calephelis mutica	Swamp Metalmark		SC	G3	S1S2
Catocala amestris	Three-staff Underwing		E	G4	S1
Catocala dulciola	Quiet Underwing		SC	G3	S1S2
Catocala illecta	Magdalen Underwing		SC	G5	S2S3
Catocala robinsoni	Robinson's Underwing		SC	G4	S2S3
Acronicta falcula	Corylus Dagger Moth		SC	G2G4	S2S3
Pachypolia atricornis	Three-horned Moth		SC	G3G4	S1S2
Phyciodes batesii	Tawny Crescent		SC	G4	S4
Oeneis macounii	Macoun's Arctic		SC	G5	S2S3
Oncocnemis piffardi	3-striped Oncocnemis		SC	G4	S1S2
Papaipema aweme	Aweme Borer		SC	GH	SH

Appendix B - Rare terrestrial animal list - continued

Scientic Name	Common Name	Federal status	State status	Global rank	State rank
Papaipema beeriana	Blazing Star Borer		SC	G3	S1S2
Papaipema cerina	Golden Borer		SC	G4	S1S2
Papaipema maritima	Maritime Sunflower Borer		SC	G3	S1S2
Papaipema sciata	Culvers Root Borer		SC	G3G4	S2S3
Papaipema silphii	Silphium Borer Moth		T	G3G4	S1S2
Papaipema speciosissima	Regal Fern Borer		SC	G4	S2S3
Pyrgus wyandot	Grizzled Skipper		SC	G1G2Q	S1S2
Spartiniphaga inops	Spartina Moth		SC	G2G4	S1S2
Speyeria idalia	Regal Fritillary		E	G3	SH
Polygonia gracilis	Hoary Comma		SC	G5	S3
Proserpinus flavofasciata	Yellow-banded Day-sphinx		SC	G4	S2S3
Schinia indiana	Phlox Moth		E	G2G4	S1S2
Schinia lucens	Leadplant Flower Moth		E	G4	S1
Pygarctia spraguei	Sprague's Pygarctia		SC	G5	S2S3
Cicadas and Hoppers					
Prosapia ignipectus	Red-legged Spittlebug		SC	G4	S2S3
Philaenarcys killa	Spittlebug		SC	GNR	S1S2
Dorydiella kansana	Leafhopper		SC	GNR	S1S2
Flexamia delongi	Leafhopper		SC	GNR	S1S2
Flexamia huroni	Huron River Leafhopper		SC	GNR	S1
Flexamia reflexus	Leafhopper		SC	GNR	S1
Lepyronia angulifera	Angular Spittlebug		SC	G3	S1S2
Lepyronia gibbosa	Great Plains Spittlebug		T	G3G4	S1S2
Damselflies and Dragonflies					
Tachopteryx thoreyi	Grey Petaltail		SC	G4	S1S3
Williamsonia fletcheri	Ebony Boghaunter		SC	G3G4	S1S2
Grasshoppers and Crickets					
Trimerotropis huroniana	Lake Huron Locust		T	G2G3	S2S3
Psinidia fenestralis	Atlantic-coast Locust		SC	G5	S1S3
Scudderia fasciata	Pine Katydid		SC	GNR	S1S3
Orchelimum concinnum	Red-faced Meadow Katydid		SC	GNR	S2S3
Orchelimum delicatum	Delicate Meadow Katydid		SC	GNR	S1S3
Orphulella pelidna	Green Desert Grasshopper		SC	G5	S1S3
Paroxya hoosieri	Hoosier Locust		SC	G5	S2S3
Atlanticus davisi	Davis's Shield-bearer		SC	GNR	S2S3
Appalachia arcana	Secretive Locust		SC	G2G3	S2S3
Melanoplus flavidus	Blue-legged Locust		SC	G4	S1S3
Oecanthus laricis	Tamarack Tree Cricket		SC	G1G2	S1S2
Oecanthus pini	Pinetree Cricket		SC	GNR	S1S2
Neoconocephalus lyristes	Bog Conehead		SC	GNR	S1S3
Neoconocephalus retusus	Conehead Grasshopper		SC	GNR	S1
Mammals					
Myotis sodalis	Indiana Bat or Indiana Myotis	LE	E	G2	S1
Microtus ochrogaster	Prairie Vole		E	G5	S1
Microtus pinetorum	Woodland Vole		SC	G5	S3S4
Felis concolor	Cougar	PS	E	G5	SH
Felis lynx	Lynx	LT	E	G5	S1
Alces alces	Moose		SC	G5	S4

Appendix B - Rare terrestrial animal list - continued

Scientic Name	Common Name	Federal status	State status	Global rank	State rank
Canis lupus	Gray Wolf	LT	T	G4	S3
Cryptotis parva	Least Shrew		T	G5	S1S2
Pipistrellus subflavus	Eastern Pipistrelle		SC	G5	S2
Sorex fumeus	Smoky Shrew		SC	G5	S1
Reptiles					
Nerodia erythrogaster neglecta	Copperbelly Watersnake	LT	E	G5T2T3	S1
Glyptemys insculpta	Wood Turtle		SC	G4	S2S3
Emydoidea blandingii	Blanding's Turtle		SC	G4	S3
Clonophis kirtlandii	Kirtland's Snake		E	G2	S1
Cnemidophorus sexlineatus	Six-lined Racerunner		SC	G5	SU
Clemmys guttata	Spotted Turtle		T	G5	S2
Pantherophis gloydi	Eastern Fox Snake		T	G5T3	S2
Pantherophis spiloides	Black Rat Snake		SC	G5T5	S3
Sistrurus catenatus catenatus	Eastern Massasauga	C	SC	G3G4T3T4	S3S4
Terrapene carolina carolina	Eastern Box Turtle		SC	G5T5	S2S3
Snails					
Pupilla muscorum	Widespread Column		SC	G5	SU
Philomycus carolinianus	Carolina Mantleslug		SC	G5	SU
Planogyra asteriscus	Eastern Flat-whorl		SC	G3G4	S3
Vertigo bollesiana	Delicate Vertigo		SC	G3	S2
Vertigo cristata	Land Snail		SC	G4	S3
Vertigo elatior	Tapered Vertigo		SC	G5	S3
Vertigo hubrichti	Hubricht's Vertigo		SC	G3	S2
Vertigo modesta	Cross Vertigo		SC	G5	S1
Vertigo modesta parietalis	Land Snail		SC	G5T1	S1
Vertigo morsei	Six-whorl Vertigo		SC	G2G3	S2
Vertigo nylanderi	Deep-throat Vertigo		SC	G2	S1
Vertigo paradoxa	Land Snail		SC	G3G4Q	S3
Vertigo pygmaea	Crested Vertigo		SC	G5	SU
Vallonia gracilicosta albula	Land Snail		SC	G4Q	S1
Xolotrema denotata	Velvet Wedge		SC	G5	SU
Discus patulus	Domed Disc		SC	G5	SU
Appalachina sayanus	Spike-lip Crater		SC	G5	SU
Anguispira kochi	Banded Globe		SC	G5	SU
Catinella exile	Land Snail		SC	G2	SU
Gastrocopta holzingeri	Lambda Snaggletooth Snail		SC	G5	S1
Guppya sterkii	Land Snail		SC	G5Q	S1
Hendersonia occulta	Cherrystone Drop		T	G5	S1
Euconulus alderi	Land Snail		SC	G3Q	S2
Mesodon elevatus	Proud Globe		SC	G5	SU
Mesomphix cupreus	Copper Button		SC	G5	SU

Appendix C - Rare aquatic plant list

Species	Common name	Fed	State	Grank	Srank
Armoracia lacustris	Lake cress		T	G4?	S2
Callitriche hermaphroditica	Autumnal water-starwort		SC	G5	S2
Callitriche heterophylla	Large water-starwort		T	G5	S1
Lemna valdiviana	Pale duckweed		X	G5	SX
Myriophyllum alterniflorum	Alternate-leaved water-milfoil		SC	G5	S2S3
Myriophyllum farwellii	Farwell's water-milfoil		T	G5	S2
Nelumbo lutea	American lotus		T	G4	S2
Nuphar pumila	Small yellow pond-lily		E	G5T4T5	S1S2
Nymphaea tetragona	pygmy water-lily		E	G5	S1
Potamogeton bicupulatus	Waterthread pondweed		T	G4	S2
Potamogeton confervoides	Alga pondweed		SC	G4	S3
Potamogeton hillii	Hill's pondweed		T	G3	S2
Potamogeton pulcher	Spotted pondweed		T	G5	S2
Potamogeton vaseyi	Vasey's pondweed		T	G4	SH
Ruppia maritima	Widgeon-grass		T	G5	S1
Subularia aquatica	Awlwort		E	G5	S1
Utricularia inflata	Floating bladderwort		E	G5	S1
Utricularia subulata	Zigzag bladderwort		T	G5	S1
Wolffia papulifera	Water-meal		T	G4	S1

Appendix D - Rare aquatic animal list

Species	Common Name	Federal status	State Status	Global Rank	State Rank
BIRDS					
Gavia immer	Common loon		T	G5	S3S4
INSECTS					
Brychius hungerfordi	Hungerford's crawling water beetle	LE	E	G1	S1
Cordulegaster erronea	Tiger spiketail		SC	G4	S1S2
Gomphus lineatifrons	Splendid clubtail		SC	G4	S2S3
Gomphus quadricolor	Rapids clubtail		SC	G3G4	S2S3
Ophiogomphus anomalus	Extra-striped snaketail		SC	G3	S1
Ophiogomphus howei	Pygmy snaketail		SC	G3	S1
Stenelmis douglasensis	Douglas stenelmis riffle beetle		SC	G1G3	S1S2
Stylurus amnicola	Riverine snaketail		SC	G4	S1S2
Stylurus laurae	Laura's snaketail		SC	G4	S1S2
Stylurus notatus	Elusive snaketail		SC	G3	S1S2
Stylurus plagiatus	Russet-tipped clubtail		SC	G5	S1S2
FISH					
Acipenser fulvescens	Lake Sturgeon		T	G3G4	S2
Ammocrypta pellucida	Eastern Sand Darter		T	G3	S1S2
Clinostomus elongatus	Redside Dace		E	G4	S1S2
Coregonus artedi	Cisco or Lake Herring		T	G5	S3
Coregonus hubbsi	Ives Lake Cisco		SC	G1Q	S1
Coregonus johannae	Deepwater Cisco		X	GX	SX
Coregonus kiyi	Kiyi		SC	G3	S3
Coregonus nigripinnis	Blackfin Cisco		X	GXQ	SX
Coregonus reighardi	Shortnose Cisco		X	GH	SH
Coregonus zenithicus	Shortjaw Cisco		T	G3	S2
Coregonus zenithicus bartletti	Siskiwit Lake Cisco		SC	GHQ	S1
Cottus ricei	Spoonhead Sculpin		SC	G5	S3
Erimyzon oblongus	Creek Chubsucker		E	G5	S1S2
Etheostoma zonale	Banded Darter		SC	G5	S1
Fundulus dispar	Starhead Topminnow		SC	G4	S2
Hiodon tergisus	Mooneye		T	G5	S2
Hybopsis amblops	Bigeye Chub		X	G5	SH
Ictiobus niger	Black Buffalo		SC	G5	S3
Lepisosteus oculatus	Spotted Gar		SC	G5	S2S3
Macrhybopsis storeriana	Silver Chub		SC	G5	S2S3
Moxostoma carinatum	River Redhorse		T	G4	S1
Notropis anogenus	Pugnose Shiner		SC	G3	S3
Notropis chalybaeus	Ironcolor Shiner		X	G4	S1
Notropis photogenis	Silver Shiner		E	G5	S1
Notropis texanus	Weed Shiner		X	G5	S1
Noturus miurus	Brindled Madtom		SC	G5	S2S3
Noturus stigmosus	Northern Madtom		E	G3	S1
Opsopoeodus emiliae	Pugnose Minnow		E	G5	S1
Percina copelandi	Channel Darter		E	G4	S1S2
Percina shumardi	River Darter		E	G5	S1
Phoxinus erythrogaster	Southern Redbelly Dace		E	G5	S1
Polyodon spathula	Paddlefish		X	G4	SX

Appendix D - Rare aquatic animal list continued

Species	Common Name	Federal status	State Status	Global Rank	State Rank
Sander canadensis	Sauger		T	G5	S1
Stizostedion vitreum glaucum	Bluepike		X	G5TX	SX
Thymallus arcticus	Arctic Grayling		X	G5	SX
MUSSELS					
Alasmidonta marginata	Elktoe		SC	S2S3	G4
Alasmidonta viridis	Slippershell Mussel		SC	S2S3	G4G5
Anodonta subgibbosa	Lake Floater		T	S1	G1Q
Cyclonaias tuberculata	Purple Wartyback		SC	S2S3	G5
Dysnomia sulcata	Catspaw	LE	E	SH	G1
Epioblasma obliquata perobliqua	White Catspaw	LE	E	SH	G1T1
Epioblasma torulosa rangiana	Northern Riffleshell	LE	E	S1	G2T2
Epioblasma triquetra	Snuffbox		E	S1	G3
Lampsilis fasciola	Wavy-rayed Lampmussel		T	S2	G4
Leptodea leptodon	Scaleshell	LE	SC	SU	G1
Obovaria olivaria	Hickorynut		SC	S2S3	G4
Obovaria subrotunda	Round Hickorynut		E	S1	G4
Pleurobema clava	Clubshell	LE	E	S1	G2
Pleurobema coccineum	Round Pigtoe		SC	S2S3	G4
Simpsonaias ambigua	Salamander Mussel		E	S1	G3
Toxolasma lividus	Purple Lilliput		E	S1	G2
Venustaconcha ellipsiformis	Ellipse		SC	S2S3	G3G4
Villosa fabalis	Rayed Bean	C	E	S1	G1G2
Villosa iris	Rainbow		SC	S2S3	G5
SNAILS					
Acella haldemani	Spindle Lymnaea		SC	S3	G3
Fontigens nickliniana	Watercress Snail		SC	SU	G5
Planorbella multivolvis	Acorn Ramshorn		E	SX	GX
Planorbella smithi	Aquatic Snail		SC	S2	G2
Pomatiopsis cincinnatiensis	Brown Walker		SC	SU	G4
Pyrgulopsis letsoni	Gravel Pyrg		SC	SU	G5
Stagnicola contracta	Deepwater Pondsnail		T	S1	G1
Stagnicola petoskeyensis	Petoskey Pondsnail		E	SH	GH

Appendix E - Global and State rank descriptions

GLOBAL RANKS

G1 = critically imperiled globally because of extreme rarity (5 or fewer occurrences range-wide or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2 = imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.
G3 = either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g. a single western state, a physiographic region in the East) or because of other factor(s) making it vulnerable to extinction throughout its range; in terms of occurrences, in the range of 21 to 100.
G4 = apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery.
G5 = demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GH = of historical occurrence throughout its range, i.e. formerly part of the established biota, with the expectation that it may be rediscovered (e.g. Bachman's Warbler).
GU = possibly in peril range-wide, but status uncertain; need more information.
GX = believed to be extinct throughout its range (e.g. Passenger Pigeon) with virtually no likelihood that it will be rediscovered.

STATE RANKS

S1 = critically imperiled in the state because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extirpation in the state.
S2 = imperiled in state because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extirpation from the state.
S3 = rare or uncommon in state (on the order of 21 to 100 occurrences).
S4 = apparently secure in state, with many occurrences.
S5 = demonstrably secure in state and essentially ineradicable under present conditions.
SA = accidental in state, including species (usually birds or butterflies) recorded once or twice or only at very great intervals, hundreds or even thousands of miles outside their usual range.
SE = an exotic established in the state; may be native elsewhere in North America (e.g. house finch or catalpa in eastern states).
SH = of historical occurrence in state and suspected to be still extant.
SN = regularly occurring, usually migratory and typically nonbreeding species.
SR = reported from state, but without persuasive documentation which would provide a basis for either accepting or rejecting the report.
SRF = reported falsely (in error) from state but this error persisting in the literature.
SU = possibly in peril in state, but status uncertain; need more information.
SX = apparently extirpated from state.

Appendix F - MNFI Natural Community List

(Names in italics represent categories that are not currently tracked as separate natural communities)

Community Name	**State Rank**	**Global Rank**
Alvar [Alvar grassland]	S1	G2
Bedrock glade		
Basalt bedrock glade	S2	G3
Igneous bedrock glade	S2	G3G4
Limestone bedrock glade [Alvar glade]	S2	G2?
Sandstone bedrock glade	S2?	G3G4
Volcanic conglomerate bedrock glade	S2	G3
Bedrock lakeshore		
Basalt bedrock lakeshore	S2	G4G5
Igneous bedrock lakeshore	S2	G?
Limestone pavement lakeshore [Alvar pavement]	S2	G?
Volcanic conglomerate bedrock lakeshore	S2	G4G5
Bog	S4	G5
Boreal forest	S3	G4G5
Bur oak plains	SX	G1
Cave	S1	G4?
Cliff		
Dry acid cliff	S2?	G4G5
Dry non-acid cliff	S2	G4G5
Moist acid cliff	S2?	G4G5
Moist non-acid cliff	S2	G4G5
Coastal plain marsh	S2	G2?
Cobble beach [Cobble shore]	S3	G4G5
Dry northern forest [Pine forest]	S3	G4
Dry sand prairie	S2	G2G3
Dry southern forest [Oak forest]	S3	G4?
Dry-mesic northern forest [Pine-hardwood forest]	S3	G4?
Dry-mesic southern forest [Oak-hardwood forest]	S3	G4?
Emergent marsh	S4	G5
Great Lakes barrens	S2	G2
Great Lakes marsh	S3	G4
Hardwood-conifer swamp	S3	G3G4
Hillside prairie	S1	G3
Inland salt marsh	S1	G1
Interdunal wetland	S2	G3?
Intermittent wetland [Boggy seepage wetland]	S3	G3
Inundated shrub swamp	S3	G4
Lakeplain mesic sand prairie	S1	G1
Lakeplain oak openings	S1	G1
Lakeplain wet prairie	S2	G2G3
Lakeplain wet-mesic prairie	S2	G2
Lakeshore cliff		
Basalt lakeshore cliff	S1	G3?
Sandstone lakeshore cliff	S2	G3?
Volcanic conglomerate lakeshore cliff	S1	G3?
Mesic northern forest [Northern hardwood forest; Hemlock-hardwood forest]	S3	G4
Mesic prairie	S1	G1G2
Mesic sand prairie	S1	G2
Mesic southern forest [Southern hardwood forest]	S3	G3G4
Muskeg	S3	G4G5

Appendix F - MNFI Natural Community List - Continued

Northern bald [Krummholz ridgetop]	S1	G3G4
Northern fen	S3	G4G5
Northern shrub thicket	S5	G5?
Northern swamp	S3?	G4?
Northern wet meadow	S4	G4G5
Northern wet-mesic prairie	S1	G?
Oak barrens	S2	G3
Oak openings	S1	G1
Oak-pine barrens	S2	G2?
Open dunes	S3	G3G5
Patterned fen	S2	G3G4
Pine barrens	S2	G2
Poor conifer swamp	S4	G5
Poor fen	S3	G3G4
Prairie fen	S3	G3G4
Relict conifer swamp	S3	G3
Rich conifer swamp	S3	G4
Sand/gravel beach	S3	G3?
Sinkhole	S2	G3G5
Southern floodplain forest	S3	G3G5
Southern shrub-carr	S5	G5
Southern swamp	S3	G4?
Southern wet meadow	S3	G4?
Submergent marsh	S4	G5
Wet prairie	S2	G3?
Wet-mesic prairie	S2	G2G3
Wooded dune and swale complex	S3	G3
Woodland prairie	S2	G3

Appendix G - Description of Ecological Drainage Units

There are nine Ecological Drainage Units in Michigan, we combined them into 7 EDUs. The following paragraphs briefly describe each one in terms of climate, within ecoregion sections and subsections, major landforms, water features, and zoogeography.

(16) Southeast Michigan Interlobate and Lake Plain (SEMILP) contains most of the Lake Erie drainage in Michigan. Mean annual temperature is 48.6ˆF (sd 1.1) and has a mean annual precipitation of 30.5 inches (sd 4.8). This EDU contains many kettle lakes, ponds, and wetland complexes in the interlobate headwaters region. In the lake and till plains, there are few lakes but many low gradient streams. Historically, all streams flow to the Ohio River via the Teays River but today they all flow into western Lake Erie and Lake St. Clair.

(2) Only a small portion of the Western Lake Erie (WLE) EDU is in Michigan, most of the EDU is in Ohio. The mean annual temperature in this EDU is 48.6-50.1ˆF (sd 1.0-1.2) and the mean annual precipitation is between 30.5-34.3 (sd 4.6-4.8) inches. This EDU mainly has low gradient, surface water-fed streams except in the interlobate area (along the glacial boundary) where moderate gradient streams occur. Historically, all streams drained to the Ohio River via Teays River but today they all flow into western Lake Erie. Because only a small area of this EDU is in Michigan, it will be combined with the SEMILP EDU for this analysis.

(4) The Saginaw Bay (SB) EDU if found in the lower half of the Huron River Basin. The mean annual temperature is 48.5 to 43.3 (sd 1.08) ˆF and the mean annual precipitation is 29.2 (sd 3.8) to 31.7 (sd 4.56) inches from south to north respectively. Many of the streams in this EDU are intermittent. Those that are perennial are part of the Saginaw River system and are generally low gradient streams. Historically, all streams drained west out to the Grand River into Lake Chicago but today they drain to Saginaw Bay and Lake St. Clair.

(3) The Southeast Lake Michigan (SELM) EDU is the southern portion of the Lake Michigan basin. Mean annual air temperatures range from 48.6 (sd 1.15) to 47.4 (sd 1.11) ˆF and mean annual precipitation is 35.1 (sd 4.9) to 31.7 (sd 4.56) inches with the rain shadow from west to east. This EDU has three major river systems (Grand, Kalamazoo, and St. Joseph) which flow east to west. There are many kettle lakes in the interlobate region to the east, which forms the headwaters of all three river systems. Historically, all waters in this region drained west out the Grand River into Lake Chicago, today all rivers flow west to southern Lake Michigan.

(5) The Northern Lake Michigan, Lake Huron, and Straits of Mackinac (NLMLHSM) EDU encompasses the northern half of the lower peninsula of Michigan. Mean annual air temperatures range from 46.1 (sd 1.16) to 43.3 (sd 1.08) ˆF from west to east and mean annual precipitation ranges from 33.1 (sd 4.38) to 29.5 (sd 3.29) inches from west to each with a rain shadow from southwest to northwest. There are kettle lakes in the outwash plains areas. In the lake plain area there are some large lakes, lakes of many geneses, and intermittent streams. Groundwater streams can be found in the outwash surrounded by coarse moraines and ice contact. Historically, this area likely drained to the St. Lawrence River via the Ottowa River and Champlain Sea but today, rivers drain west to Lake Michigan, east to Lake Huron, and north to the straits. The Lake Michigan and Lake Huron drainage divide roughly bisects this EDU.

(7) In the Eastern Upper Peninsula (EUP) EDU the mean annual temperature is 41.1 (sd 1.06) ˆF and the mean annual precipitation is 32.5 (sd 4.07) inches. This EDU has many small and medium sized low-gradient streams which are underlain by deep sandy outwash deposits or sedimentary rock. They are also often connected to wetlands. Historically, the streams in this area likely drained to the St. Lawrence River via the Ottowa River and Champlain Sea, but today waters drain to the north to Lake Superior and to the south to Lakes Michigan and Huron and to the St. Mary's River.

(8) In the Central Upper Peninsula (CUP) EDU the mean annual temperature is 40.4 (sd 1.22) ˆF and the mean annual precipitation is 32.5 (sd 4.39) inches. Half of this EDU is within the Menominee River drainage. There are many lakes, spring ponds, springs, wetlands, and streams in this EDU. Kettle lakes are common. Streams tend to be low in density and have dendritic drainages and high spring and fall water flows with relatively low flows in the summer. These low gradient streams are underlain by sandy outwash, limestone, or shale. Historically, the waters in this EDU drained south to the Mississippi River via a connection through Green Bay (Wolf/Fox Rivers), but today it drains north to Lake Superior and south to northern Lake Michigan / Green Bay.

(6) The Western Upper Peninsula and Keweenaw Peninsula (WUPKP) EDU has mean annual air temperatures of 40.42 (sd 1.22) ˆF and a mean annual precipitation of 32.5 (sd 4.39) inches. This EDU has many kettle lakes in the outwash plains. Historically, the waters in this EDU drained to the upper Mississippi River via St. Croix River drainage of glacial Lake Duluth with a possible connection to Hudson Bay and Lake Agassiz. Today the waters drain to the southwest into Lake Superior.

(12) A very small portion of Michigan is in the Bayfield Peninsula and Uplands (BPU) EDU. The mean annual temperature in this EDU is 41.41 (sd 1.16) ˆF and the mean annual precipitation is 31.29 (sd 5.39) inches, this precipitation. There are few lakes in this EDU and the streams are low gradient and flow from west to east into Lake Michigan. Historically, this EDU drained to the Mississippi River via the Fox River, but today it drains to western Lake Michigan. Only a very small portion of this EDU is in Michigan, hence we will combine it with the WUPKP EDU during our analysis because it is in the same ecoregion.

Appendix H - Natural Vegetation Type datalayers and descriptions

File Name	Vegetation Type	road layer	minimum size patches (acres)	buffer size in meters
allforgps	All Forest	none	20	0
allfor_min	All Forest	none	5000	0
allfor_90	All Forest	none	5000	90
allfor_210	All Forest	none	5000	210
allfor_300	All Forest	none	5000	300
allforjgps	All Forest	major	20	0
allforj_min	All Forest	major	5000	0
allforj_90	All Forest	major	5000	90
allforj_210	All Forest	major	5000	210
allforj_300	All Forest	major	5000	300
allformgps	All Forest	all	20	0
allform_min	All Forest	all	5000	0
allform_90	All Forest	all	5000	90
allform_210	All Forest	all	5000	210
allform_300	All Forest	all	5000	300
upfgps	Upland Forest	none	20	0
upf_min	Upland Forest	none	5000	0
upf_90	Upland Forest	none	5000	90
upf_210	Upland Forest	none	5000	210
upf_300	Upland Forest	none	5000	300
upfjgps	Upland Forest	major	20	0
upfj_min	Upland Forest	major	5000	0
upfj_90	Upland Forest	major	5000	90
upfj_210	Upland Forest	major	5000	210
upfj_300	Upland Forest	major	5000	300
upfmgps	Upland Forest	all	20	0
upfm_min	Upland Forest	all	5000	0
upfm_90	Upland Forest	all	5000	90
upfm_210	Upland Forest	all	5000	210
upfm_300	Upland Forest	all	5000	300
updecgps	Upland decidious forest	none	20	0
updec_min	Upland decidious forest	none	5000	0
updec_90	Upland decidious forest	none	5000	90
updec_210	Upland decidious forest	none	5000	210
updec_300	Upland decidious forest	none	5000	300
updecjgps	Upland decidious forest	major	20	0
updecj_min	Upland decidious forest	major	5000	0
updecj_90	Upland decidious forest	major	5000	90
updecj_210	Upland decidious forest	major	5000	210
updecj_300	Upland decidious forest	major	5000	300
updecmgps	Upland decidious forest	all	20	0
updecm_min	Upland decidious forest	all	5000	0
updecm_90	Upland decidious forest	all	5000	90
n/a	Upland decidious forest	all	5000	210
n/a	Upland decidious forest	all	5000	300
upmgps	Upland mixed forest	none	20	0

Appendix H - Natural Vegetation Type datalayers and descriptions - continued

File Name	Vegetation Type	road layer	minimum size patches (acres)	buffer size in meters
upmix_min	Upland mixed forest	none	5000	0
n/a	Upland mixed forest	none	5000	90
n/a	Upland mixed forest	none	5000	210
n/a	Upland mixed forest	none	5000	300
upmjgps	Upland mixed forest	major	20	0
upmixj_min	Upland mixed forest	major	5000	0
n/a	Upland mixed forest	major	5000	90
n/a	Upland mixed forest	major	5000	210
n/a	Upland mixed forest	major	5000	300
upmmgps	Upland mixed forest	all	20	0
upmixm_min	Upland mixed forest	all	5000	0
n/a	Upland mixed forest	all	5000	90
n/a	Upland mixed forest	all	5000	210
n/a	Upland mixed forest	all	5000	300
upcongps	Upland coniferous forest	none	20	0
upcon_min	Upland coniferous forest	none	50	0
upcon_90	Upland coniferous forest	none	50	90
upcon_210	Upland coniferous forest	none	50	210
upcon_300	Upland coniferous forest	none	50	300
upconjgps	Upland coniferous forest	major	20	0
upconj_min	Upland coniferous forest	major	50	0
upconj_90	Upland coniferous forest	major	50	90
upconj_210	Upland coniferous forest	major	50	210
upconj_300	Upland coniferous forest	major	50	300
upconmgps	Upland coniferous forest	major	20	0
upconm_min	Upland coniferous forest	all	50	0
upconm_90	Upland coniferous forest	all	50	90
upconm_210	Upland coniferous forest	all	50	210
upconm_300	Upland coniferous forest	all	50	300
wetforgps	Lowland forest	none	20	0
wetfor_min	Lowland forest	none	50	0
wetfor_90	Lowland forest	none	50	90
wetfor_210	Lowland forest	none	50	210
wetfor_300	Lowland forest	none	50	300
wetforjgps	Lowland forest	major	20	0
wetforj_min	Lowland forest	major	50	0
wetforj_90	Lowland forest	major	50	90
wetforj_210	Lowland forest	major	50	210
wetforj_300	Lowland forest	major	50	300
wetformgps	Lowland forest	all	20	0
wetform_min	Lowland forest	all	50	0
wetform_90	Lowland forest	all	50	90
wetform_210	Lowland forest	all	50	210
wetform_300	Lowland forest	all	50	300
lowdecgps	Lowland deciduous forest	none	20	0
lowdec_min	Lowland deciduous forest	none	50	0

Appendix H - Natural Vegetation Type datalayers and descriptions - continued

File Name	Vegetation Type	road layer	minimum size patches (acres)	buffer size in meters
lowdec_90	Lowland deciduous forest	none	50	90
lowdec_210	Lowland deciduous forest	none	50	210
lowdec_300	Lowland deciduous forest	none	50	300
lowdecgps	Lowland deciduous forest	major	20	0
lowdecj_min	Lowland deciduous forest	major	50	0
lowdecj_90	Lowland deciduous forest	major	50	90
lowdecj_210	Lowland deciduous forest	major	50	210
lowdecj_300	Lowland deciduous forest	major	50	300
lowdecmgps	Lowland deciduous forest	all	20	0
lowdecm_min	Lowland deciduous forest	all	50	0
lowdecm_90	Lowland deciduous forest	all	50	90
lowdecm_210	Lowland deciduous forest	all	50	210
lowdecm_300	Lowland deciduous forest	all	50	300
lowmixgps	Lowland mixed forest	none	20	0
lowmix_min	Lowland mixed forest	none	50	0
lowmix_90	Lowland mixed forest	none	50	90
n/a	Lowland mixed forest	none	50	210
n/a	Lowland mixed forest	none	50	300
lowmixjgps	Lowland mixed forest	major	20	0
lowmixj_min	Lowland mixed forest	major	50	0
lowmixj_90	Lowland mixed forest	major	50	90
n/a	Lowland mixed forest	major	50	210
n/a	Lowland mixed forest	major	50	300
lowmixmgps	Lowland mixed forest	all	20	0
lowmixm_min	Lowland mixed forest	all	50	0
lowmixm_90	Lowland mixed forest	all	50	90
n/a	Lowland mixed forest	all	50	210
n/a	Lowland mixed forest	all	50	300
lowcongps	Lowland coniferous forest	none	20	0
lowcon_min	Lowland coniferous forest	none	50	0
lowcon_90	Lowland coniferous forest	none	50	90
lowcon_210	Lowland coniferous forest	none	50	210
lowcon_300	Lowland coniferous forest	none	50	300
lowconjgps	Lowland coniferous forest	none	20	0
lowconj_min	Lowland coniferous forest	major	50	0
lowconj_90	Lowland coniferous forest	major	50	90
lowconj_210	Lowland coniferous forest	major	50	210
lowconj_300	Lowland coniferous forest	major	50	300
lowconmgps	Lowland coniferous forest	all	20	0
lowconm_min	Lowland coniferous forest	all	50	0
lowconm_90	Lowland coniferous forest	all	50	90
lowconm_210	Lowland coniferous forest	all	50	210
lowconm_300	Lowland coniferous forest	all	50	300
grassgps	Filtered grassland	none	20	0
grass_min	Filtered grassland	none	50	0
grass_90	Filtered grassland	none	50	90

Appendix H - Natural Vegetation Type datalayers and descriptions - continued

File Name	Vegetation Type	road layer	minimum size patches (acres)	buffer size in meters
grass_210	Filtered grassland	none	50	210
grass_300	Filtered grassland	none	50	300
grassjgps	Filtered grassland	major	20	0
grassj_min	Filtered grassland	major	50	0
grassj_90	Filtered grassland	major	50	90
grassj_210	Filtered grassland	major	50	210
grassj_300	Filtered grassland	major	50	300
grassmgps	Filtered grassland	all	20	0
grassm_min	Filtered grassland	all	50	0
grassm_90	Filtered grassland	all	50	90
grassm_210	Filtered grassland	all	50	210
grassm_300	Filtered grassland	all	50	300
nonforgps	Non-forested wetland	none	0.1	0
nonfor_90	Non-forested wetland	none	0.1	90
nonfor_210	Non-forested wetland	none	0.1	210
nonfor_300	Non-forested wetland	none	0.1	300
nonforjgps	Non-forested wetland	major	0.1	0
nonforj_90	Non-forested wetland	major	0.1	90
nonforj_210	Non-forested wetland	major	0.1	210
nonforj_300	Non-forested wetland	major	0.1	300
nonformgps	Non-forested wetland	all	0.1	0
nonform_90	Non-forested wetland	all	0.1	90
nonform_210	Non-forested wetland	all	0.1	210
nonform_300	Non-forested wetland	all	0.1	300

All forests
Allforgps
Patches of all forest types.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Allforjgps
Patches of all forest types, cut by major roads.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches.

Allformgps
Patches of all forest types, cut by all roads.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches.

Allfor_min
Patches of all forest types, greater than 2000 hectares.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Allforj_min
Patches of all forest types, cut by major roads, greater than 2000 hectares.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Allform_min
Patches of all forest types, cut by all roads, greater than 2000 hectares.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Allfor_90
Patches of all forest types, greater than 2000 hectares, after buffering inward 90 meters.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Allfor_210
Patches of all forest types, greater than 2000 hectares, after buffering inward 210 meters.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Allfor_300
Patches of all forest types, greater than 2000 hectares, after buffering inward 300 meters.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Allforj_90
Patches of all forest types, cut by major roads, greater than 2000 hectares, after buffering inward 90 meters.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Allforj_210
Patches of all forest types, cut by major roads, greater than 2000 hectares, after buffering inward 210 meters.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Allforj_300
Patches of all forest types, cut by major roads, greater than 2000 hectares, after buffering inward 300 meters.
All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Allform_90
Patches of all forest types, cut by all roads, greater than 2000 hectares, after buffering inward 90 meters.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Allform_210
Patches of all forest types, cut by all roads, greater than 2000 hectares, after buffering inward 210 meters.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Allform_300
Patches of all forest types, cut by all roads, greater than 2000 hectares, after buffering inward 300 meters.

All forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the forest land cover types. The remaining forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Lowland coniferous forests

Lcgps
Patches of lowland coniferous forest types.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Lcjgps
Patches of lowland coniferous forest types, cut by major roads.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches.

Lcmgps
Patches of lowland coniferous forest types, cut all roads.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches.

Lowcon_min
Patches of lowland coniferous forest types, greater than 50 hectares.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowconj _min
Patches of lowland coniferous forest types, cut by major roads, greater than 50 hectares.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland coniferous forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowconm _min
Patches of lowland coniferous forest types, cut by all roads, greater than 50 hectares.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland coniferous forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowcon _90
Patches of lowland coniferous forest types, greater than 50 hectares, after buffering inward 90 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowcon _210
Patches of lowland coniferous forest types, greater than 50 hectares, after buffering inward 210 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowcon _300
Patches of lowland coniferous forest types, greater than 50 hectares, after buffering inward 300 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowconj_90
Patches of lowland coniferous forest types, cut by major roads, greater than 50 hectares, after buffering inward 90 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland coniferous forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowconj_210
Patches of lowland coniferous forest types, cut by major roads, greater than 50 hectares, after buffering inward 210 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland coniferous forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowconj_300
Patches of lowland coniferous forest types, cut by major roads, greater than 50 hectares, after buffering inward 300 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland coniferous forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowconm_90
Patches of lowland coniferous forest types, cut by all roads, greater than 50 hectares, after buffering inward 90 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland coniferous forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowconm_210
Patches of lowland coniferous forest types, cut by all roads, greater than 50 hectares, after buffering inward 210 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland coniferous forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowconm_300
Patches of lowland coniferous forest types, cut by all roads, greater than 50 hectares, after buffering inward 300 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland coniferous forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowland deciduous
Ldgps
Patches of lowland deciduous forest types.

Lowland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Ldjgps
Patches of lowland deciduous forest types, cut by major roads.

Lowland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland forest land cover types. The remaining lowland coniferous forest cover type cells are then grouped together into patches.

Ldmgps
Patches of lowland deciduous forest types, cut by all roads.

Lowland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland forest land cover types. The remaining lowland deciduous forest cover type cells are then grouped together into patches.

Lowdec_min
Patches of lowland deciduous forest types, greater than 50 hectares.

Lowland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowdecj _min
Patches of lowland deciduous forest types, cut by major roads, greater than 50 hectares.

Lowland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland deciduous forest land cover types. The remaining lowland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowdecm _min
Patches of lowland deciduous forest types, cut by all roads, greater than 50 hectares.

Lowland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland deciduous forest land cover types. The remaining lowland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowdec _90
Patches of lowland deciduous forest types, greater than 50 hectares, after buffering inward 90 meters.

Lowland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowdecj_90
Patches of lowland deciduous forest types, cut by major roads, greater than 50 hectares, after buffering inward 90 meters.

Lowland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland deciduous forest land cover types. The remaining lowland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowdecm_90
Patches of lowland deciduous forest types, cut by all roads, greater than 50 hectares, after buffering inward 90 meters.

Lowland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland deciduous forest land cover types. The remaining lowland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowland mixed
Lmgps
Patches of lowland mixed forest types.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Lmjgps
Patches of lowland mixed forest types, cut by major roads.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the forest land cover types. The remaining lowland mixed forest cover type cells are then grouped together into patches.

Lmmgps
Patches of lowland mixed forest types, cut by all roads.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the forest land cover types. The remaining lowland mixed forest cover type cells are then grouped together into patches.

Lowmix_min
Patches of lowland mixed forest types, greater than 50 hectares.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowmixj _min
Patches of lowland mixed forest types, cut by major roads, greater than 50 hectares.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland mixed forest land cover types. The remaining lowland mixed forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowmixm _min
Patches of lowland mixed forest types, cut by all roads, greater than 50 hectares.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland mixed forest land cover types. The remaining lowland mixed forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Lowmix_90
Patches of lowland deciduous forest types, greater than 50 hectares, after buffering inward 90 meters.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowmixj_90
Patches of lowland mixed forest types, cut by major roads, greater than 50 hectares, after buffering inward 90 meters.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the lowland mixed forest land cover types. The remaining lowland mixed forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Lowmixm_90
Patches of lowland mixed forest types, cut by all roads, greater than 50 hectares, after buffering inward 90 meters.

Lowland mixed forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the lowland mixed forest land cover types. The remaining lowland mixed forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upland coniferous
Upcgps
Patches of upland coniferous forest types.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Upcjgps
Patches of upland coniferous forest types, cut by major roads.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches.

Upcmgps
Patches of upland coniferous forest types, cut by all roads.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland forest coniferous land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches.

Upcon_min
Patches of upland coniferous forest types, greater than 50 hectares.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Upconj _min
Patches of upland coniferous forest types, cut by major roads, greater than 50 hectares.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Upconm _min
Patches of upland coniferous forest types, cut by all roads, greater than 50 hectares.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Upcon _90
Patches of upland coniferous forest types, greater than 50 hectares, after buffering inward 90 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upcon _210
Patches of upland coniferous forest types, greater than 50 hectares, after buffering inward 210 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upcon _300
Patches of upland coniferous forest types, greater than 50 hectares, after buffering inward 300 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upconj_90
Patches of upland coniferous forest types, cut by major roads, greater than 50 hectares, after buffering inward 90 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upconj_210
Patches of upland coniferous forest types, cut by major roads, greater than 50 hectares, after buffering inward 210 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upconj_300
Patches of upland coniferous forest types, cut by major roads, greater than 50 hectares, after buffering inward 300 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upconm_90
Patches of upland coniferous forest types, cut by all roads, greater than 50 hectares, after buffering inward 90 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upconm_210
Patches of upland coniferous forest types, cut by all roads, greater than 50 hectares, after buffering inward 210 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upconm_300
Patches of upland coniferous forest types, cut by all roads, greater than 50 hectares, after buffering inward 300 meters.

Upland coniferous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland coniferous forest land cover types. The remaining upland coniferous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Upland deciduous
Updgps
Patches of upland deciduous forest types.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Updjgps
Patches of upland deciduous forest types, cut by major roads.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland deciduous forest land cover types. The remaining upland deciduous forest cover type cells are then grouped together into patches.

Updmgps
Patches of upland deciduous forest types, cut by all roads.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland deciduous forest land cover types. The remaining upland deciduous forest cover type cells are then grouped together into patches.

Updec_min
Patches of deciduous forest types, greater than 2000 hectares.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Updecj_min
Patches of deciduous forest types, cut by major roads, greater than 2000 hectares.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland deciduous forest land cover types. The remaining upland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Updecm_min
Patches of deciduous forest types, cut by all roads, greater than 2000 hectares.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland deciduous forest land cover types. The remaining upland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Updec_90
Patches of deciduous forest types, greater than 2000 hectares, after buffering inward 90 meters.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Updec_210

Patches of deciduous forest types, greater than 2000 hectares, after buffering inward 210 meters.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Updec_300

Patches of deciduous forest types, greater than 2000 hectares, after buffering inward 300 meters.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Updecj_90

Patches of upland deciduous forest types, cut by major roads, after buffering inward 90 meters.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland deciduous forest land cover types. The remaining upland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Updecj_210

Patches of upland deciduous forest types, cut by major roads, after buffering inward 210 meters.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland deciduous forest land cover types. The remaining upland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Updecj_300

Patches of upland deciduous forest types, cut by major roads, after buffering inward 300 meters.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland deciduous forest land cover types. The remaining upland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Updecm_90
Patches of upland deciduous forest types, cut by all roads, after buffering inward 90 meters.

Upland deciduous forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland deciduous forest land cover types. The remaining upland deciduous forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upland forests
Upfgps
Patches of all upland forest types.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Upfjgps
Patches of all upland forest types, cut by major roads.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches.

Upfmgps
Patches of all upland forest types, cut by all roads.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches.

Upf_min
Patches of all upland forest types, greater than 2000 hectares.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Upfj_min
Patches of all upland forest types, cut by major roads, greater than 2000 hectares.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Upfm_min
Patches of all upland forest types, cut by all roads, greater than 2000 hectares.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted.

Upf_90
Patches of all upland forest types, greater than 2000 hectares, after buffering inward 90 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upfor_210
Patches of all upland forest types, greater than 2000 hectares, after buffering inward 210 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upf_300
Patches of all upland forest types, greater than 2000 hectares, after buffering inward 300 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upfj_90
Patches of all upland forest types, cut by major roads, greater than 2000 hectares, after buffering inward 90 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upfj_210
Patches of all upland forest types, cut by major roads, greater than 2000 hectares, after buffering inward 210 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upfj_300
Patches of all upland forest types, cut by major roads, greater than 2000 hectares, after buffering inward 300 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upfm_90
Patches of all upland forest types, cut by all roads, greater than 2000 hectares, after buffering inward 90 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upfm_210
Patches of all upland forest types, cut by all roads, greater than 2000 hectares, after buffering inward 210 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Upfm_300
Patches of all upland forest types, cut by all roads, greater than 2000 hectares, after buffering inward 300 meters.

All upland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the upland forest land cover types. The remaining upland forest cover type cells are then grouped together into patches. Patches greater than or equal to 2000 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 2000 hectares extracted.

Wetland forests
Wforgps
Patches of all wetland forest types.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Wforjgps
Patches of all wetland forest types, cut by major roads.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches.

Wformgps
Patches of all wetland forest types, cut by all roads.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches.

Wetfor_min
Patches of all wetland forest types, greater than 50 hectares.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Wetforj_min
Patches of all wetland forest types, cut by major roads, greater than 50 hectares.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Wetform_min
Patches of all wetland forest types, cut by all roads, greater than 50 hectares.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted.

Wetfor_90
Patches of all wetland forest types, greater than 50 hectares, after buffering inward 90 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Wetfor_210
Patches of all wetland forest types, greater than 50 hectares, after buffering inward 210 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Wetfor_300
Patches of all wetland forest types, greater than 50 hectares after buffering inward 300 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Wetforj_90
Patches of all wetland forest types, cut by major roads, greater than 50 hectares after buffering inward 90 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Wetforj_210
Patches of all wetland forest types, cut by major roads, greater than 50 hectares after buffering inward 210 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Wetforj_300
Patches of all wetland forest types, cut by major roads, greater than 50 hectares after buffering inward 300 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Wetform_90
Patches of all wetland forest types, cut by all roads, greater than 50 hectares after buffering inward 90 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Wetform_210
Patches of all wetland forest types, cut by all roads, greater than 50 hectares after buffering inward 210 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Wetform_300
Patches of all wetland forest types, cut by all roads, greater than 50 hectares after buffering inward 300 meters.

All wetland forest land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the wetland forest land cover types. The remaining wetland forest cover type cells are then grouped together into patches. Patches greater than or equal to 50 hectares are extracted. Patches are shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grasslands
Grassgps
Patches of current grasslands in areas know to have historic grasslands.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches.

Grassjgps
Patches of current grasslands in areas know to have historic grasslands, cut by major roads.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches.

Grassmgps
Patches of current grasslands in areas know to have historic grasslands, cut by all roads.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. All roads are converted to raster and the road raster removed from grassland cover types. The remaining grassland cover type cells are then grouped together into patches.

Grass_min
Patches of current grasslands in areas know to have historic grasslands, greater than 50 hectares.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches and patches greater than or equal to 50 hectares are extracted.

Grassj_min
Patches of current grasslands in areas know to have historic grasslands, cut by major roads, greater than 50 hectares.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches and patches greater than or equal to 50 hectares are extracted.

Grassm_min
Patches of current grasslands in areas know to have historic grasslands, cut by all roads, greater than 50 hectares.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches and patches greater than or equal to 50 hectares are extracted.

Grass_90
Patches of current grasslands in areas known to have historic grasslands, greater than 50 hectares after buffering inward 90 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the

Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grass_210
Patches of current grasslands in areas known to have historic grasslands, greater than 50 hectares after buffering inward 210 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grass_300
Patches of current grasslands in areas known to have historic grasslands, greater than 50 hectares after buffering inward 300 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grassj_90
Patches of current grasslands in areas known to have historic grasslands, cut by major roads, greater than 50 hectares after buffering inward 90 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grassj_210
Patches of current grasslands in areas known to have historic grasslands, cut by major roads, greater than 50 hectares after buffering inward 210 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grassj_300
Patches of current grasslands in areas known to have historic grasslands, cut by major roads, greater than 50 hectares after buffering inward 300 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grassm_90
Patches of current grasslands in areas known to have historic grasslands, cut by all roads, greater than 50 hectares after buffering inward 90 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND

DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grassm_210
Patches of current grasslands in areas known to have historic grasslands, cut by all roads, greater than 50 hectares after buffering inward 210 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 7 cells (210 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Grassm_300
Patches of current grasslands in areas known to have historic grasslands, cut by all roads, greater than 50 hectares after buffering inward 300 meters.

All grassland cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) that coincide with grassland cover types in the Circa 1800 vegetation layer (BLACK OAK BARREN, EXPOSED BEDROCK, GRASSLAND, JACK PINE-RED PINE FOREST, MIXED OAK FOREST, MIXED OAK SAVANNA, MIXED PINE-OAK FOREST, OAK-HICKORY FOREST, OAK/PINE BARRENS, PINE BARRENS, SAND DUNE, WHITE PINE-RED PINE FOREST, WHITE PINE-WHITE OAK FOREST, WET PRAIRIE) are extracted and grouped together into patches. Major roads are converted to raster and the road raster removed from the grassland cover types. The remaining grassland cover type cells are then grouped together into patches and patches greater than or equal to 50 hectares are extracted. These patches are then shrunk by 10 cells (300 meters), regrouped into patches, and patches greater than or equal to 50 hectares extracted.

Non-forested wetlands
Nforgps
Patches of all non-forested wetland types.
All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches.

Nforjgps
Patches of all non-forested wetland types, cut by major roads.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the non-forested wetland land cover types. The remaining non-forested wetland cover type cells are then grouped together into patches.

Nformgps
Patches of all non-forested wetland types, cut by major roads.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the non-forested wetland land cover types. The remaining non-forested wetland cover type cells are then grouped together into patches.

Nonfor_90
Patches of all non-forested wetland types, after buffering inward 90 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches are shrunk by 3 cells (90 meters) and then regrouped into patches.

Nonfor_210
Patches of all non-forested wetland types, after buffering inward 210 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches are shrunk by 7 cells (210 meters) and regrouped into patches.

Nonfor_300
Patches of all non-forested wetland types, after buffering inward 210 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted and grouped together into patches. Patches are shrunk by 10 cells (300 meters) and regrouped into patches.

Nonforj_90
Patches of all non-forested wetland types, cut by major roads, after buffering inward 90 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the non-forested wetland land cover types. The remaining non-forested wetland cover type cells are then grouped together into patches. Patches are shrunk by 3 cells (90 meters) and then regrouped into patches.

Nonforj_210
Patches of all non-forested wetland types, cut by major roads, after buffering inward 210 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the non-forested wetland land cover types. The remaining non-forested wetland cover type cells are then grouped together into patches. Patches are shrunk by 7 cells (210 meters) and then regrouped into patches.

Nonforj_300
Patches of all non-forested wetland types, cut by major roads, after buffering inward 300 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. Major roads are converted to raster and the road raster removed from the non-forested wetland land cover types. The remaining non-forested wetland cover type cells are then grouped together into patches. Patches are shrunk by 10 cells (300 meters) and then regrouped into patches.

Nonform_90
Patches of all non-forested wetland types, cut by major roads, after buffering inward 90 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the non-forested wetland land cover types. The remaining non-forested wetland cover type cells are then grouped together into patches. Patches are shrunk by 3 cells (90 meters) and then regrouped into patches.

Nonform _210
Patches of all non-forested wetland types, cut by major roads, after buffering inward 210 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the non-forested wetland land cover types. The remaining non-forested wetland cover type cells are then grouped together into patches. Patches are shrunk by 7 cells (210 meters) and then regrouped into patches.

Nonform_300
Patches of all non-forested wetland types, cut by major roads, after buffering inward 300 meters.

All non-forested wetland land cover types in the Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover (Michigan DNR, 2003) are extracted. All roads are converted to raster and the road raster removed from the non-forested wetland land cover types. The remaining non-forested wetland cover type cells are then grouped together into patches. Patches are shrunk by 10 cells (300 meters) and then regrouped into patches.

Appendix I - natural vegetation core area datalayers and descriptions

File Name	Description	Ecoregion	road layer	minimum size (acres)	buffer size in meters
nat2up	all natural vegetation	UP	none	5,000	0
nat2up_c1	all natural vegetation	UP	none	5,000	90
nat2up_c2	all natural vegetation	UP	none	5,000	210
nat2up_c3	all natural vegetation	UP	none	5,000	300
nat2mup	all natural vegetation	UP	major	5,000	0
nat2mup_c1	all natural vegetation	UP	major	5,000	90
nat2mup_c2	all natural vegetation	UP	major	5,000	210
nat2mup_c3	all natural vegetation	UP	major	5,000	300
nat2jup	all natural vegetation	UP	all	5,000	0
nat2jup_c1	all natural vegetation	UP	all	5,000	90
nat2jup_c2	all natural vegetation	UP	all	5,000	210
nat2jup_c3	all natural vegetation	UP	all	5,000	300
nat2nlp	all natural vegetation	NLP	none	2,500	0
nat2nlp_c1	all natural vegetation	NLP	none	2,500	90
nat2nlp_c2	all natural vegetation	NLP	none	2,500	210
nat2nlp_c3	all natural vegetation	NLP	none	2,500	300
nat2jnlp	all natural vegetation	NLP	major	2,500	0
nat2jnlp_c1	all natural vegetation	NLP	major	2,500	90
nat2jnlp_c2	all natural vegetation	NLP	major	2,500	210
nat2jnlp_c3	all natural vegetation	NLP	major	2,500	300
nat2mnlp	all natural vegetation	NLP	all	2,500	0
nat2mnlp_c1	all natural vegetation	NLP	all	2,500	90
nat2mnlp_c2	all natural vegetation	NLP	all	2,500	210
nat2mnlp_c3	all natural vegetation	NLP	all	2,500	300
nat2slp	all natural vegetation	SLP	none	500	0
nat2slp_c1	all natural vegetation	SLP	none	500	90
nat2slp_c2	all natural vegetation	SLP	none	500	210
nat2slp_c3	all natural vegetation	SLP	none	500	300
nat2jslp	all natural vegetation	SLP	major	500	0
nat2jslp_c1	all natural vegetation	SLP	major	500	90
nat2jslp_c2	all natural vegetation	SLP	major	500	210
nat2jslp_c3	all natural vegetation	SLP	major	500	300
nat2mslp	all natural vegetation	SLP	all	500	0
nat2mslp_c1	all natural vegetation	SLP	all	500	90
nat2mslp_c2	all natural vegetation	SLP	all	500	210
nat2mslp_c3	all natural vegetation	SLP	all	500	300

minimum patch sizes dependent on ecoregion

Nat2up
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2nlp
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2slp
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2jup
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by major roads.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2jnlp
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by major roads.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2jslp
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by major roads.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2mup
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by all roads.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2mnlp
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by all roads.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2mslp
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by all roads.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2up_c
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2nlp_c
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2slp_c
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2jup_c
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2jnlp_c
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2jslp_c
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2mup_c
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2mnlp_c
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2mslp_c
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2up_c1
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2nlp_c1
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2slp_c1
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2jup_c1
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2jnlp_c1
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2jslp_c1
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2mup_c1
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2mnlp_c1
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2mslp_c1
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2up_c2
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2nlp_c2
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2slp_c2
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2jup_c2
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by major roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2jnlp_c2
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by major roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2jslp_c2
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by major roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2mup_c2
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by all roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2mnlp_c2
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by all roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2mslp_c2
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by all roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2up_c3
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 5000 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2nlp_c3
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 2500 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2slp_c3
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 500 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2jup_c3
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by major roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 5000 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2jnlp_c3
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by major roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 2500 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2jslp_c3
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by major roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 500 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Nat2mup_c3
Michigan Upper Peninsula natural vegetation classes, patches greater than 5000 acres after cutting by all roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 5000 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 5000 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 5000 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 5000 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 5000 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 5000 acres extracted.

Nat2mnlp_c3
Michigan Northern Lower Peninsula natural vegetation classes, patches greater than 2500 acres after cutting by all roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 2500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 2500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 2500 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 2500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2500 acres extracted.

Nat2mslp_c3
Michigan Southern Lower Peninsula natural vegetation classes, patches greater than 500 acres after cutting by all roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 500 acres are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to 500 acres are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to 500 acres are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to 500 acres are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to 500 acres are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 500 acres extracted.

Merged core areas

Nat2
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula).

All natural vegetation classes, including water, are grouped together. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets, patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the criteria are extracted. The three raster datasets are then merged into one statewide raster.

Nat2j
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula) after the patches are cut by major roads.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower

Peninsula. For each of the three raster datasets, patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the criteria are extracted. The three raster datasets are then merged into one statewide raster.

Nat2m
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula) after the patches are cut by all roads.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets, patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the criteria are extracted. The three raster datasets are then merged into one statewide raster.

Nat2_c
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets, patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional thresholds are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those greater than or equal to the ecoregional thresholds are extracted. The three raster datasets are then merged into one statewide raster.

Nat2j_c
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets, patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional thresholds are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those greater than or equal to the ecoregional thresholds are extracted. The three raster datasets are then merged into one statewide raster.

Nat2m_c
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets, patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional thresholds are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those greater than or equal to the ecoregional thresholds are extracted. The three raster datasets are then merged into one statewide raster.

Nat2_c1
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Nat2j_c1
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Nat2m_c1
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Nat2_c2
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to the ecoregional threshold are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Nat2j_c2
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after cutting by major roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to the ecoregional threshold are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Nat2m_c2
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after cutting by all roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to the ecoregional threshold are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Nat2_c3
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to the ecoregional threshold are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to the ecoregional threshold are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Nat2j_c3
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after cutting by major roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to the ecoregional threshold are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to the ecoregional threshold are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Nat2m_c3
Natural vegetation patches with the patch size dependent on ecoregion (Michigan Upper Peninsula, Northern Lower Peninsula, or Southern Lower Peninsula), after cutting by all roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Three raster datasets are created, one for the Upper Peninsula, one for the Northern Lower Peninsula, and one for the Southern Lower Peninsula. For each of the three raster datasets patches greater than or equal to a threshold (UP 5000 acres, NLP 2500 acres, SLP 500 acres) are extracted. These patches are then shrunk by 3 cells (90 meters), regrouped, and those patches greater than or equal to the ecoregional threshold are extracted. To eliminate small connectors, the patches are further shrunk by 3 cells (90 meters) grouped, and patches greater than or equal to the ecoregional threshold are extracted, then 3 cells (90 meters) added back to the patches. These patches are shrunk a further four cells (120 meters, 210 meters total) and patches greater than or equal to the ecoregional threshold are extracted. The remaining patches are then shrunk a further 3 cells (90 meters, 300 meters total) and all patches greater than or equal to the ecoregional threshold are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than the ecoregional threshold extracted. The three raster datasets are then merged into one statewide raster.

Appendix J - Potentially unchanged natural vegetation core area datalayers and descriptions

File Name	Ecoregion	road layer	minimum size (acres)	buffer size in meters
up_un_core	UP	none	0	0
up_un_500	UP	none	500	0
up_un_500_c1	UP	none	500	90
up_unj_500	UP	major	500	0
up_unj_500_c1	UP	major	500	90
up_unm_500	UP	all	500	0
up_unm_500_c1	UP	all	500	90
nlp_un_core	NLP	none	0	0
nlp_un_250	NLP	none	250	0
nlp_un_250_c1	NLP	none	250	90
nlp_unj_250	NLP	major	250	0
nlp_unj_250_c1	NLP	major	250	90
nlp_unm_250	NLP	all	250	0
nlp_unm_250_c1	NLP	all	250	90
slp_un_core	SLP	none	0	0
slp_un_50	SLP	none	50	0
slp_un_50_c1	SLP	none	50	90
slp_unj_50	SLP	major	50	0
slp_unj_50_c1	SLP	major	50	90
slp_unm_50	SLP	all	50	0
slp_unm_50_c1	SLP	all	50	90

Appendix J - Potentially unchanged natural vegetation core area datalayers and descriptions - continued

un_core
Potentially unchanged vegetation communities.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted and grouped into patches.

un_core_90
Potentially unchanged vegetation communities after buffering inward 90 meters.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted and grouped into patches. These patches are then shrunk inward by 90 meters (3 cells) and regrouped into patches.

unj_core
Potentially unchanged vegetation communities after removing major roads.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. Major roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches.

unj_core_90
Potentially unchanged vegetation communities after removing major roads and buffering inward 90 meters.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. Major roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches and these patches shrunk by 90 meters (3 cells) and regrouped.

unm_core
Potentially unchanged vegetation communities after removing major roads.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. All roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches.

unm_core_90
Potentially unchanged vegetation communities after removing major roads and buffering inward 90 meters.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. All roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches and these patches shrunk by 90 meters (3 cells) and regrouped.

Nlp_un_core
Potentially unchanged vegetation communities in Michigan's Northern Lower Peninsula.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted and grouped into patches.

Nlp_unj_core
Potentially unchanged vegetation communities in Michigan's Northern Lower Peninsula after removing major roads.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. Major roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches.

Nlp_unm_core
Potentially unchanged vegetation communities in Michigan's Northern Lower Peninsula after removing all roads.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. All roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches.

Slp_un_core
Potentially unchanged vegetation communities in Michigan's Southern Lower Peninsula.

Appendix J - Potentially unchanged natural vegetation core area datalayers and descriptions

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted and grouped into patches.

Slp_unj_core
Potentially unchanged vegetation communities in Michigan's Southern Lower Peninsula after removing major roads.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. Major roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches.

Slp_unm_core
Potentially unchanged vegetation communities in Michigan's Southern Lower Peninsula after removing all roads.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. All roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches.

Up_un_core
Potentially unchanged vegetation communities in Michigan's Upper Peninsula.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted and grouped into patches.

Up_unj_core
Potentially unchanged vegetation communities in Michigan's Upper Peninsula after removing major roads.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. Major roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches.

Appendix J - Potentially unchanged natural vegetation core area datalayers and descriptions

Up_unm_core
Potentially unchanged vegetation communities in Michigan's Upper Peninsula after removing all roads.

The Integrated Forest Monitoring Assessment and Prescription (IFMAP) / GAP Landuse/Landcover dataset (Michigan DNR, 2003) and the Circa 1800 Vegetation dataset (Michigan Natural Features Inventory, 1995) are combined. Vegetation communities in the two datasets that are similar to each other are extracted. All roads from the Michigan Framework are converted to a raster and subtracted from the potentially unchanged vegetation communities. The remaining unchanged vegetation cells are then grouped into patches.

Appendix K - Matrix vegetation datalayers and descriptions

File Name	Description	road layer	minimum size (acres)
nat2_min	Matrix vegetation patches statewide - water removed	none	5000
nat2_90	Matrix vegetation patches statewide - water removed	none	5000
nat2_210	Matrix vegetation patches statewide - water removed	none	5000
nat2_300	Matrix vegetation patches statewide - water removed	none	5000
nat2j_min	Matrix vegetation patches statewide - water removed	major	5000
nat2j_90	Matrix vegetation patches statewide - water removed	major	5000
nat2j_210	Matrix vegetation patches statewide - water removed	major	5000
nat2j_300	Matrix vegetation patches statewide - water removed	major	5000
nat2m_min	Matrix vegetation patches statewide - water removed	all	5000
nat2m_90	Matrix vegetation patches statewide - water removed	all	5000
nat2m_210	Matrix vegetation patches statewide - water removed	all	5000
nat2m_300	Matrix vegetation patches statewide - water removed	all	5000

Appendix K - Matrix vegetation datalayers and descriptions

Nat2gps
All natural vegetation classes, including water, are grouped together.

Nat2jgps
All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes.

Nat2mgps
All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes.

Matrix vegetation, patch sizes not differentiated by ecoregion.

Nat2_min
Michigan statewide natural vegetation classes, patches greater than 2000 hectares.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2000 hectares are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2j_min
Michigan statewide natural vegetation classes, patches greater than 2000 hectares after cutting by major roads.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2000 hectares are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2m_min
Michigan statewide natural vegetation classes, patches greater than 2000 hectares after cutting by major roads.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2000 hectares are extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2_90
Michigan statewide natural vegetation classes, patches greater than 2000 hectares, after buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2000 hectares are extracted. These patches are shrunk by 3 cells (90 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted

Appendix K - Matrix vegetation datalayers and descriptions

Nat2j_90
Michigan statewide natural vegetation classes, patches greater than 2000 hectares after cutting by major roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2000 hectares are extracted. These patches are shrunk by 3 cells (90 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2m_90
Michigan statewide natural vegetation classes, patches greater than 2000 hectares after cutting by all roads and buffering inward 90 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2000 hectares are extracted. These patches are shrunk by 3 cells (90 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2_210
Michigan statewide natural vegetation classes, patches greater than 2000 hectares, after buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2000 hectares are extracted. These patches are shrunk by 7 cells (210 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2j_210
Michigan statewide natural vegetation classes, patches greater than 2000 hectares after cutting by major roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2000 hectares are extracted. These patches are shrunk by 7 cells (210 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2m_210
Michigan statewide natural vegetation classes, patches greater than 2000 hectares after cutting by all roads and buffering inward 210 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2000 hectares are extracted. These patches are shrunk by 7 cells (210 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2_300
Michigan statewide natural vegetation classes, patches greater than 2000 hectares, after buffering inward 3000 meters.

All natural vegetation classes, including water, are grouped together. Patches greater than or equal to 2000 hectares are extracted. These patches are shrunk by 10 cells (300 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2j_300
Michigan statewide natural vegetation classes, patches greater than 2000 hectares after cutting by major roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. Major roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2000 hectares are extracted. These patches are shrunk by 10 cells (300 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Nat2m_300
Michigan statewide natural vegetation classes, patches greater than 2000 hectares after cutting by all roads and buffering inward 300 meters.

All natural vegetation classes, including water, are grouped together. All roads are converted to raster and then removed from the natural vegetation classes. Patches are re-grouped and those greater than or equal to 2000 hectares are extracted. These patches are shrunk by 10 cells (300 meters) and patches greater than or equal to 2000 hectares extracted. Water bodies greater than ten acres are then removed from the patches, the patches regrouped, and those larger than 2000 hectares extracted.

Appendix L - EO based datalayers and descriptions

File name	Field	Description
EO Frequency		
Ter_EO_trs_0906.shp	F_noc	all species - no communities - all dates
Ter_EO_trs_0906.shp	F_noc_85	all species - no communities - only dates > 1985
Ter_EO_trs_0906.shp	F_ter	only terrestrial species - all dates
Ter_EO_trs_0906.shp	F_ter_85	only terrestrial species - only dates > 1985
Ter_EO_trs_0906.shp	F_all	all element occurrences - all dates
Ter_EO_trs_0906.shp	F_all_85	all element occurrences - only dates > 1985
Aq_EO_trs_0906.shp	F_aq	only aquatic species - all dates
Aq_EO_trs_0906.shp	F_aq_85	only aquatic species - only dates > 1985
Aq_EO_trs_0906.shp	F_aq_nl	only aquatic species - all dates - no loons
Aq_EO_trs_0906.shp	Faq85_nl	only aquatic species - only dates > 1985 - no loons
EO Likelihood		
Ter_EO_trs_0906.shp	L_noc	all species - no communities - all dates
Ter_EO_trs_0906.shp	L_noc_85	all species - no communities - only dates > 1985
Ter_EO_trs_0906.shp	L_ter	only terrestrial species - all dates
Ter_EO_trs_0906.shp	L_ter_85	only terrestrial species - only dates > 1985
Ter_EO_trs_0906.shp	L_all	all element occurrences - all dates
Ter_EO_trs_0906.shp	L_all_85	all element occurrences - only dates > 1985
Aq_EO_trs_0906.shp	L_aq	only aquatic species - all dates
Aq_EO_trs_0906.shp	L_aq_85	only aquatic species - only dates > 1985
Aq_EO_trs_0906.shp	L_aq_nl	only aquatic species - all dates - no loons
Aq_EO_trs_0906.shp	Laq85_nl	only aquatic species - only dates > 1985 - no loons
Bio-rarity		
Ter_EO_trs_0906.shp	B_noc	all species - no communities - all dates
Ter_EO_trs_0906.shp	B_noc_85	all species - no communities - only dates > 1985
Ter_EO_trs_0906.shp	B_ter	only terrestrial species - all dates
Ter_EO_trs_0906.shp	B_ter_85	only terrestrial species - only dates > 1985
Ter_EO_trs_0906.shp	B_all	all element occurrences - all dates
Ter_EO_trs_0906.shp	B_all_85	all element occurrences - only dates > 1985
Aq_EO_trs_0906.shp	B_aq	only aquatic species - all dates
Aq_EO_trs_0906.shp	B_aq_85	only aquatic species - only dates > 1985
Aq_EO_trs_0906.shp	B_aq_nl	only aquatic species - all dates - no loons
Aq_EO_trs_0906.shp	Baq85_nl	only aquatic species - only dates > 1985 - no loons
Best 2 occurrences of each species		
best2_ter_subsubsection_trs_0906.shp		best 2 occurrences of each terrestrial species for each sub-subsection
best2_ter_subsub_summed_trs_0906.shp		the sum of the best 2 occurrences of each terrestrial species by sub-subsection
best2_aq_watershed_0906.shp		best 2 occurrences of each aquatic species by watershed
Aquatic species richness		
aq_EO_richness_subwatershed.shp		aquatic rare species richness per river mile by sub-watershed
aq_SGCN_richness_subwatershed.shp		aquatic species of greatest conservaton need per river mile by sub-watershed

Appendix L - EO based datalayers and descriptions - continued

File name	Field	Description
High quality natural communities		
natcomm_bcrank.shp		all natural communities with an EO rank > B/C
natcomm_combined.shp		the best 3 occurrences of each natural community type in the state and by section, subsection, and sub-subsection
natcomm_state.shp		the best 3 occurrences of each natural community type in the state
natcomm_section.shp		the best 3 occurrences of each natural community type for each section (4)
natcomm_subsections.shp		the best 3 occurrences of each natural community type for each subsection (22)
natcomm_subsubsection.shp		the best 3 occurrences of each natural community type for each sub-subsection (38)

Appendix M - Aquatic datalayers and descriptions

File name	Description
Rivers	
mi_subwatersheds.shp	michigan subwatersheds
vsec_size_temp.shp	River classification framework - one of 2 shapefiles - this one shows the size and water temperature classes used in this report
vsec_gradient.shp	River classification framework - one of 2 shapefiles - this one shows the gradient classes used in this report
vsec_unique_statewide_5pct.shp	Potentially unique vsecs statewide using 5% rule
vsec_unique_statewide_1pct.shp	Potentially unique vsecs statewide using 1% rule
vsec_unique_edu_5pct.shp	Potentially unique vsecs within an EDU using 5% rule
vsec_unique_edu_1pct.shp	Potentially unique vsecs within an EDU using 1% rule
vsec_HQ_edu.shp	High quality common vsecs by EDU
Lakes	
milakes_conn_shoreline.shp	Lake classification framework - one of 2 shapefiles - this one shows the connectivity and shoreline classes used in this report
milakes_proxgeol.shp	Lake classification framework - one of 2 shapefiles - this one shows the proximate geology classes used in this report
lake_unique_statewide_5pct.shp	Potentially unique lakes statewide using 5% rule
lake_unique_statewide_1pct.shp	Potentially unique lakes statewide using 1% rule
lake_unique_EDU_5pct.shp	Potentially unique lakes within an EDU using 5% rule
lake_unique_EDU_1pct.shp	Potentially unique lakes within an EDU using 1% rule
lake_HQ_edu.shp	High quality common lakes by EDU - based on landscape context
Subwatersheds	
pctNat_subwatershed.shp	Percent natural landcover in sub-watershed
pctNat_Riparian_subwatershed.shp	Percent natural landcover in riparian zones of sub-watershed
rdXStrCount_subwatershed.shp	Number of road and stream crossings per river mile in sub-watershed
damCount_subwatershed.shp	Number of dams per river mile in sub-watershed
fragmentation_subwatershed.shp	Overall fragmentation analysis metric by sub-watersheds
imperv_subwatershed.shp	Percent impervious suface in sub-watersheds
npdesCount_subwatershed.shp	Number of DEQ non-point source pollution permits per river mile in sub-watersheds
mineCounts_subwatershed.shp	Number of active mines per river mile in sub-watersheds
pollution_subwatershed.shp	Overall pollution analysis metric by sub-watersheds
functional_subwatershed.shp	Overall functional analysis metric by sub-watersheds
headwaters100natural.shp	100 percent natural landcover in catchments of headwater (order 1) streams
headwatersPctnatural.shp	Percent natural landcover in catchments of headwater (order 1) streams