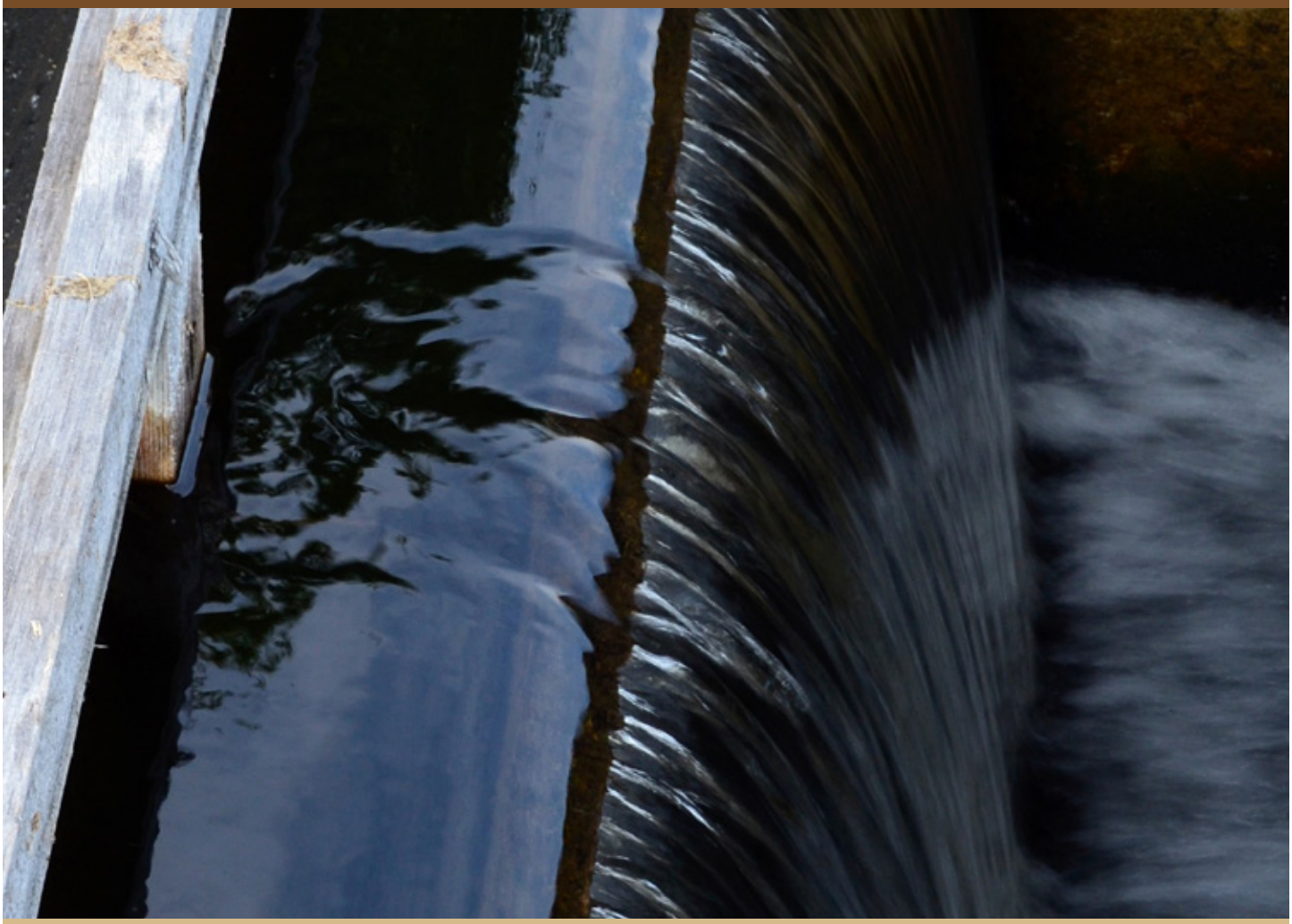
July 12, 2018

COMMERCIAL AQUACULTURE

in Michigan

SITING GUIDEBOOK



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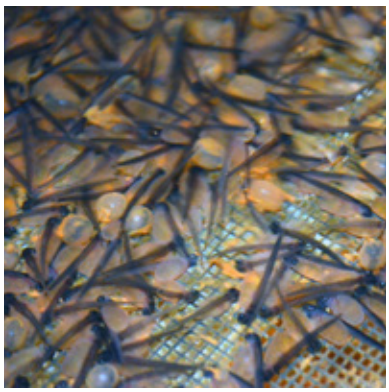

ACKNOWLEDGMENTS

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MICHIGAN STATE UNIVERSITY | Extension

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ONLINE REGIONAL MAPS

Detailed maps of aquaculture siting data layers are available for regions throughout Michigan.

michiganseagrant.org/aquaculture

INTRODUCTION

Approximately 90 percent of seafood consumed in the United States originates overseas (Diana, 2015) and demand for fish for consumption regionally, nationally, and globally is expected to continue, despite an estimated 50- to 80-million-ton shortage of seafood worldwide within the next 15 years (Miller, Mann, and Knudson, 2015). The shortage of domestically produced seafood has sparked a recent growth and interest in commercial aquaculture. Michigan's abundant water resources make it an attractive and logical location for siting commercial aquaculture operations. Michigan's Quality of Life Agencies (departments of Agriculture and Rural Development; Natural Resources; and Environmental Quality) support thoughtful, environmentally responsible expansion of the aquaculture industry, so long as operations are sited and designed with protection of the state's aquatic resources kept as a primary consideration.

To date, the industry has struggled to grow, and some of that struggle can be attributed to a lack of understanding of issues and considerations that are unique to each of the four primary modes of aquaculture production, and siting considerations. This project will serve as a first step for prospective operators as they research and explore the possibility of doing business in Michigan. There are four primary modes of doing aquaculture on a commercial scale, including extensive rearing in ponds; flow through; closed loop, or recirculating aquaculture systems; and net-pen aquaculture.

After an extensive review of two proposals for net-pen aquaculture in the Great Lakes that were received in late 2014, the three Michigan Quality of Life agencies recommended against permitting net pens in the Great Lakes. However, the Quality of Life agencies agreed to support the development of other types of aquaculture operations in Michigan. Upon conversations with aquaculture industry stakeholders and the Quality of Life agencies it was determined that map-based information on suitable locations for land-based aquaculture was needed. Stakeholder engagement to identify next steps for commercial aquaculture development with a supporting supply chain would be beneficial to informing Michigan's aquaculture industry.

The objectives of this project were to:

1) Facilitate engagement with Michigan's Quality of Life Agencies (departments of Agriculture and Rural Development, Natural Resources, and Environmental Quality) with GIS data experts from Michigan State University's Institute of Water Research and Aquatic Landscape Ecology Lab; industry; and other partners to integrate existing GIS data;

2) Produce an integrated GIS map and guidebook of existing GIS data layers (see methodology below) of factors important for consideration of commercial aquaculture business siting;

3) In partnership with other Michigan stakeholders (e.g., Regional Planning Organizations, Michigan Aquaculture Association, Native Fish Producers, or related), conduct an educational workshop to present the integrated GIS maps and guidebook, and to develop a prioritized list of next steps for the enhancement of a commercial aquaculture sector in Michigan.

DESCRIPTION OF THEMES IMPORTANT TO AQUACULTURE SITING

Another effort by Michigan Sea Grant and MSU Extension is to develop suggestions for developing aquaculture siting recommendations to inform the development of best practices for aquaculture. These works identify factors important to siting an aquaculture facility, and the recommended themes are below:

- **General site suitability** – designed to include features which partners identified as generally useful to their understanding of siting decisions. It includes where current facilities are now (both public and private), land cover, National Fish Habitat Partnership fish habitat degradation scores, and important natural resource considerations, such as conservation easements.

- **Current aquaculture and hatchery facilities** – Michigan has private aquaculture facilities, as well as federal, state, and tribal hatcheries for fish stocking. Each source is described as:

  - **Private aquaculture facilities.** Private aquaculture facilities are licensed through the Michigan Department of Agriculture and Rural Development. The dataset includes 54 facilities in 2016.
  - **Federal hatcheries.** Locations of federal hatcheries are available on the U.S. Fish and Wildlife website. The dataset included 3 federal hatcheries in Michigan in 2016.
  - **State hatcheries.** State hatchery data are available through the Michigan Department of Natural Resources. The dataset includes 6 hatcheries.
  - **Tribal hatcheries.** Tribal hatchery locations were acquired through conversations with Michigan Sea Grant/MSU Extension staff who work regularly with tribal hatchery managers. The dataset includes 3 hatcheries.

- **Water sourcing** – designed to focus in on considerations that aquaculture farmers will need to make regarding the source water for their facilities, including stream temperature classification and impaired waterways according to the total maximum daily load (TMDL) 303d listed streams. The ability to source water with minimal cost is a key consideration for running an economically viable aquaculture business.

- **Water discharge** – designed to highlight those features which would make water discharge easier or more difficult for an aquaculture facility, including State Designated Natural Rivers, National Wild and Scenic Rivers, stream TMDL discharge limits, wellhead protection areas, stream temperature classification, and impaired waterways according to the total maximum daily load (TMDL) 303d listings. The ability to discharge wastewater with minimal cost is a key consideration for running an economically viable aquaculture business.

- **Managing aquatic invasive species and disease risks** – One of the key concerns surrounding aquaculture facilities is the risk of disease transmission between farmed and wild fish. This theme addresses information on the currently documented locations of non-game fish aquatic invasive species (AIS). These include modeled locations of protected species and locations which have special state or federal protection such as State Designated Natural Rivers, and National Wild and Scenic Rivers, among others.

- **Supply chain systems** – this theme focus is economic, highlighting information which aquaculture farmers can use to ensure their siting location has the infrastructure to get their desired product to market. This layer includes the locations of fish processors, main roads which farmers can use for transporting their products, airports, and the locations of major urban and population centers which can provide viable markets.

  - **Fish processing facilities.** Fish processing facilities were provided by the Michigan Department of Agriculture and Rural Development. These facilities are important components to the aquaculture industry as they are essential for getting farmed fish to consumer markets.
  - **Urban areas and clusters.** The urban areas layer was acquired from the United States Census website. We are using this layer to show areas with higher population density and in turn a potentially higher demand for farmed fish. Urban areas are classified as >50,000 people whereas urban clusters are classified as >2,500 people.

- **TIGER 2016 Primary Roads.** TIGER 2016 Primary Roads were acquired from the United States Census website. This layer is used to help orient users with primary roads on maps.
- **Population density.** Population density was calculated using the 2010 Census blocks. This layer is used to show high vs. low concentration of people. Higher concentration of people may indicate a higher market demand for aquaculture fish.
- **Airports.** Airports were downloaded from coordinates.com. Airports are a possible transportation option for shipping aquaculture fish.

TABLE 1. Data sources relevant to aquaculture siting themes.

LAYER	GENERAL SITE SUITABILITY	CURRENT FACILITIES	WATER SOURCING	WATER DISCHARGE	MANAGE AIS & DISEASE RISK	SUPPLY CHAIN
Private aquaculture facilities	X	X				
Federal hatcheries	X	X				
State hatcheries	X	X				
Tribal hatcheries	X	X				
Agricultural lands	X					
Fish habitat condition scores	X					
Discharge water bodies	X			X		
Fish production facilities	X					X
Urban centers						X
Tiger2016 primary and secondary roads						X
Population density	X					X
State Designated Natural Rivers				X	X	
National Wild and Scenic Rivers				X	X	
Michigan wellhead protection areas				X		
Final wetland inventory*	X			X		
Stream thermal classes			X	X		
TMDL listed streams**			X	X		
Water table depth*			X			
Protected areas of the landscape	X				X	
MDEQ conservation easements	X				X	
T and E species, Species of Greatest Conservation Need (modeled)					X	
Non-game, non-indigenous aquatic species	X				X	
Airports and airfields	X					X
Flowing wells			X			
Market potential	X					

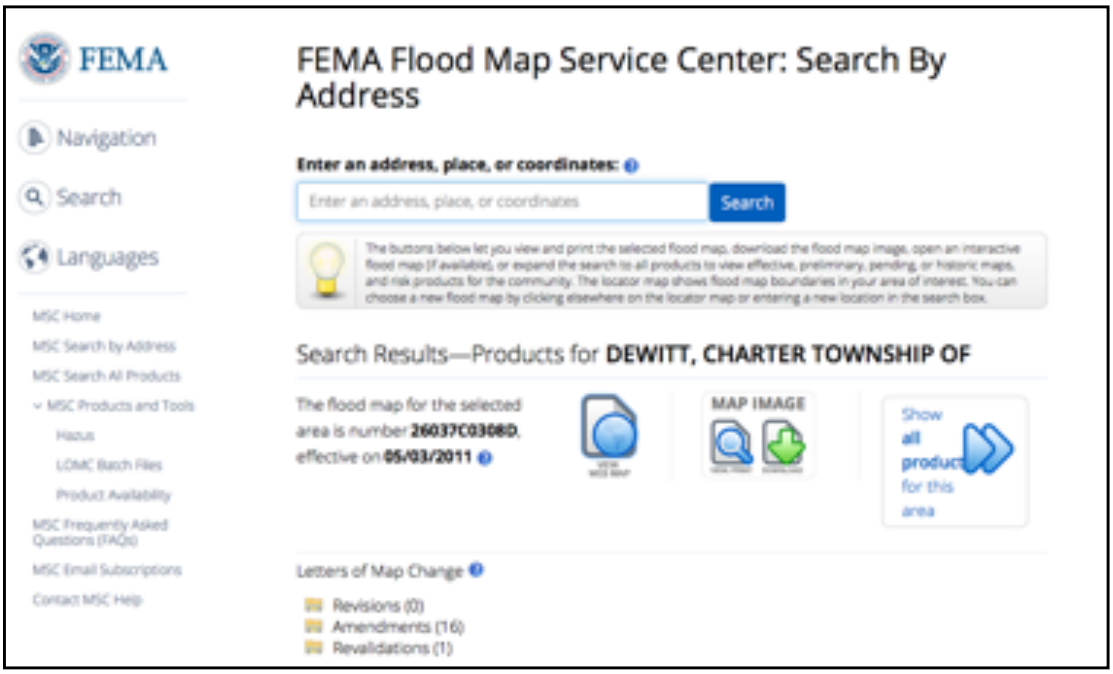
Notes: *Layer is not mapped at this time but could potentially be used in next steps. **Streams that may require extra consideration in water sourcing decisions are listed for DDT, selenium, PFOs, or dioxin. Streams that may require extra consideration in water discharge decisions are listed for sedimentation, siltation, oxygen depletion, nutrients, excess algal growth, thermal impacts, or aquatic plants.

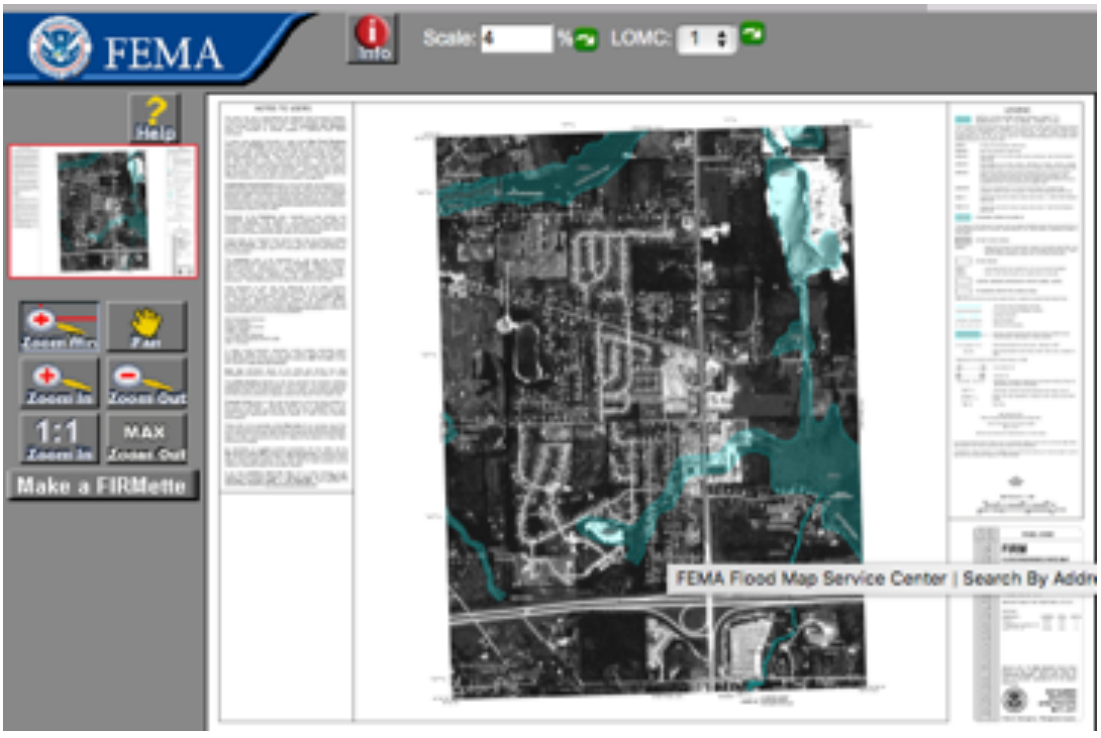
ADDITIONAL DATA AND TOOLS

Additional data and tools that were not incorporated into this aquaculture siting mapping toolkit that can be useful at informing aquaculture business siting are:

Federal Emergency Management Agency Flood Plain Mapper – www.fema.gov/flood-mapping-products

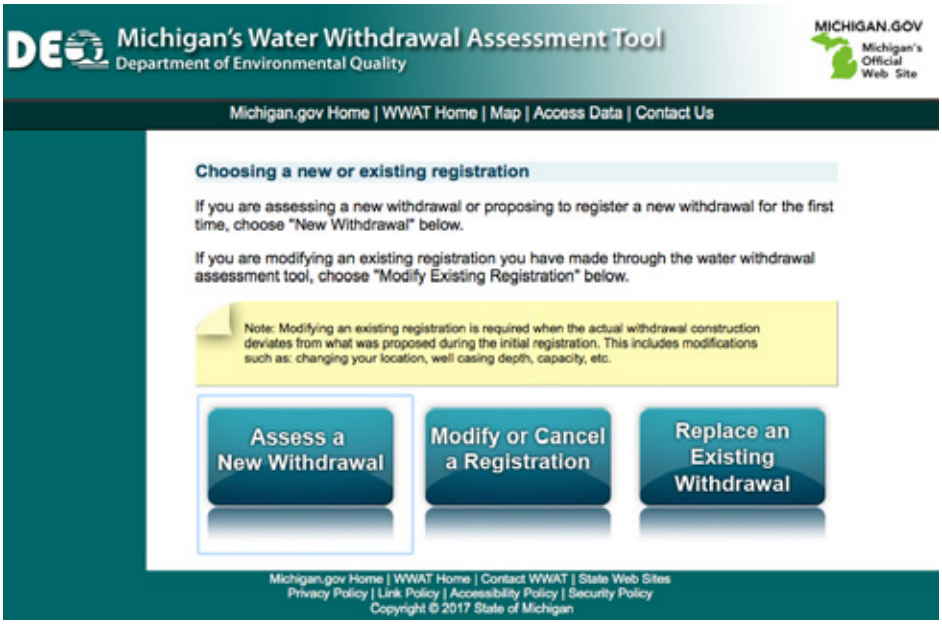
Understanding the floodplain areas is important for determine location of business siting to manage potential risks of unintentional species discharge if a flood occurs and damages aquaculture facilities operations.





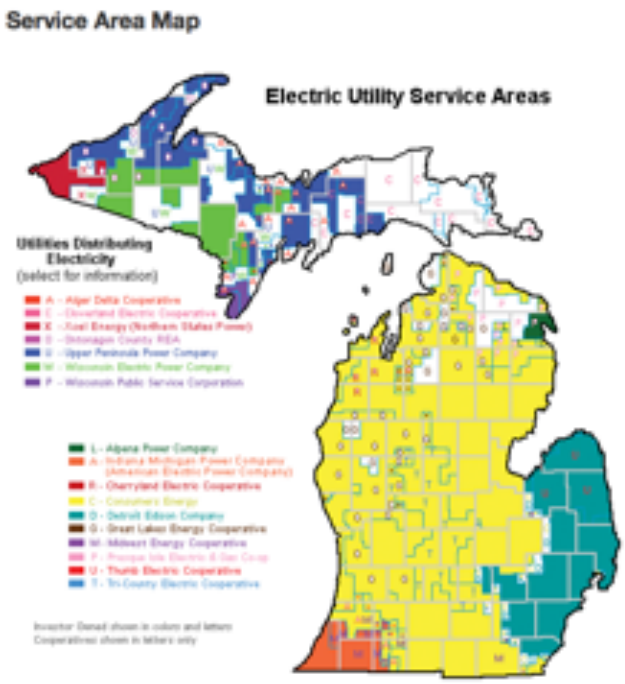
2. Michigan Water Withdrawal Assessment Tool – www.michigan.gov/deq/0,4561,7-135-3313_3684_45331-201102--,00.html

The state of Michigan has a Water Use Program which began in February 2006. Any new water uses are prohibited from having an adverse impact on waters of the state. The Michigan Water Withdrawal Assessment Tool can be used to determine the feasibility of potential water-withdrawal locations for source water for aquaculture operations.

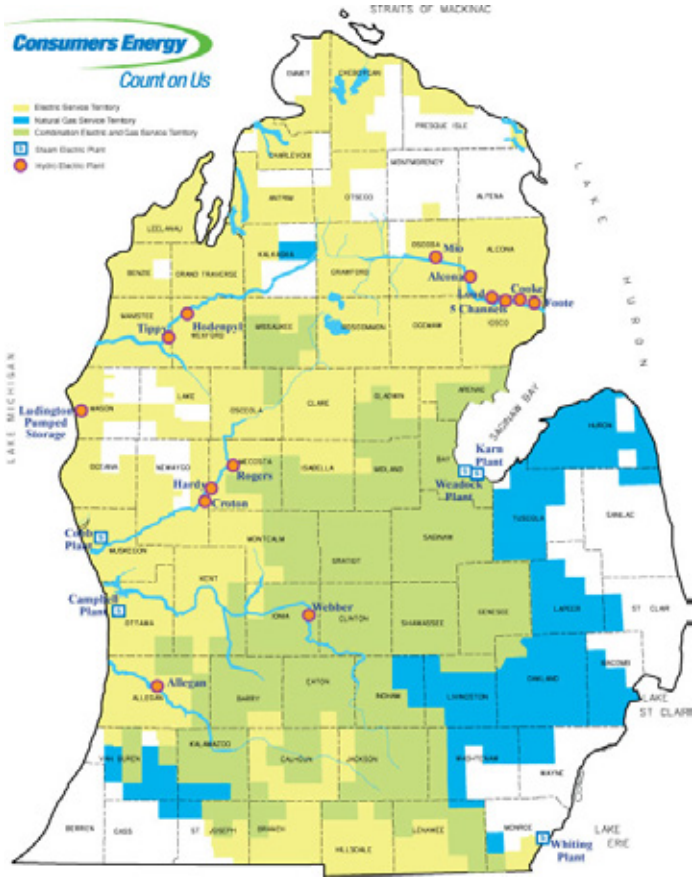


3. Energy Service Provider Maps

a. Michigan Energy Service Areas – www.michigan.gov/mpsc/0,4639,7-159-16377-41337--,00.html

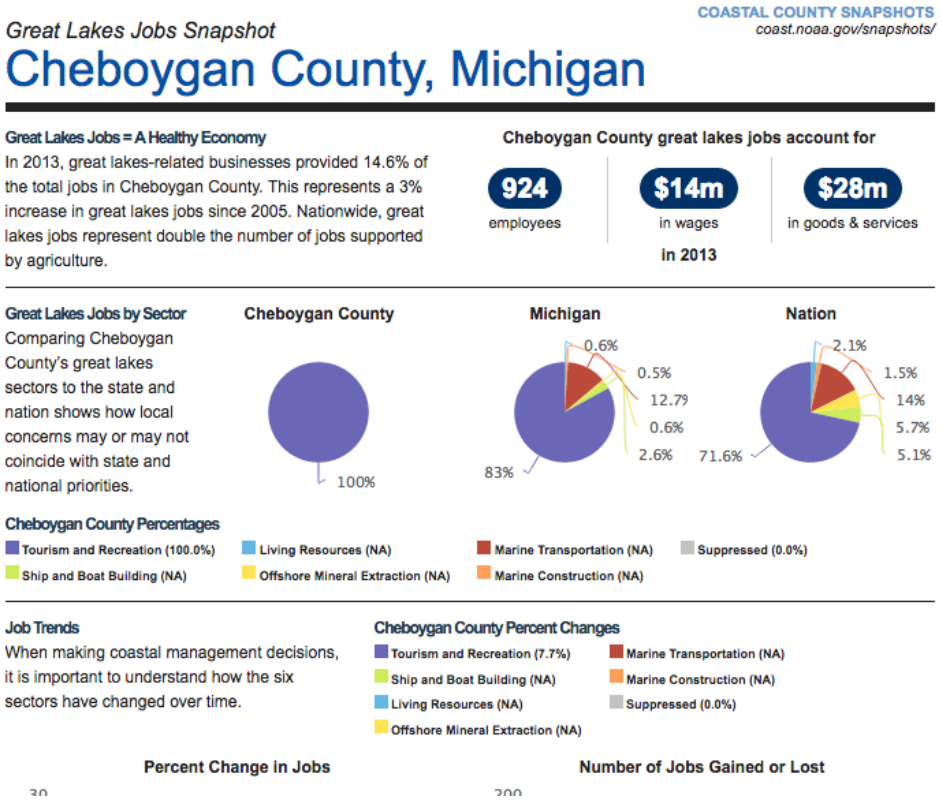


b. Consumers Energy Service Area Information – www.consumersenergy.com/company/what-we-do/service-territories



c. DTE Energy Service Area Information – www.newlook.dteenergy.com/wps/wcm/connect/dte-web/home/service-request/residential/moving/service-map

NOAA Office of Coastal Management Coastal County Snapshots - coast.noaa.gov/digitalcoast/tools/snapshots.html



NOAA's National Centers for Coastal Ocean Science (NCCOS) program launched the Coastal Aquaculture Planning Portal (CAPP), a tool designed to assist in the planning and siting of sustainable coastal aquaculture facilities. It has more than 20 tools that have applications for planning and siting of aquaculture operations and industries within marine context.

AQUACULTURE SUPPLY CHAIN OPERATIONS

This section analyzes the following: the supply chain for aquaculture products, the market for aquaculture products, and possible future scenarios for the Michigan aquaculture sector. While seafood production in Michigan is small, the supply chain is developed. However some inputs such as fish-meal-based feeds may be difficult to obtain. There is also some potential for growth of the market.

Consumers are increasingly interested in locally sourced food products that are produced with limited environmental impact. Michigan aquaculture could address these consumer trends. Products that appeal to millennials and men could also be successful. There are several opportunities to expand the demand for seafood. The Midwest lags other parts of the country in the consumption of seafood. Due to the potential health benefits of seafood consumption, the demand for seafood could increase.

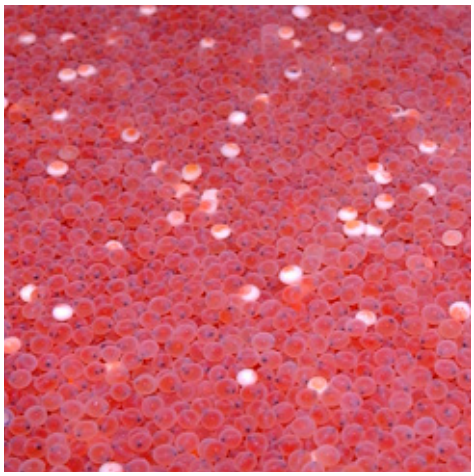
There are several species that have potential for expanded production. Shrimp and tilapia have potential; the vast majority of these species are imported often with questionable management practices. Trout and salmon could also be popular because they are naturally cold water species and are popular with consumers. Whitefish and walleye have potential because they are native to Michigan and are good tasting. As they are native to the region, issues with respect to the introduction of exotic species are avoided. Restaurants are an important outlet for seafood so developing products that are popular with restaurants is important.

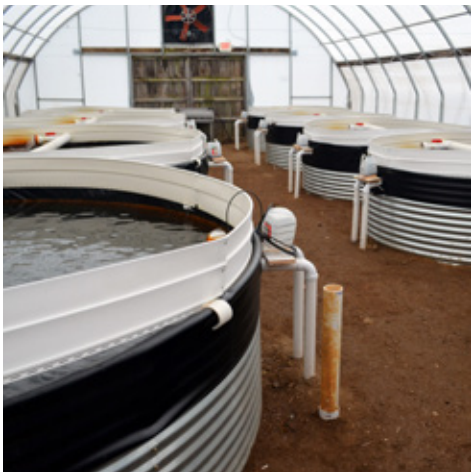
Regions of the state that had the most potential for success were also analyzed. Using income and education as filters, metropolitan areas and the northwest Lower Peninsula were identified as the most promising markets. Of particular interest was the greater Grand Rapids area extending west to Holland and Ottawa County and Washtenaw County including Ann Arbor.

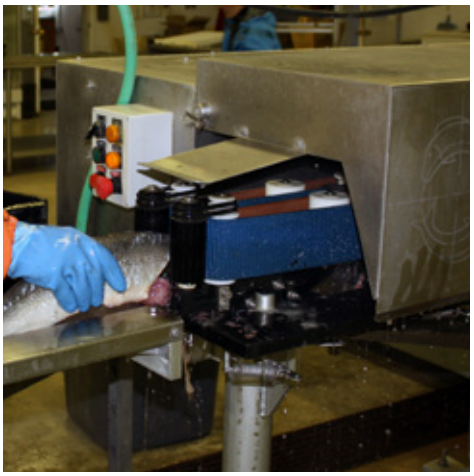
THE SUPPLY CHAIN FOR AQUACULTURE PRODUCTS

Supply chains outline the flow of a product from the input suppliers for that product to the final consumer. The supply chain for aquaculture is similar to other agri-food products; the supply chain is outlined in Figure 1.

FIGURE 1: The Supply Chain for Aquaculture Products.







The first link of the supply chain is the input suppliers. These firms supply the inputs that aquaculture firms use to grow seafood to market weight and size. Input supply firms provide financing and equipment to the firm. In the case of finfish, they often supply fingerlings or eggs. Most aquaculture firms do not operate their own hatcheries. Of particular importance is the feed provider. Feed is the largest single cost item for aquaculture firms, often accounting for 50 percent to 80 percent of the production cost (Weeks et al., 2014). Vegetarian seafood species can consume a wide variety of feeds; these are often soybean-based feeds. Carnivore species such as trout and salmon are dependent on suppliers of fish meal, although there is research being conducted to supplement fish meal with feeds from plant- and insect-based material. A well-integrated feed system is necessary for a functioning aquaculture sector in the state.

The aquaculture producer manages these inputs to produce seafood suitable for market. Additionally, the aquaculture producer markets the seafood to a processor. Some aquaculture producers will do some initial processing such as killing and gutting the seafood. Other producers sell live animals to the processors.

The primary function of the processor is to convert the seafood into a form desired by consumers. They also aggregate output from aquaculture producers into sufficient quantities to be useful to wholesalers, retailers, and others. Most of the seafood processors in the state are relatively small and are located near major population centers; especially in southeast Michigan and the greater Grand Rapids region. There are some smaller processors located in northern Michigan and the Upper Peninsula. Overall, there appears to be sufficient processing capacity in Michigan to handle increased aquaculture production.

Many processors are vertically integrated into wholesaling. Some firms are also dedicated wholesalers; who link the processors to retailers and restaurants. There are relatively few dedicated seafood wholesalers in Michigan, they are often meat wholesalers that also have a seafood business. The primary activity of wholesalers is to supply retailers and restaurants with a sufficient quantity and variety of seafood to meet their consumer needs.

Retailers and restaurants are the links between the rest of the supply chain and the consumer. Restaurants are particularly important in the seafood industry because most seafood in dollar terms is consumed in restaurants (Seafood Health Facts, 2017). This is particularly true for the seafood species produced in Michigan. At the retail level, most seafood is sold in traditional supermarkets which account for 56 percent of retail sales (Mintel, p.18). Compared to coastal regions, there are few dedicated seafood retailers in Michigan.

CONSUMER TRENDS

There are several market fundamentals that could promote the growth of aquaculture production. China, the world's largest producer of seafood is now a net importer of seafood (Weeks et al., 2014). The U.S. imports the vast majority of its seafood, although much of the seafood is caught in American waters and processed in other countries. Michigan, which borders 20 percent of the world's fresh water in the Great Lakes, as well as 11,000 inland lakes and many rivers, is well suited to aquaculture production.

Consumers are becoming more accustomed to buying farm-raised seafood. In 2015, for the first time, the global consumption of farm-raised seafood exceeded the consumption of wild-raised seafood (Weeks et al., 2014). In the U.S. approximately 40 percent of all the seafood consumed is farm raised (NOAA, 2017). Despite these strong numbers

in the U.S., only 608 million pounds of seafood was farm raised in 2014 compared to 9.5 billion pounds of wild-caught fish. Catfish is the dominant farm-raised fish in the U.S. (Seafood Health Facts, 2017). In 2015, per capita consumption of seafood was 15.5 lbs. which is about 60 percent of the recommended amount suggested by health experts (Weeks et al., 2014, Seafood Health Facts, 2017). Consumption in the Midwest is even lower than the national average (EPA, 2014). Michigan is within a one-day drive of 70 to 100 million people (Weeks et al., 2014), and could be the source of seafood for the entire region.

Developing a local seafood industry can tap into some of the biggest trends in the food industry. In 2014, the National Restaurant Association identified locally sourced meat and seafood as the number one trend in the industry, environmental sustainability ranked third, gluten free ranked fifth and sustainable seafood ranked ninth (Weeks et al., 2014). By 2018, sustainable seafood ranked fifth in top food trends and environmental sustainability ranked sixth and locally sourced meat and seafood ranked seventh in overall restaurant concepts (Food Trends, 2018). There has been an increase in new seafood products that make environmental and ethical claims (Mintel, 2016). A survey of consumers indicate that wild-caught, no additives/preservatives, American-caught, American-farmed and sustainable were product claims that had the most consumer interest (Mintel, 2016). Given the excellent feed conversion rates of many types of seafood, appeals to sustainability are particularly compelling. Michigan aquaculture could tap into all of these trends. To our knowledge the National Restaurant Association or Mintel surveys did not define environmental sustainability or sustainable seafood for their survey. Best aquaculture practices (BAP) has offered a third-party certification program since 2002. If Michigan aquaculture producers achieve BAP certification, consumers and the public will know that the seafood meets established standards for food safety, social welfare, environmental, and animal health and welfare standards. For more information, see www.bapcertification.org.

Another important trend is increased ethnicity in the greater Midwest and Ontario. Michigan is home to a large Arab population. The Census Bureau estimates that approximately 223,000 people in the state are Arab American and the Arab American Institute Foundation estimates this figure as more than 500,000. Chicago and Toronto are also large cities with a large ethnically diverse populations. According to the U.S. Census Bureau, 32 percent of Chicagoans are white, approximately 30 percent are Hispanic or Latino, and more than 5 percent are Asian. According to the city of Toronto, half the city's residents in 2006 were born outside of Canada, and the city is home to more than 200 distinct ethnic groups; major groups being Indian, Chinese, Italian, and Filipino. Some of these ethnic groups are interested in fresh seafood products and in some cases prefer to purchase live animals; this is especially the case for Asian consumers (Quagrainie, Xing, and Hughes, 2011). Species that show the most promise in live markets are tilapia, catfish and shrimp (Quagrainie, Xing, and Hughes, 2011).

Convenience has long been a demand driver in the food system. Cooking skills appear to be continuing to decline and many families are too busy to cook from scratch. Developing products that are easy to cook or have easily understood directions could be popular. Some buyers are interested in seafood in resealable packages and preseasoned or marinated seafood products (Mintel, 2016).

Another demand driver is wellness; a set of attributes that both help and hurt seafood. Most seafood can be marketed as not genetically modified. Most seafood is naturally healthy and either have a low-fat content or have a high level of healthy fats. After taste, various health attributes are the most important reason why people consume seafood (Mintel, 2016).

However, there have been health warnings in the past to limit fish consumption from fish caught in the Great Lakes. This creates some confusion in the minds of some consumers. Also, some species such as precooked shrimp have a high sodium content. Some consumers are also interested in seafood without additives or preservatives (Mintel, 2016).

Most people, particularly in the Midwest eat less seafood than is recommended. In 2015, national per capita consumption of seafood was 15.5 pounds a year (White, 2016); the U.S. Department of Agriculture recommends 26 pounds per year for a person with a 2,000 calorie per day diet (Kantor, 2016). An extremely rough estimate using data from the EPA and the Census Bureau indicates that per capita consumption in the Midwest is approximately 9.0 pounds per year. This creates a potential to increase demand in this part of the country. Consumers in the Midwest have limited exposure to truly fresh seafood and how much better it tastes compared to the seafood they currently have access to. Michigan produced seafood products have the potential to provide this truly fresh experience. Developing products that appeal to restaurants is especially important. In 2012, more than two-thirds of the seafood consumed in the U.S. was purchased at restaurants (York, 2012).

Households most likely to buy seafood include millennials (defined as those born between 1977 and 1994), Hispanics, and households with children (Mintel, 2016). These consumers prefer fresh compared to frozen seafood and other forms such as canned (Mintel, 2016). Sales of fresh seafood increased 7.2 percent from 2014 to 2016; while frozen seafood sales increased by 0.2 percent and shelf-stable seafood declined by 8.7 percent (Mintel, 2016). Michigan is well positioned to meet this preference; one reason seafood consumption in the Midwest trails other regions is the lack of access to fresh seafood (Mintel, 2016), a gap in the market Michigan aquaculture producers could fill.

There are several consumer behaviors that work against the growth of the aquaculture sector in Michigan. One is that 12 percent of consumers believe they have a seafood or shellfish allergy; in fact approximately 3 percent actually have such an allergy (Mintel, 2016). Some consumers simply do not like the taste or smell of seafood (Mintel, 2016). Smell is particularly problematic because it can take a long time to dissipate. Seven percent of consumers who do not eat seafood indicate that they do not know how to cook it (Mintel, 2016). Also, many consumers prefer wild-caught seafood (Mintel, 2016). Despite consumers becoming more accustomed to buying farm-raised seafood, they still prefer wild-caught seafood (Thorn, 2016). This preference is greatest for households earning more than $100K a year and for people between ages 25 and 34. Appealing to high income households is particularly important because they are the highest consumers of seafood (Mintel, 2016).

One interesting aspect of seafood consumption is that men are more likely to eat seafood than women. Furthermore, they appear to consume more seafood in different forms (e.g. fresh, frozen, breaded, etc.) (Mintel, 2016). Millennials also consume more seafood than other age group; these consumers are more likely to be engaged in social media and post meals and recipes online. They may also be more likely to download recipes online (Mintel, 2016).

SPECIES WITH THE GREATEST POTENTIAL

There are several species that have potential for market growth to become a successful aquaculture product. Shrimp produced in Michigan can be provided as a local seafood product which could be an advantage when compared to shrimp produced in Southeast Asia, the region where most shrimp comes from. Millennials are particularly interested in shellfish (Mintel, 2016). Shrimp produced in Michigan can be promoted as being a local seafood product which could be an advantage when compared to shrimp produced in Southeast Asia, which is the region most shrimp comes from. These same arguments also apply to tilapia; a species that is popular with restaurants due to its mild flavor.

Two other species that could be popular are whitefish and walleye. Both are native to Michigan and quite good tasting. There is a great potential to export walleye out of the state, especially to Minnesota and Wisconsin where the population is used to eating it. Managing production of walleye may be difficult given that walleye are known to eat other walleye and have a strong preference for eating natural food as opposed to prepared feeds.

Trout and salmon are two other species with potential. Consumers are used to ordering salmon in restaurants and cooking salmon is somewhat easier than cooking other types of fish. Salmon, along with shrimp, accounts for much of the seafood consumed in the U.S. (Seafood Health Facts, 2017). Trout is currently produced and processed in the state which creates a base on which to grow. Grayling may be another species of interest in specialty restaurants.

REGIONS IN MICHIGAN WITH THE GREATEST POTENTIAL

Michigan MarketMaker allows the analysis of the state by census tract. Income and education were used to assess the areas of the state that had the most potential for increased seafood consumption. Using household incomes in excess of $100,000 as a filter, the areas with the most potential include the Petoskey/Traverse City region; areas surrounding Grand Rapids including Holland and Ottawa County; the suburbs of Midland, Bay City and Saginaw, the region surrounding Lansing; the region surrounding Kalamazoo; and Livingston, Oakland and Washtenaw counties.

Filtering for education gave similar results with the exceptions being that the cities of Kalamazoo, Grand Rapids and East Lasing became better potential markets. Given how much seafood is consumed in restaurants focusing on larger cities such as Grand Rapids, Lansing, and Kalamazoo could be a successful strategy. The city of Grand Rapids has a great deal of potential because of its relatively young population despite its relatively low household income levels. Sales of native species along the coast of Lake Michigan could also be a successful strategy especially during the summer tourist season. Ann Arbor also appears to be a very strong market. Nearby Detroit area, including the racially and ethnically diverse suburbs such as Dearborn may also be an area of the state where a variety of species, including purchasing live fish may be attractive to consumers. Within the Great Lakes region, Toronto is a potential market as it is the fourth largest city in North America.

PRIORITIZED RECOMMENDATIONS FOR NEXT STEPS

1. A well-coordinated one-stop shop for educational materials relating to commercial aquaculture in Michigan and the Great Lakes region is needed. Currently resource materials and other educational products are available from a variety of sources, including Michigan Departments of Agriculture and Rural Development (MDARD), Environmental Quality, and Natural Resources, Michigan Sea Grant, MSU Extension, North Central Regional Aaquacultre Center, Lake Superior State University, Michigan Aquaculture Association, etc. While some may be able to locate these resources, others may find it difficult to locate a portfolio of materials relevant for informing decisions about commercial aquaculture in Michigan.

2. This project addressed an important need for integrating data relevant for informing aquaculture facility siting and business development. It is important to note that this project was funded as a seed project to begin engaging stakeholders and data integration. Other, broader dynamic or ArcGIS server-based aquaculture facility siting and decision-support tools exist, such as those available in Wisconsin (www.uwsp.edu/cols-ap/nadf/Pages/GIS-based-analysis.aspx) and North Carolina (uncw.edu/benthic/sitingtool) could model a suitability index for sites under consideration to inform prospective aquaculture facility developers or other decision-makers (e.g., local planning and zoning or regulators). But without a dynamic or modeled suitability index for sites, the reader is left to further investigate and evaluate the suitability of sites themselves.

3. Additional GIS-based data layers would aid in advancing a dynamic ArcGIS-server-based commercial aquaculture facility tool. Here is a summary of additional data that would be very beneficial to create or acquire:

   - Data on types of aquaculture facilities. While information on licensed aquaculture producers in the state exists through MDARD, specific information about types of facilities, including aquaponics facilities, does not exist currently. Creating this data layer and making it available would be beneficial to helping current and future producers look for opportunities in business development.
   - Data on types of species and temperature category (warm water vs. cool water species) grown. While information on licensed aquaculture facilities in the state exists through MDARD, specific information about types of species grown or temperature category of species grown is limited. Some inspection records exist, but are incomplete. Detailed information presented in a map could allow current or future producers to determine the type of species currently grown in a geographic area or possible market-niche opportunities.
   - Data on topography and soils. This information could be useful for decision making regarding situation of aquaculture facilities that might carry a risk of wastewater seepage into groundwater.
   - Data on forest harvest areas could be useful for decision making about feasibility of complementary timber management and aquaculture land uses.
   - Data on risk perceptions or social acceptance of commercial aquaculture facilities throughout Michigan. This information can inform on areas of the state where willingness to support the development of an aquaculture facility exists.
   - Data on food need areas throughout Michigan where commercial aquaculture fish production can provide protein for a niche markets, such as fine dining or farm-to-table restaurants. It might also be used to identify areas needing access to efficient and affordable protein sources. For example, Alaska has initiated serving local seafood in schools through the National School Lunch program. (www.sitkawild.org/a_guide_to_serving_local_fish_in_school_cafeterias).
   - Data on where Michigan's current aquaculture, commercial, and tribal fishery products go. Currently, we have reporting systems for fish that come into the state of Michigan (e.g., baitfish suppliers importing fish for commercial sale and inspection), however, we know very little about where Michigan's current fishery products go. Understanding where our products go can provide insights into export market development opportunities to complement existing trade patterns where inexpensive fish are imported into the U.S. contributing to the $14 billion seafood trade deficit in 2016 (NOAA, 2017), second only to the oil trade deficit. Utilizing a telecoupling framework (Liu et al., 2013) to examine the global flow of fishery products would be a useful approach for data integration and visualization. The telecoupling framework has been applied to other trade scenarios, such as soybeans (Bicuda da Silva et al., 2017).

STATEWIDE MAPS

FIGURE 2. Cold and cold transitional stream reaches mapped at the scale of local catchments. Data describing thermal classes of Michigan's stream reaches were provided by the Michigan Department of Natural Resources, Institute for Fisheries Research.

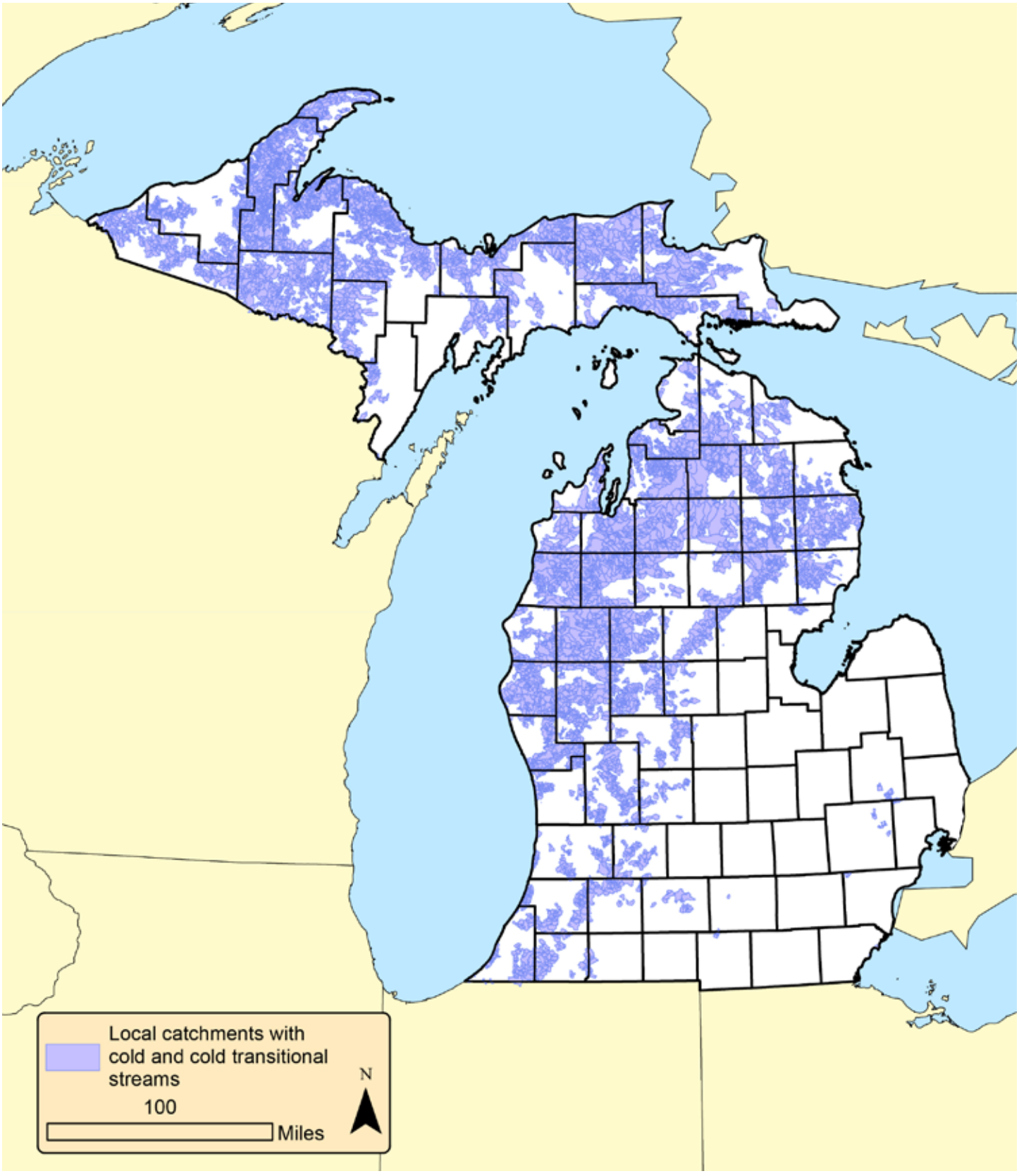


FIGURE 3. Locations of lands used for agriculture. Data were acquired from the 2011 National Land Cover Dataset (www.mrlc.gov/nlcd2011.php) and include locations of row crop and pasture lands throughout Michigan.

FIGURE 4. Locations of different types of fish production facilities. These include private aquaculture facilities producing fish and those with unknown production status as of December 2016, as well as tribal, federal, and state hatcheries. Data on fish production facilities were provided by different sources, and source information is included in Appendix C.

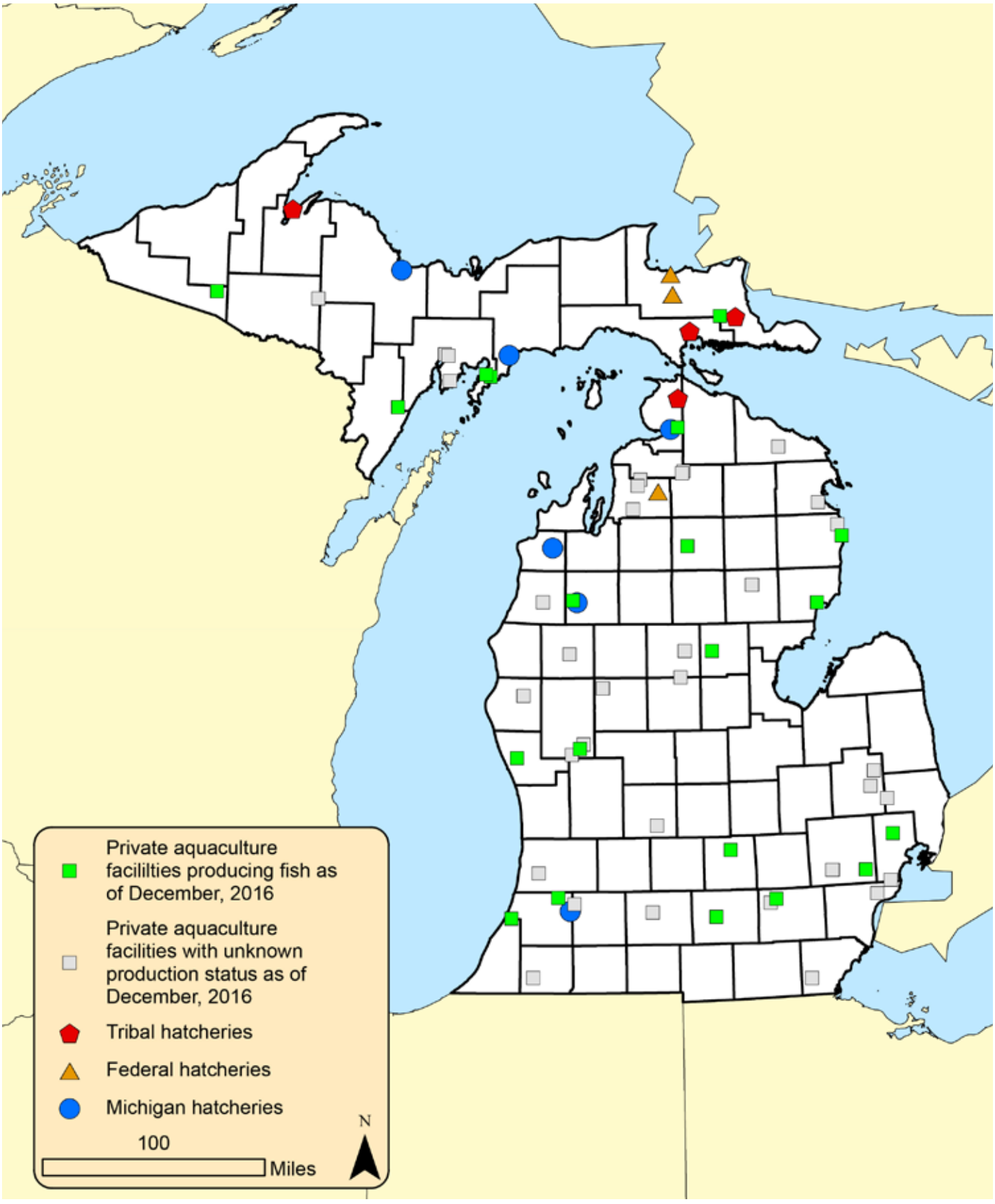


FIGURE 5. Locations of fish processing facilities and drive time from various locations around the state. Information on locations was provided by the Michigan Department of Agriculture and Rural Development and is considered current through 2016.

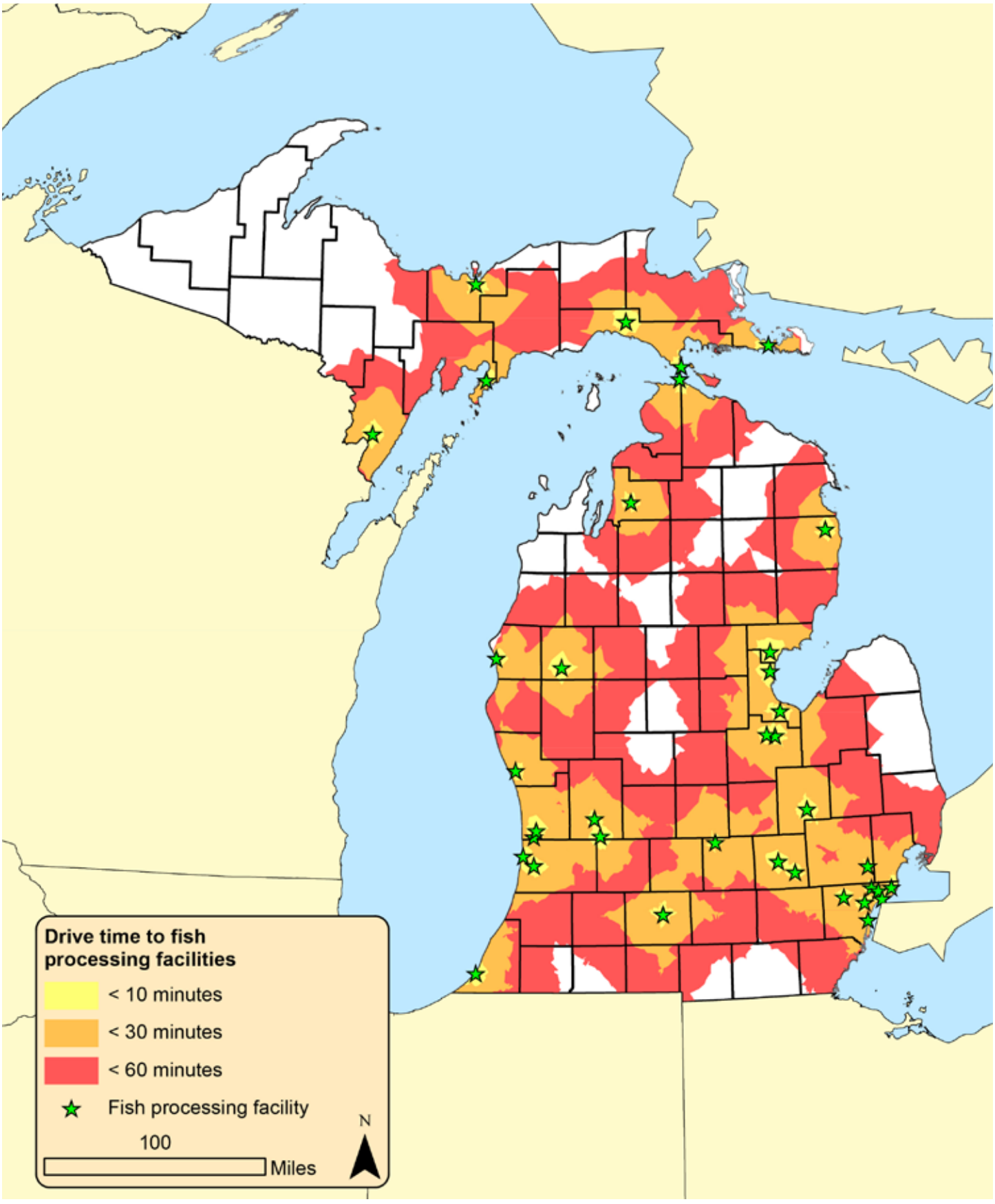


FIGURE 6. Locations of urban centers and drive times to centers. Urban centers are defined as regions that consist of urbanized areas that contain 50,000 or more people and urban clusters that contain at least 2,500 people based on the 2010 United States Census.

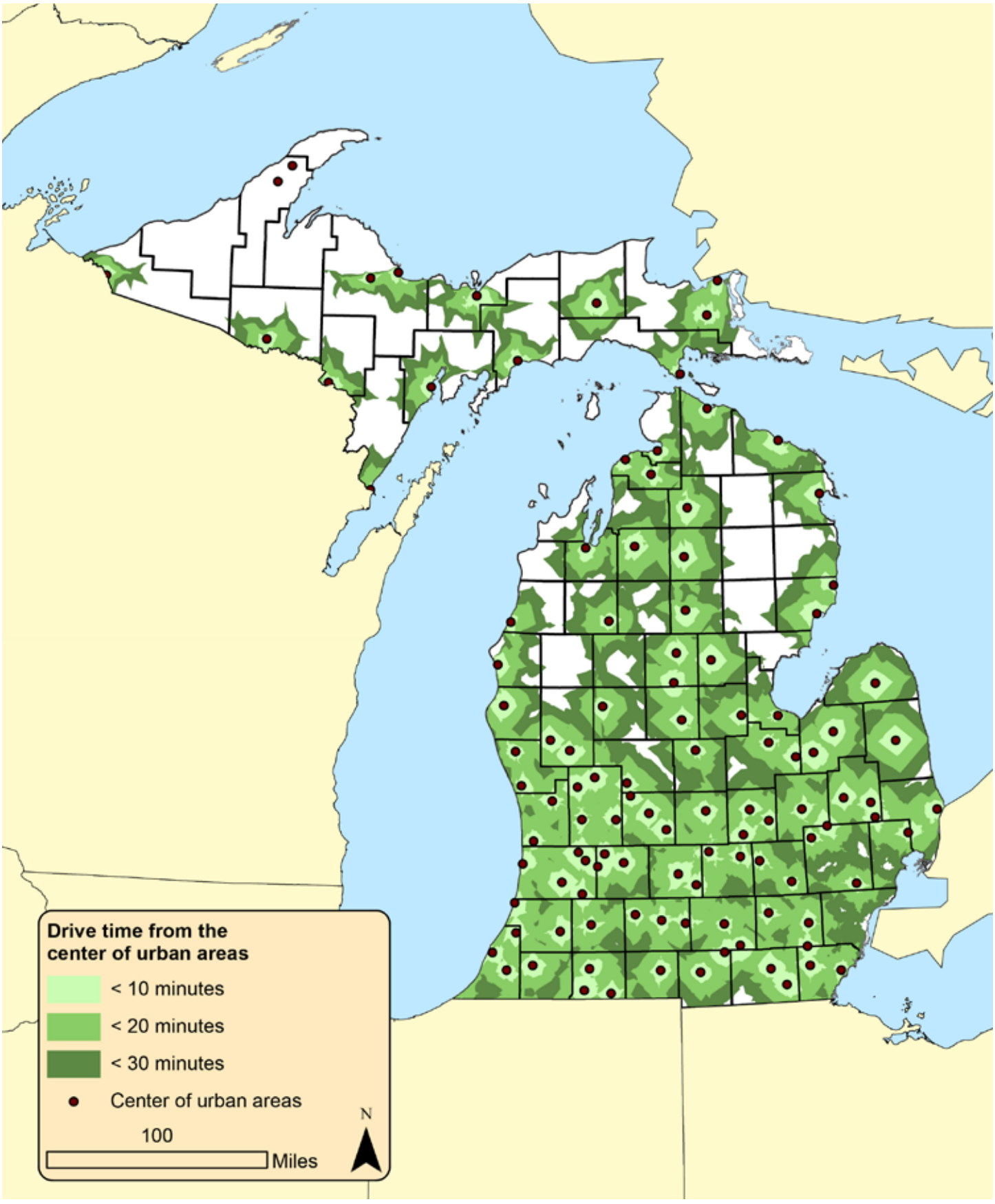


FIGURE 7. Locations of Michigan Department of Environmental Quality (MDEQ) conservation easements, which are areas protected to ensure the functionality of wetlands. Data were published in 2017 and more information can be found at: gis-michigan.opendata.arcgis.com/datasets/53b6643d18994d8db12fb13567cd3c21_10

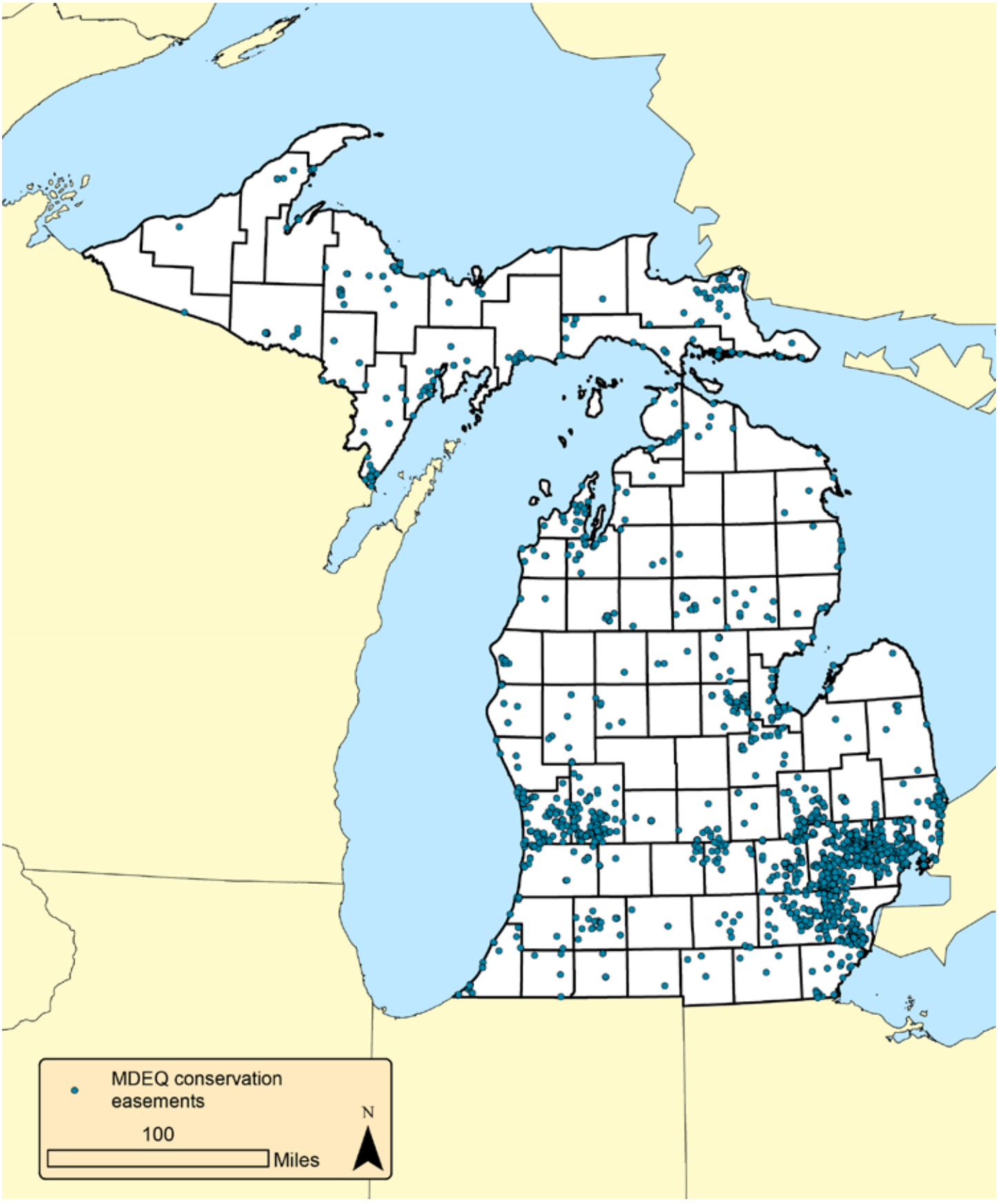


FIGURE 8. Risk of degradation to stream fish habitats mapped in local catchments of stream reaches. Risk scores were developed based on stream fish responses to multiple human disturbances for the National Fish Habitat Partnership and the 2015 National Assessment of Stream Fish Habitats. More information can be found at: assessment.fishhabitat.org

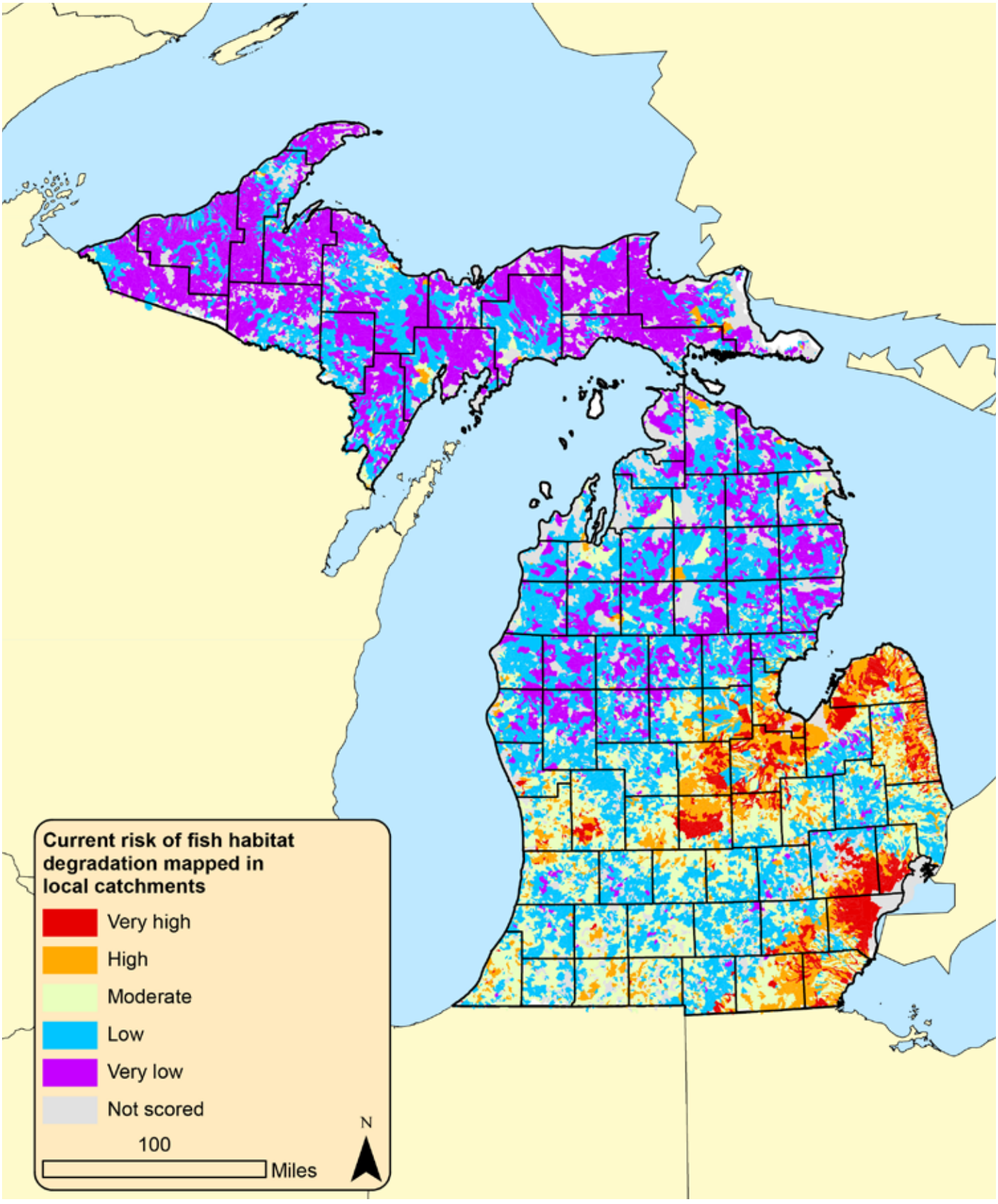


FIGURE 9. Population density mapped within census blocks. Data are from the 2010 census and more information can be found at: www.census.gov/geo/maps-data/data/tiger-data.html

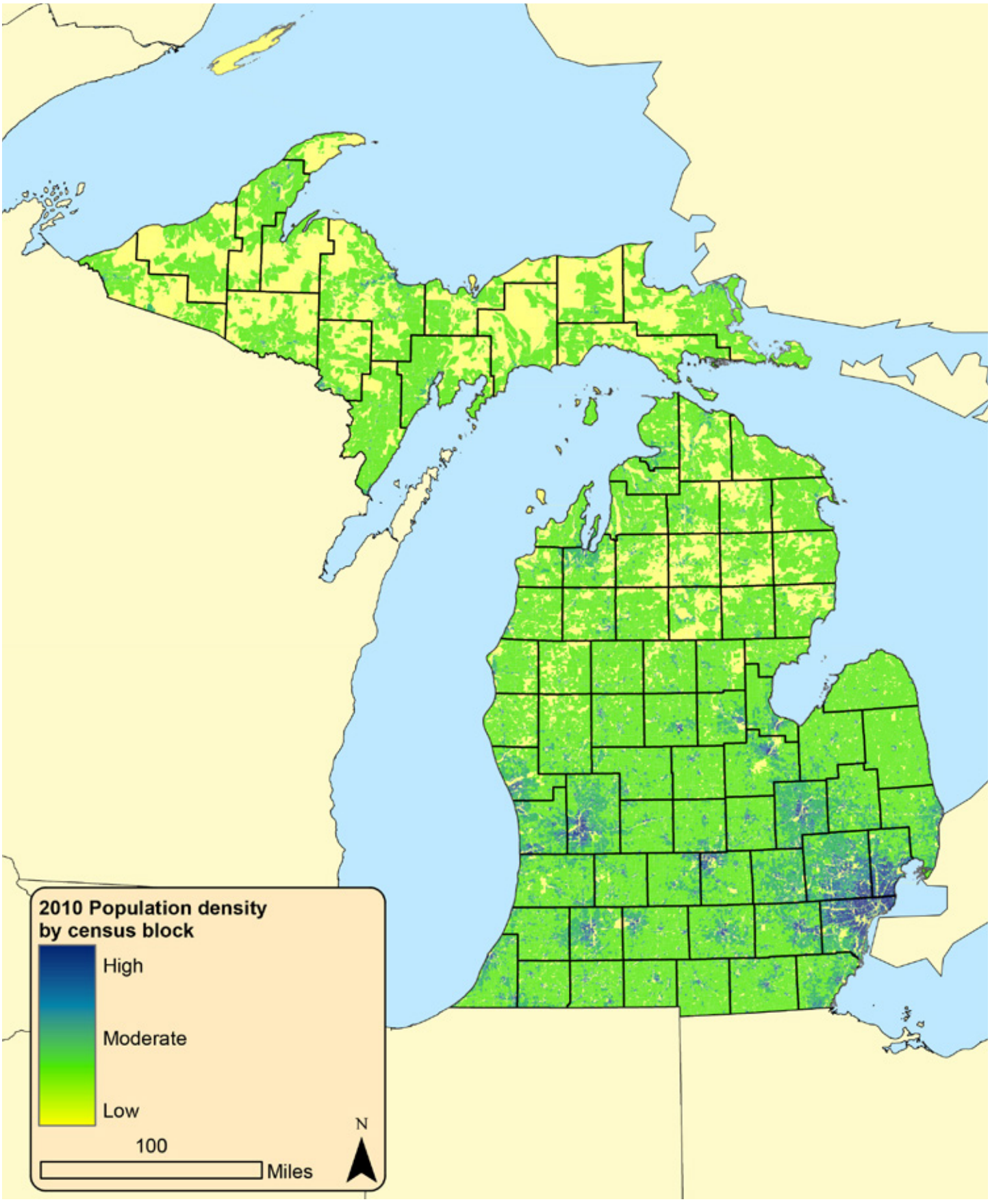


FIGURE 10. Protected areas of the landscape as identified in the Protected Areas Database of the United States (gapanalysis.usgs.gov/padus/data/metadata). These areas are defined as Status 1 and Status 2 lands, which broadly include areas with permanent protection and that are not subject to extractive uses.

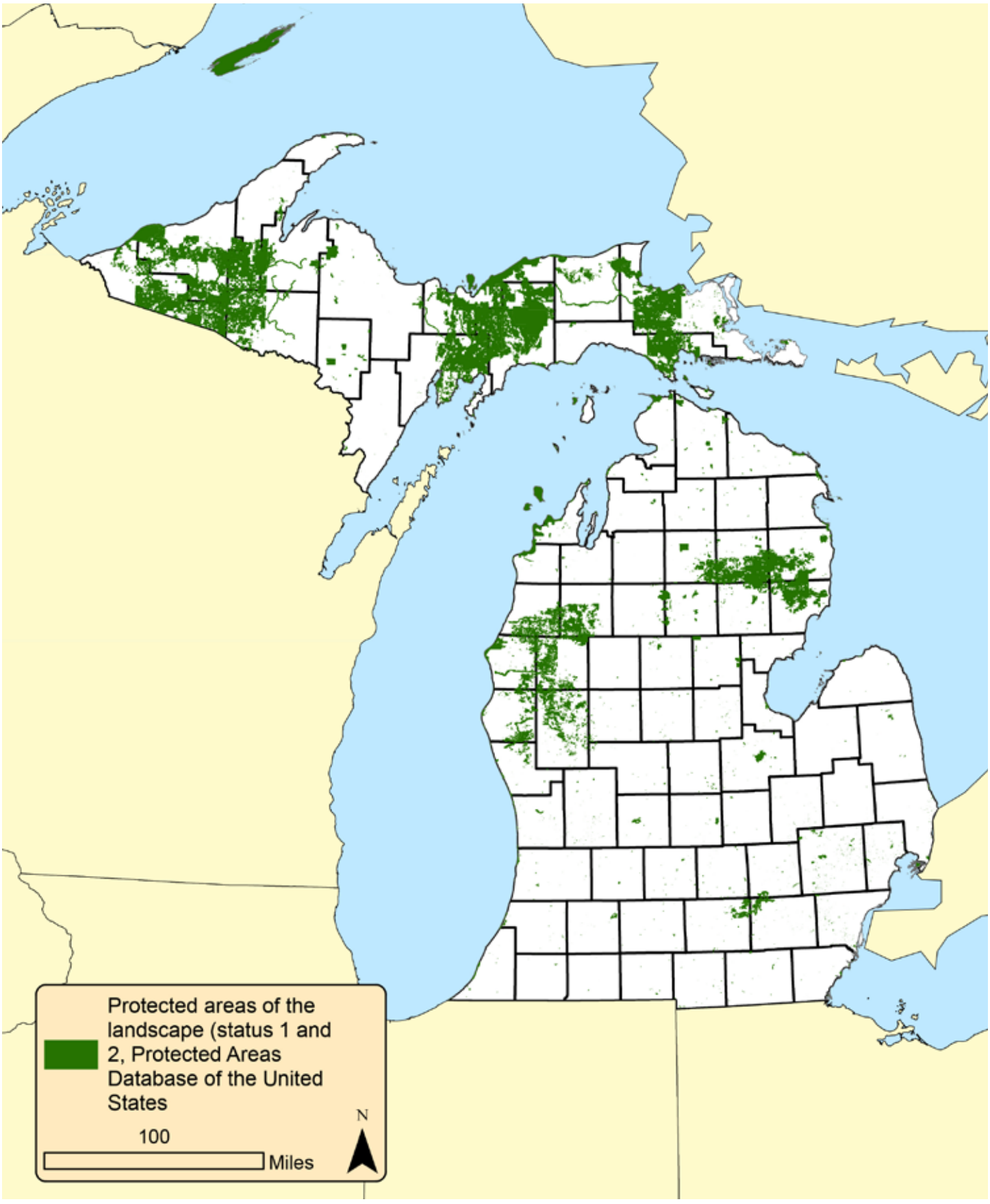


FIGURE 11. HUC-12 watersheds that potentially support state or federally listed Threatened and Endangered (T and E) aquatic species and/or Species of Greatest Conservation Need (SGCN). These data were provided by the Institute for Fisheries Research of the Michigan Department of Natural Resources. Lists of these species are included in Appendices D and E.

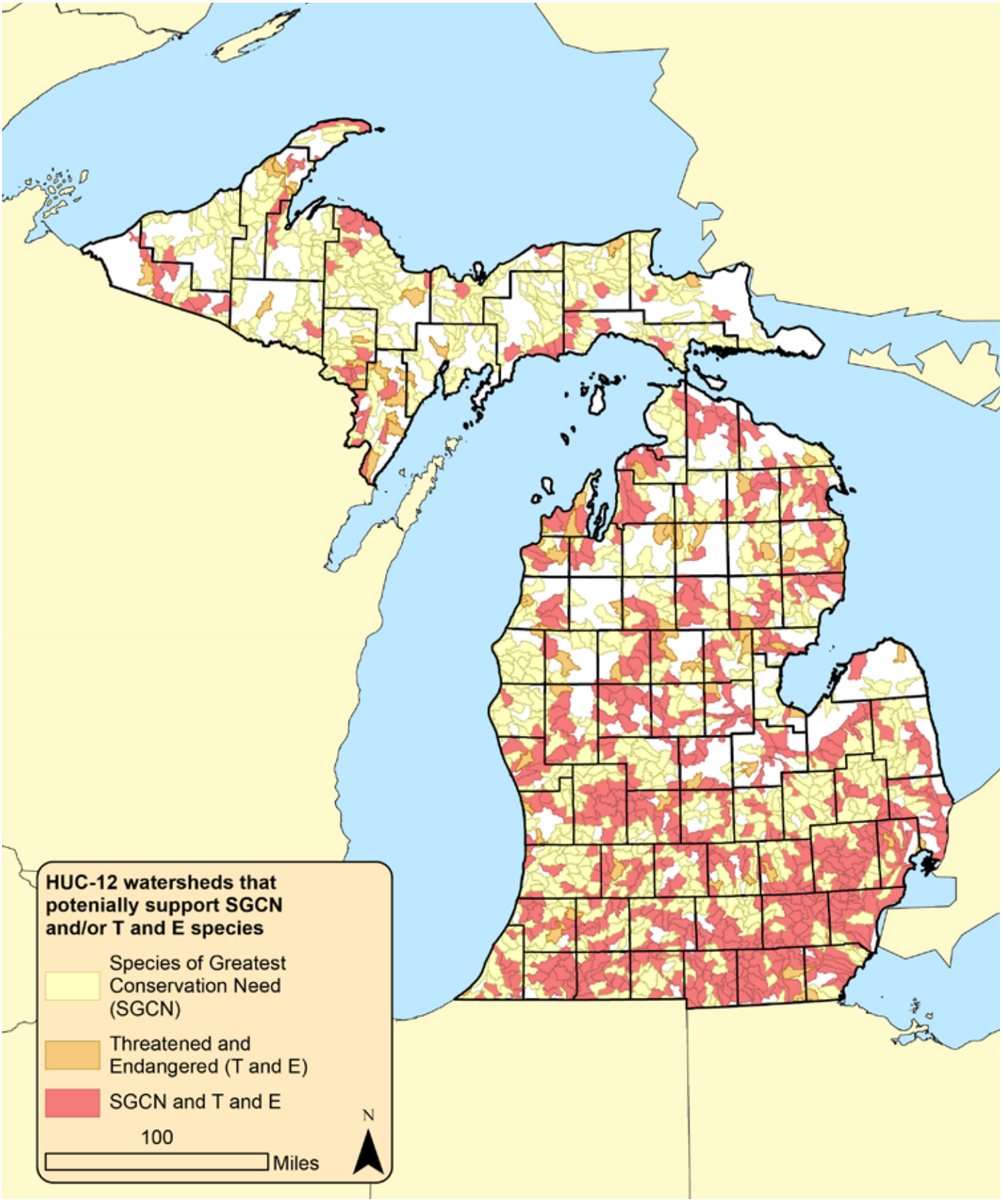


FIGURE 12. State Designated Natural Rivers and National Wild and Scenic Rivers. Natural River designations were provided by the Michigan Department of Natural Resources (www.michigan.gov/dnr/0,4570,7-350-79136_79236_82211---,00.html), and more information on National Wild and Scenic Rivers can be found at: www.rivers.gov/designation.php.

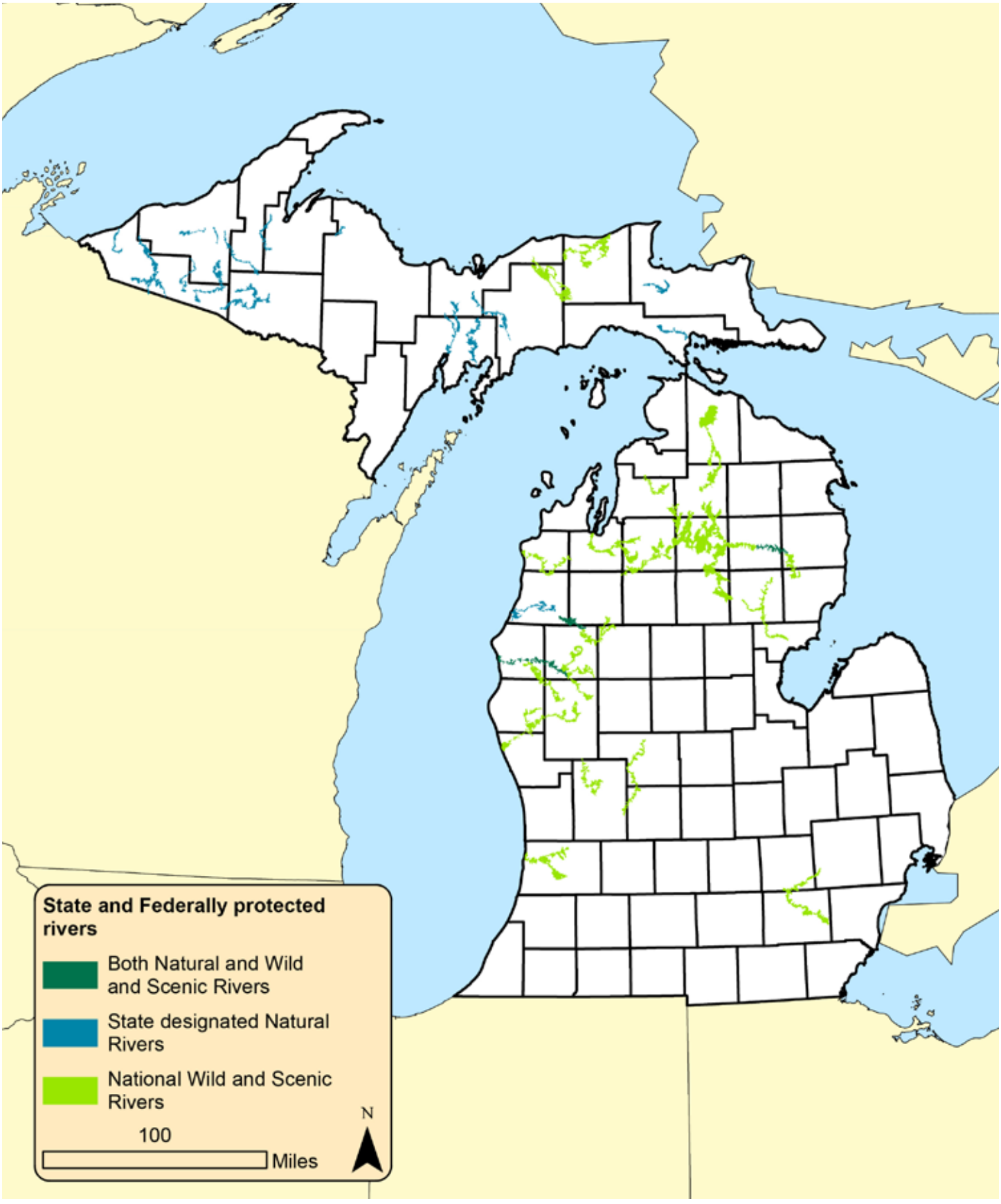


FIGURE 13. Thermal classes and sizes (based on catchment drainage area) of all of Michigan's stream reaches. Reaches draining catchments less than or equal to 80 mi^2 are considered streams, reaches draining catchments greater than 80 mi^2 and less than or equal to 300 mi^2 are considered small rivers, and reaches draining catchments larger than 300 mi^2 are considered large rivers. Data describing thermal classes of Michigan's stream reaches were provided by the Michigan Department of Natural Resources, Institute for Fisheries Research.

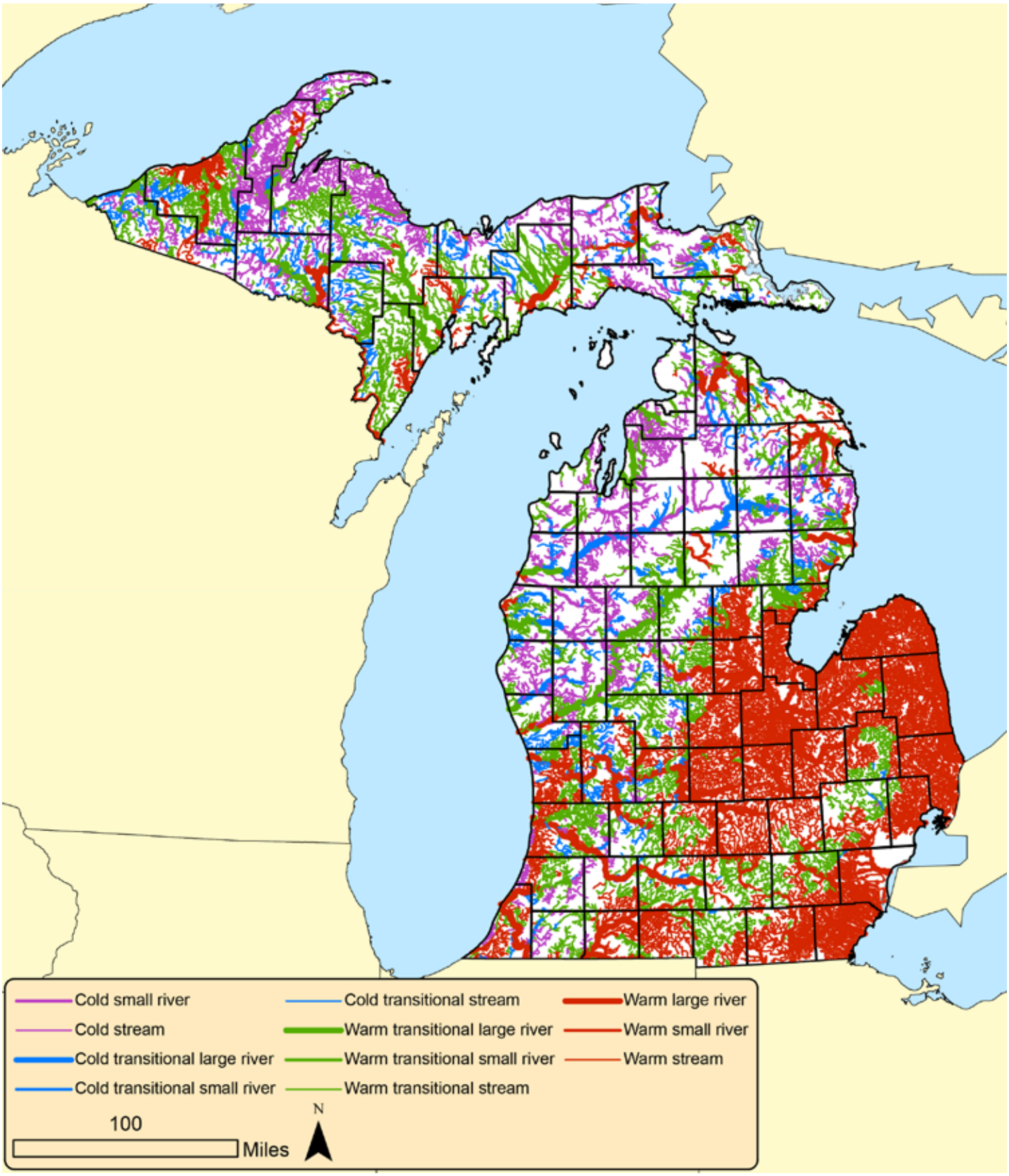


FIGURE 14. Warm and warm-transitional stream reaches mapped at the scale of local catchments. Data describing thermal classes of Michigan's stream reaches were provided by the Michigan Department of Natural Resources, Institute for Fisheries Research.

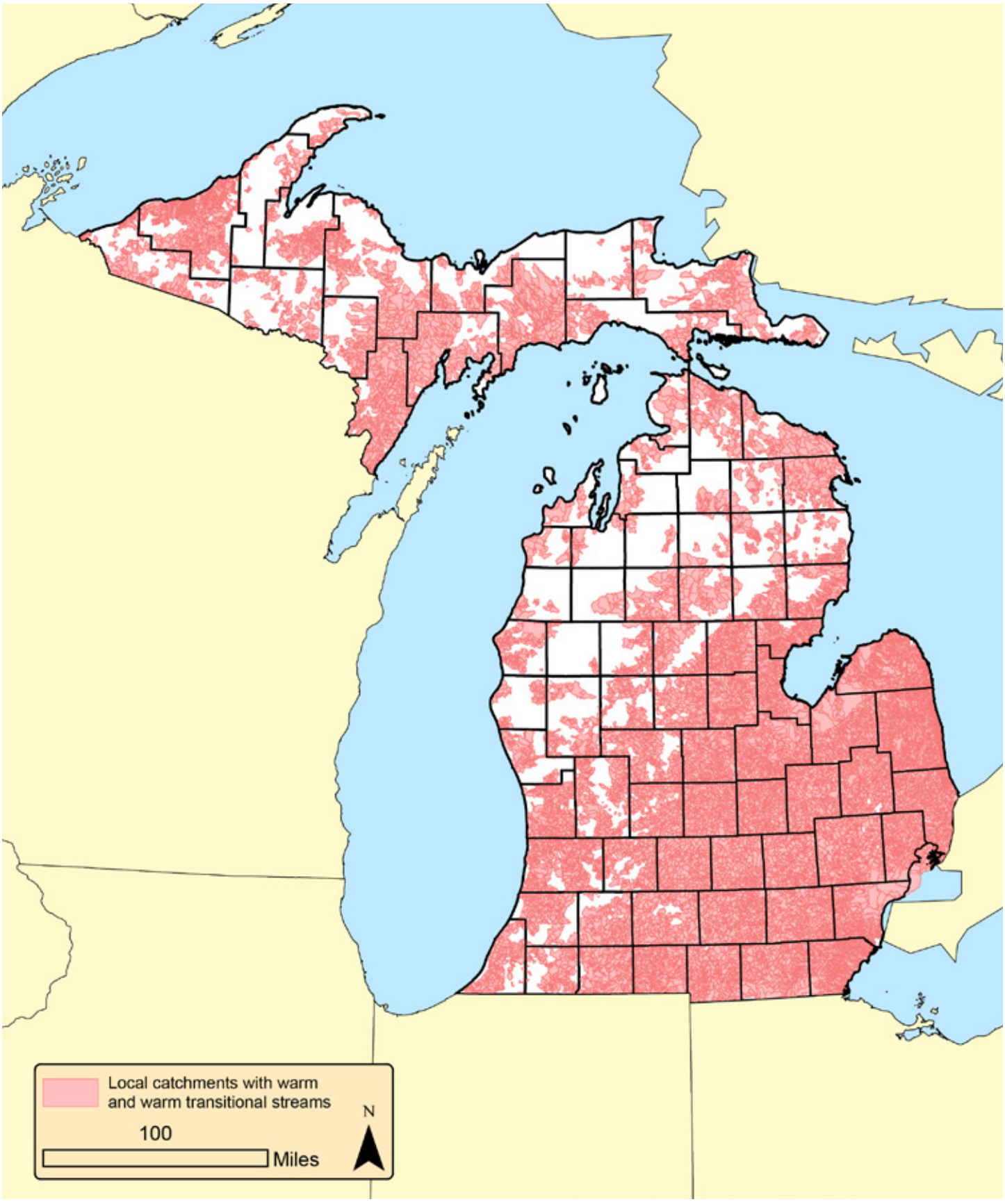


FIGURE 15. Water discharge considerations. Water bodies are included that are currently (as of 2016) assigned a total maximum daily load (TMDL) for sedimentation, siltation, oxygen depletion, nutrients, excess algal growth, thermal impacts, or aquatic plants. Also, landscapes draining to Saginaw Bay and Lake Erie are included in this map due to the susceptibility of these waterbodies to excess nutrient loading.

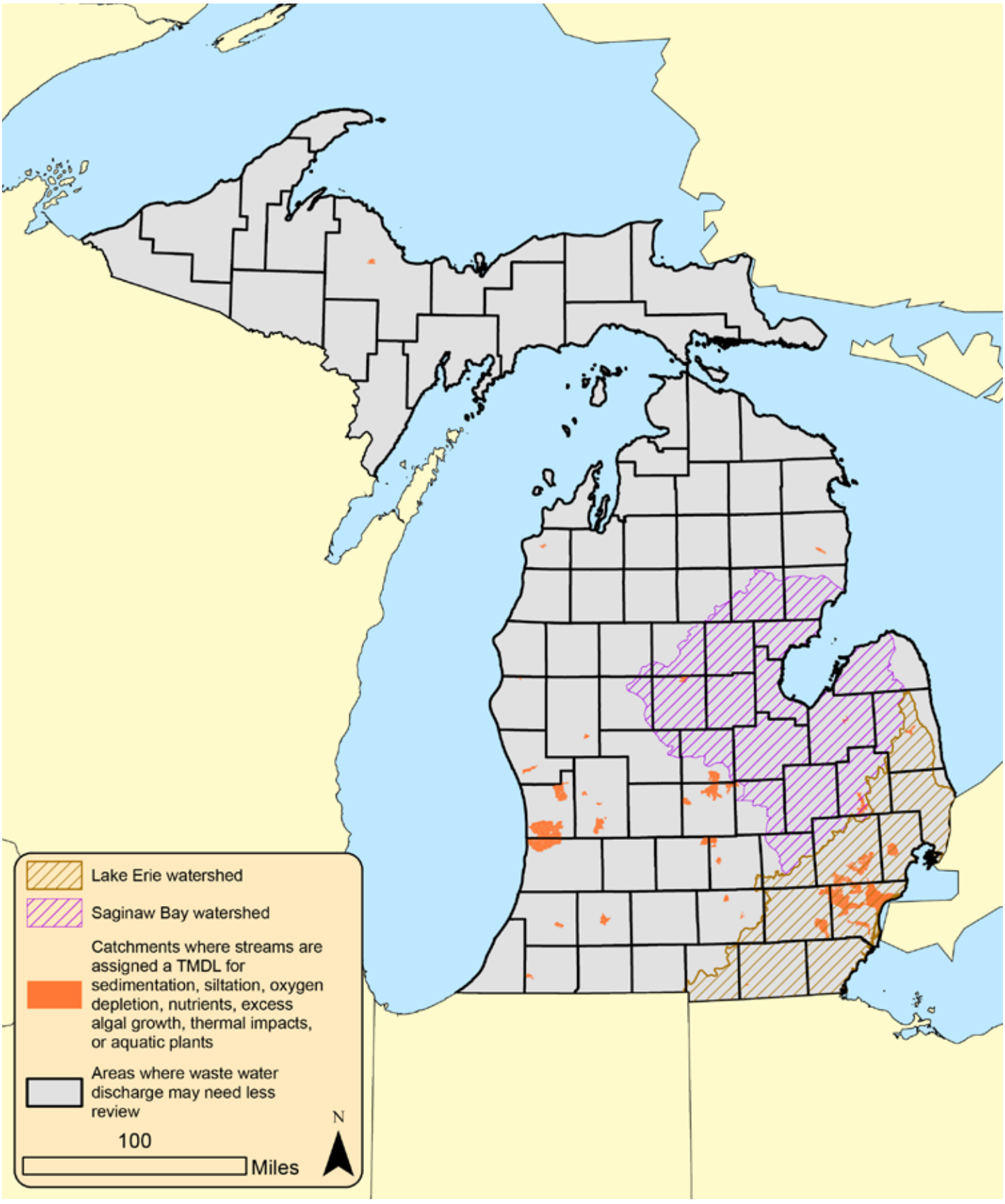


FIGURE 16. Water sourcing considerations. Water bodies are include that are currently (as of 2016) assigned an impaired waters listing for DDT, selenium, PFOs, or dioxin.

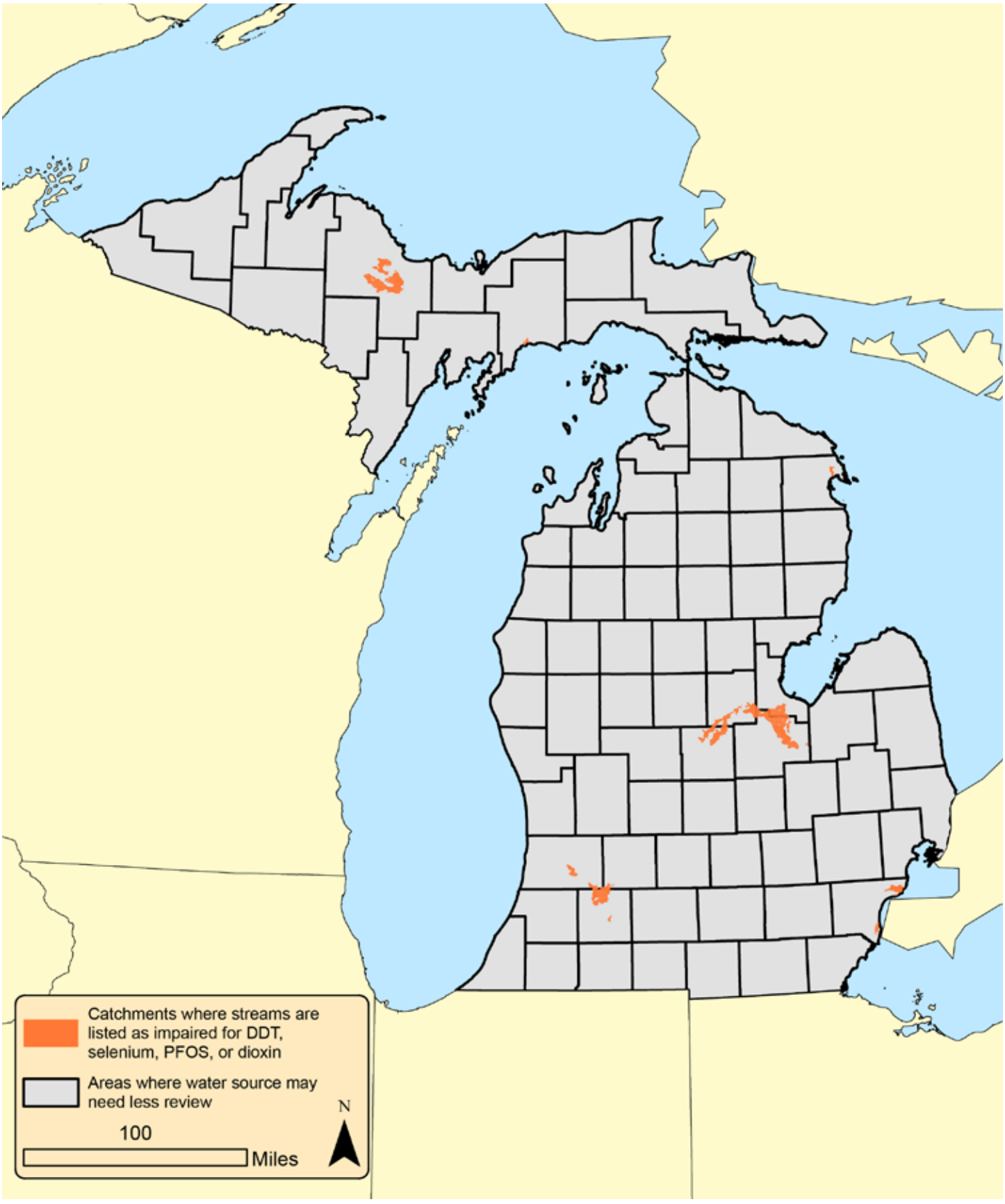


FIGURE 17. Locations of wellhead protections areas, which are landscapes designated by municipalities that are essential for drinking water supplies. Data were provided by the Michigan Department of Environmental Quality, and more information can be found at: gis-michigan.opendata.arcgis.com/datasets/1f55cd0e81184687a4975619829da561_3

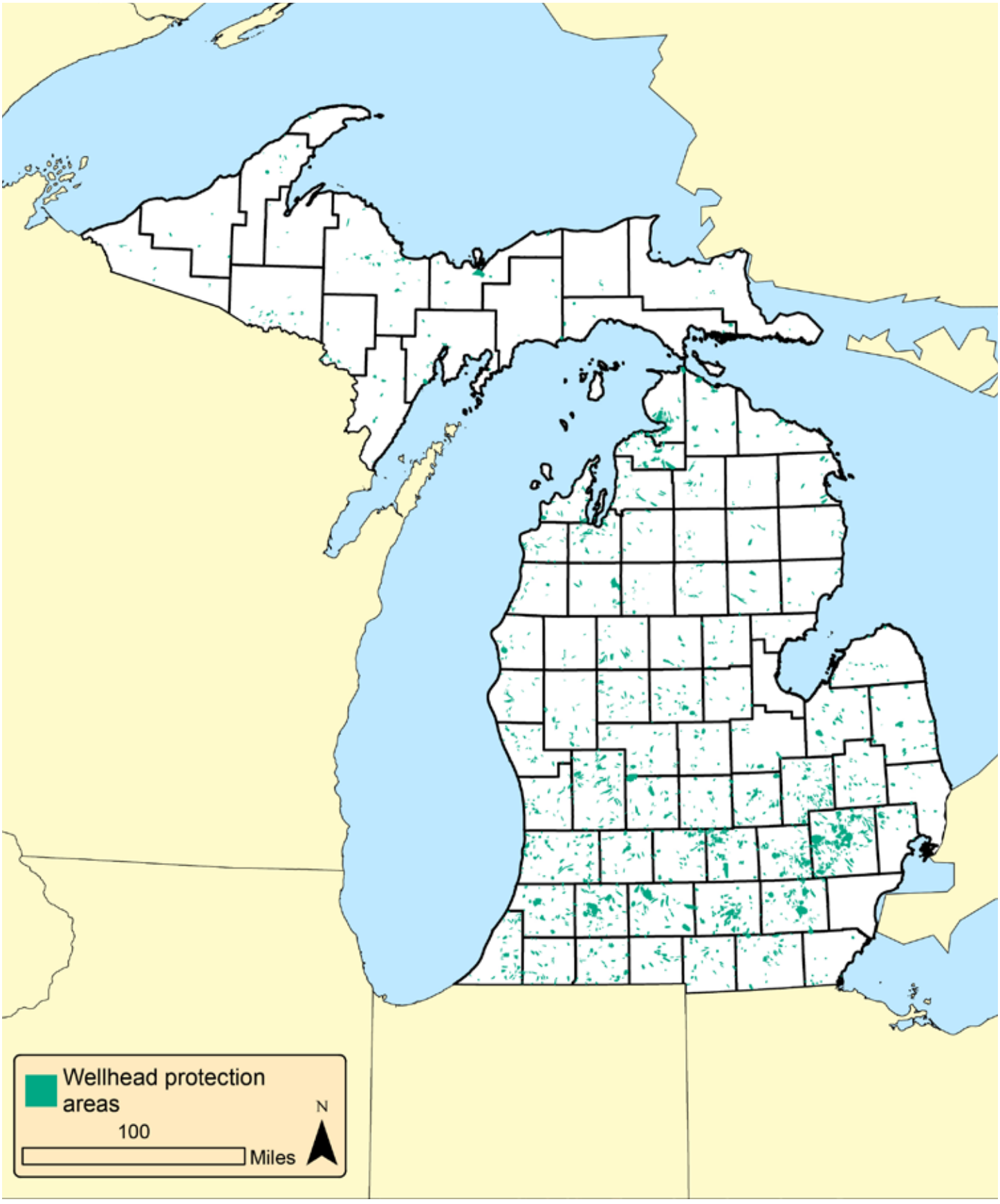


FIGURE 18. Locations of airports and airfields. Data can be found at koordinates.com/layer/748-us-airports

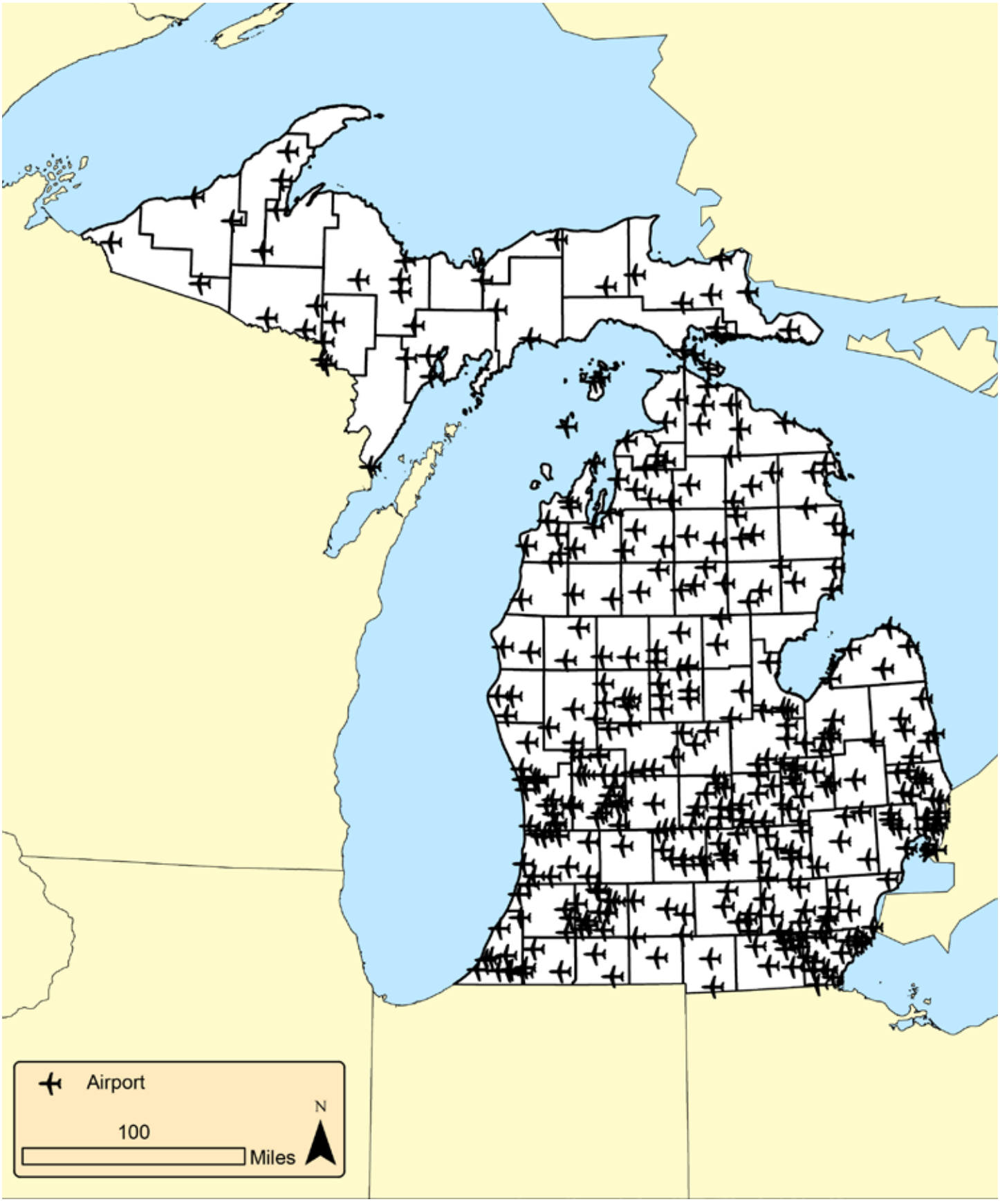


FIGURE 19. Locations of flowing wells are derived from the water wells dataset provided by the Michigan Department of Environmental Quality. Data can be found at gis-michigan.opendata.arcgis.com/datasets?q=wells&sort_by=relevance

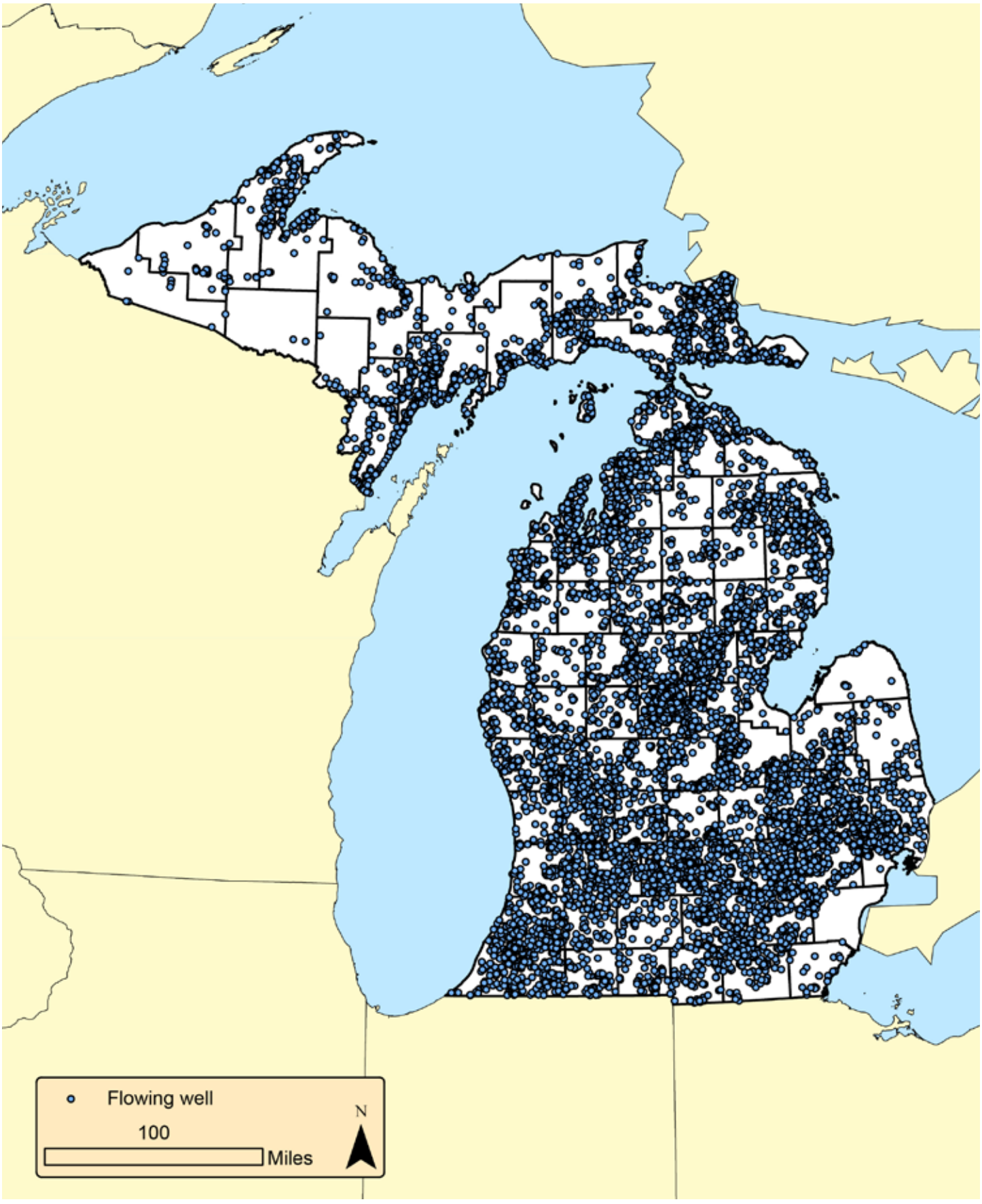


FIGURE 20. Areas where aquaculture fish have a higher market potential were identified by Dr. Bill Knudson. Polygons include urban areas provided by the United States Census and Counties.

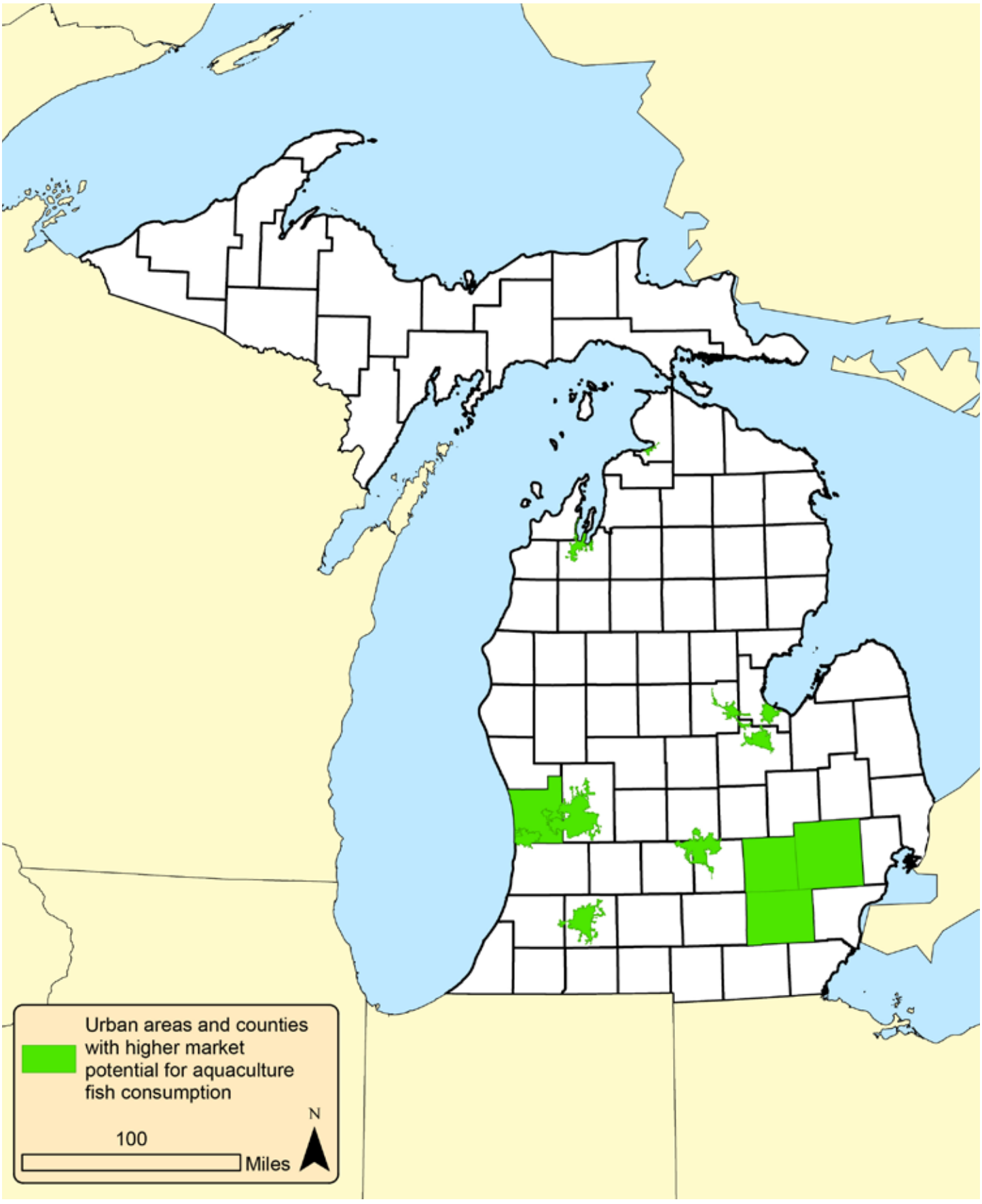


FIGURE 21. HUC-8 watersheds with reported findings of non-game, non-indigenous aquatic species. Data were provided by the United States Geological Survey Non-indigenous Aquatic Species program, nas.er.usgs.gov and include records through 2017. See Appendix G for species found in specific HUC-8 watersheds.

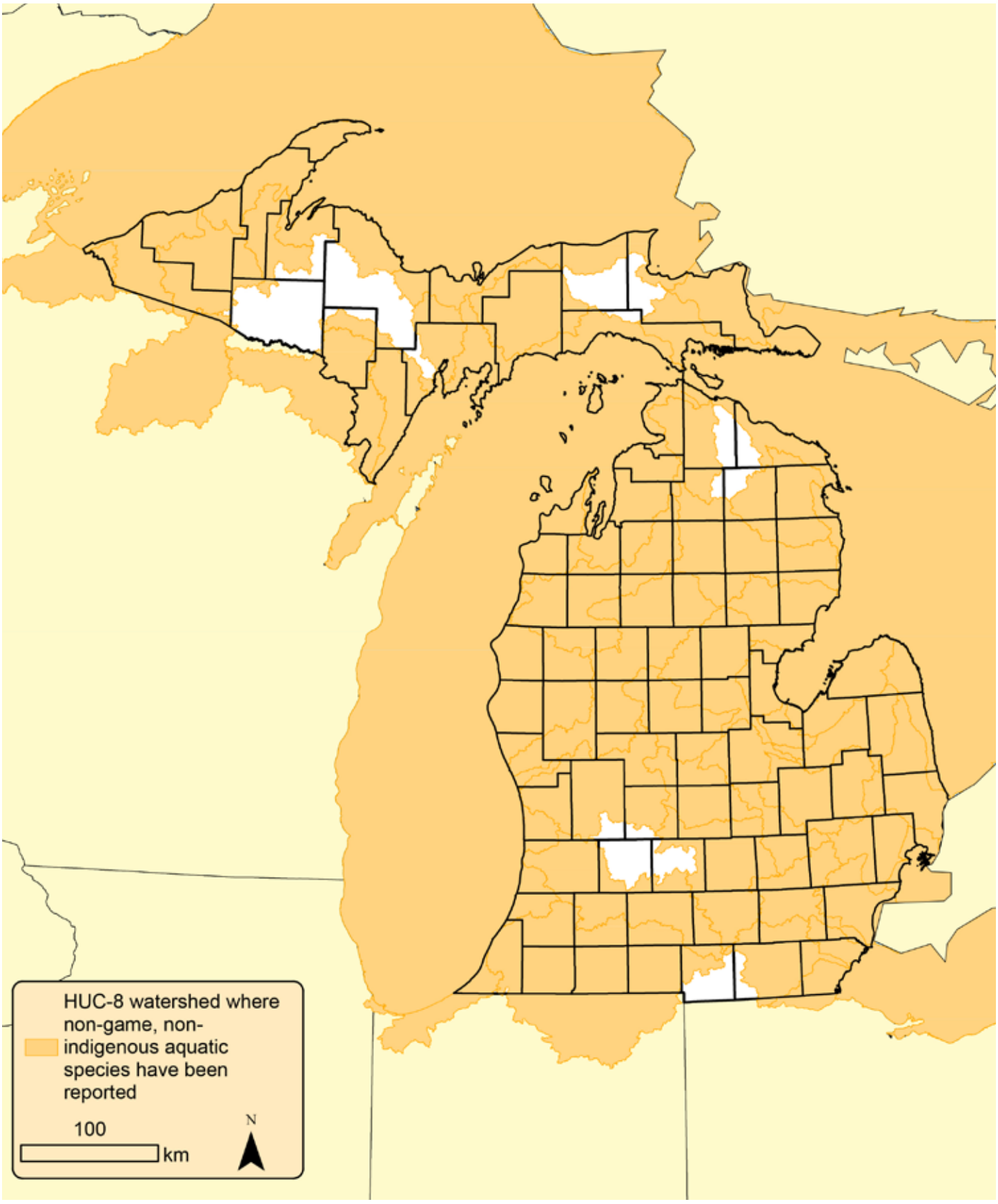


FIGURE 22. Wastewater treatment plants were identified using the National Pollutant Detection Elimination System dataset as well as the Facility Registry Service records. These datasets can be accessed through the Michigan Department of Environmental Quality and www.epa.gov/enviro/epa-frs-facilities-state-single-file-csv-download respectively.

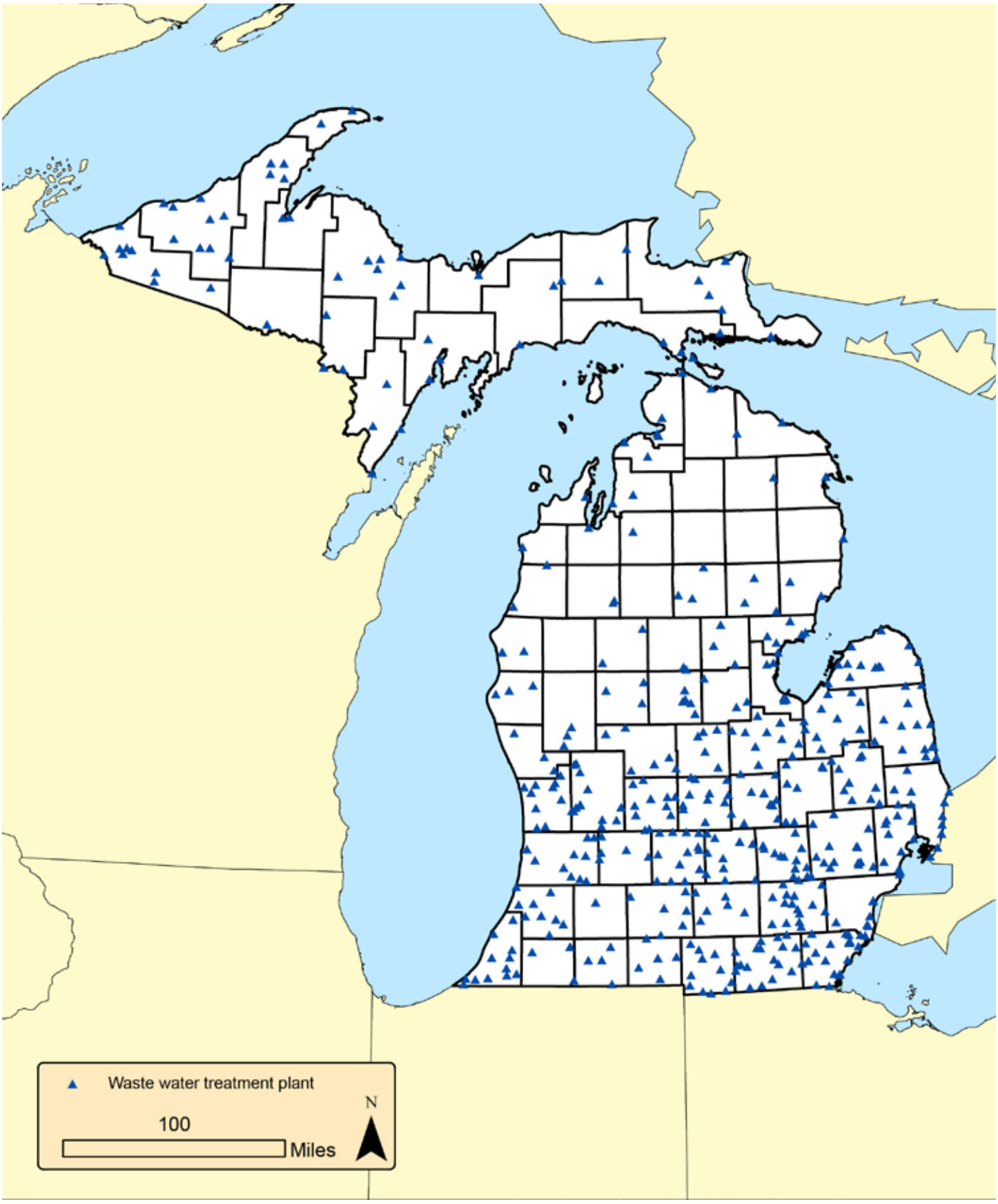
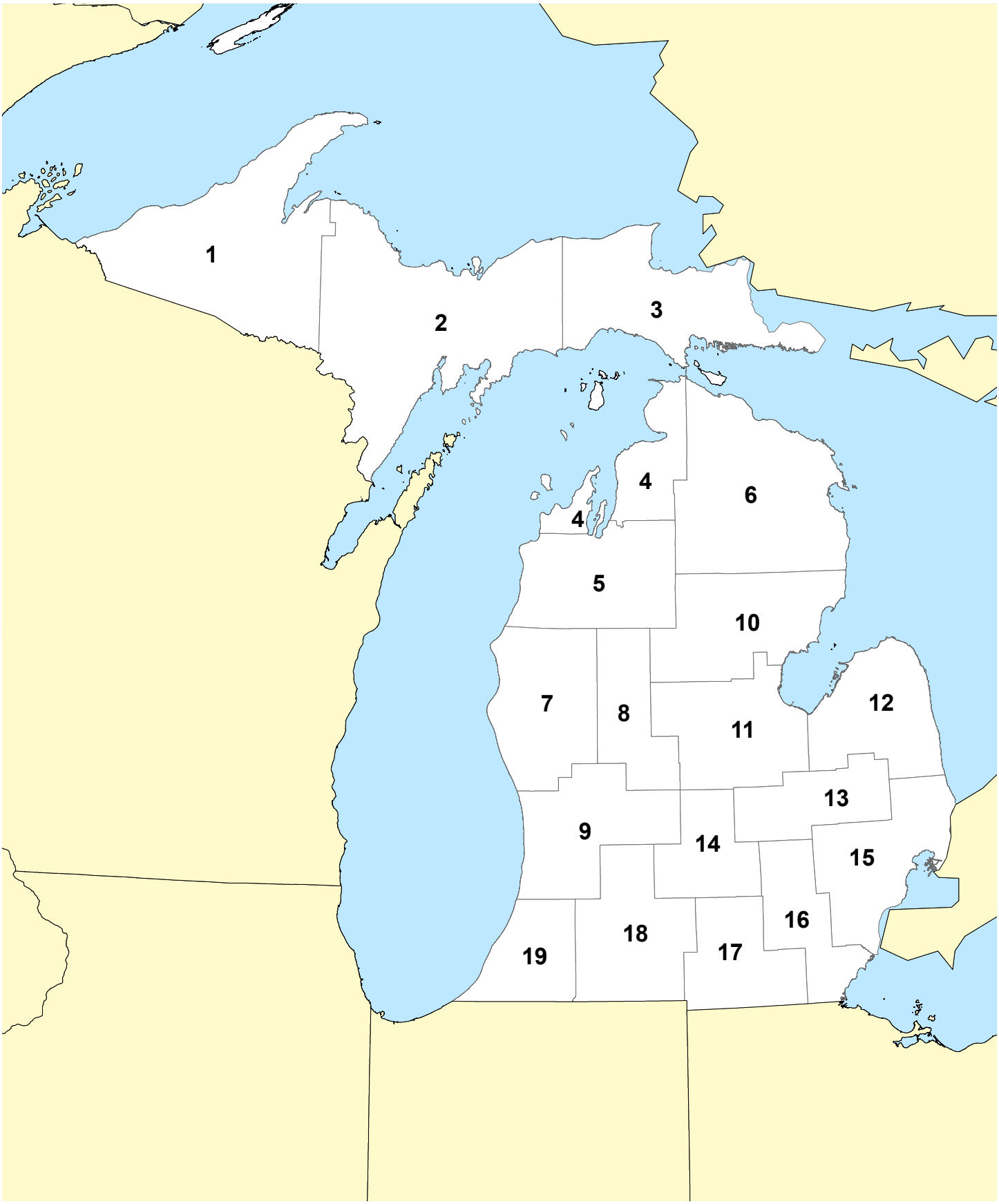


FIGURE 23. Guide to detailed regional maps available online at www.michiganseagrant.org/aquaculture



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APPENDIX A.

PROJECT CORE PARTNERS, CONTRIBUTORS, AND INVITED REVIEWERS

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Laura Campbell	Jodi Gruner	William Knudson	Catherine Riseng	Eric Wolcott
Jim Diana	Kyle Herreman	Todd Marsee	William Taylor	

APPENDIX B.

DIRECTORY OF TERMS AND ACRONYMS

Aquaculture—the rearing of aquatic animals or the cultivation of aquatic plants for food.

Aquaponics—a system of aquaculture in which the waste produced by farmed fish or other aquatic animals supplies nutrients for plants grown hydroponically, which in turn purify the water.

Catchment—the area from which rainfall flows into a river, lake, or reservoir.

Cold transitional streams—stream segments defined by the Michigan Department of Natural Resources Fisheries Division as typically having July mean water temperatures between 17.5oC and 19.5oC.

Fish processing facility—a facility where fish processing is performed, including among other activities, egg hatching, the cutting and packaging of fish and fish parts, and the preservation of fish and fish parts through processes such as salting or smoking.

Flow through aquaculture system (i.e. raceway)—an artificial channel used in aquaculture to culture aquatic organisms.

GAAMP—Generally accepted agricultural management practices to provide farmers with nuisance protection from complaints and lawsuits.

Hatchery—a place for artificial breeding, hatching, and rearing through the early lifestages of animals—finfish and shellfish in particular.

Hydrologic Unit Code 12 (HUC12)—Originally created in 2011, HUCs are spatial hydrologic units which correspond roughly to national watershed boundaries at various spatial scales. HUC12s are at the local, sub-watershed level that captures tributary systems.

National Fish Habitat Partnership (NFHP)—a national-scale partnership of public and private actors dedicated to addressing the loss and degradation of fish habitat.

National Pollutant Discharge Elimination System (NPDES)—a provision of the Clean Water Act that prohibits discharge of pollutants into waters of the U.S. unless a special permit has been issued by the U.S. Environmental Protection Agency, a state, or a tribal government.

Protected areas—a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.

Prosperity region—regional boundaries developed as part of the 2014 Michigan Regional Prosperity Initiative, with which State of Michigan departments have been directed to align their service delivery.

Perfluorooctane Sulfonic Acid (PFOS)—an anthropogenic fluorosurfactant and global pollutant listed in Annex B of the Stockholm Convention on Persistent Organic Pollutants.

Recirculating aquaculture system—an aquaculture system operated by filtering water from the fish (or shellfish) tanks so it can be reused within the tank.

River—a natural flowing water stream draining a watershed and flowing to a lake.

Spatial framework—a geographic-based scale to present data.

Species of Greatest Conservation Need (SGCN)—species identified in each state's State Wildlife Action Plan (SWAP) as requiring special conservation protection.

Stream reach—a length of stream or river.

Stream temperature class—Data layer used to show where cold, cold transitional, warm transitional and warm water stream designations are in the state.

Threatened and Endangered (T&E) Species—species which have been included in the U.S. Endangered Species Act or corresponding state legislation as having threatened or endangered status in the United States.

TMDL—Total maximum daily load. A regulatory term in the U.S. Clean Water Act.

Warm transitional streams—stream segments defined by the Michigan Department of Natural Resources Fisheries Division as typically having July mean water temperatures between 19.5oC and 21.0oC.

APPENDIX C.

DATA LAYERS, DATE, SOURCE, MAPPING UNIT, SCALE, UPDATE FREQUENCY, AND WEB ADDRESS

LAYER	DATE	SOURCE	MAPPING UNIT	SCALE OF ORIGINAL DATA	PUBLIC	UPDATE FREQUENCY	WEB ADDRESS
Private aquaculture facilities	2016	Michigan Department of Agriculture and Rural Development (MDARD)	Point		Yes	Annually	www.michigan.gov/documents/mdard/AQUACULTURE_FACILITIES_LIST_BY_COUNTY.pdf_Dec_2016_003_547168_7.pdf
Federal hatcheries	2016	US Fish and Wildlife Service	Point		Yes	As needed	www.fws.gov/midwest/fisheries/nfh.html
State hatcheries	2016	Michigan Department of Natural Resources (MDNR)	Point		Yes	As needed	
Tribal hatcheries	2016	MDNR	Point		Yes	As needed	Contact herrema5@msu.edu
State Designated Natural Rivers	2003	MDNR	Reach	1:24,000	Yes	As needed	www.michigan.gov/dnr/0,4570,7-350-79136_79236_82211---,00.html
National Wild and Scenic Rivers	2014	National Wild and Scenic Rivers System	Reach	1:24,000	Yes	As needed	www.rivers.gov/designation.php
Stream temperature classification	2009	MDNR	Reach	1:100,000	No	None planned	Contact the Michigan Department of Natural Resources Institute for Fisheries Research for more information
National Land Cover Dataset	2011	Multi Resolution Land Characteristics Consortium	Grid cell	30 m	Yes	2018	www.mrlc.gov/nlcd2011.php
NFHP 2015 fish habitat condition scores	2015	Michigan State University	Reach	1:100,00	Yes	None planned	assessment.fishhabitat.org
Population density	2010	United States Census	Census block	NA	Yes	2020	www.census.gov/geo/maps-data/data/tiger-data.html
303d listed streams assigned a Total Maximum Daily Load (TMDL)	2016	Michigan Department of Environmental Quality (MDEQ)	Reach	1:100,000	Yes	2018	Contact the Michigan Department of Environmental Quality for more information
Protected areas database	2016	US Geological Survey	Polygons		Yes	2020	gapanalysis.usgs.gov/padus/data/download
Michigan wellhead protection areas	2012	MDEQ	Polygons		Yes	Quarterly	gis-michigan.opendata.arcgis.com/datasets/1f55cd0e81184687a4975619829da561_3
Michigan flowing wells	2005	MDEQ	Point		Yes	Annually	gis-michigan.opendata.arcgis.com/datasets?q=wells&sort_by=relevance

LAYER	DATE	SOURCE	MAPPING UNIT	SCALE OF ORIGINAL DATA	PUBLIC	UPDATE FREQUENCY	WEB ADDRESS
MDEQ conservation easements	2017	Michigan Department of Environmental Quality (MDEQ)	Polygons		Yes	Quarterly	gis-michigan.opendata.arcgis.com/datasets/53b6643d18994d8db12fb13567cd3c21_10
Fish processing facilities	2016	Michigan Department of Agriculture and Rural Development (MDARD)	Point		Yes	As needed	Created by MSU with information provided by MDARD; contact herrema5@msu.edu
NPDES permits	2016	MDEQ	Point		Yes		Created by MSU with information provided by MDEQ
Discharge water bodies	2017	Michigan State University	Polygon		Yes	None planned	Created by MSU
Urban areas	2016	United States Census	Polygon	1:500,000	Yes	None planned	www.census.gov/geo/maps-data/data/cbf/cbf_ua.html
TIGER 2016 primary and secondary roads	2016	United States Census	Line	Multi-scale	Yes	Annually	www.census.gov/geo/maps-data/data/tiger-line.html
Species of Greatest Conservation Need (SGCN)	2017	Michigan Department of Natural Resources (MDNR)	HUC-12		Yes	As needed	Contact the Michigan Department of Natural Resources Institute for Fisheries Research for more information
Threatened and Endangered Species	2017	MDNR	HUC-12		Yes	As needed	Contact the Michigan Department of Natural Resources Institute for Fisheries Research for more information
Nonindigenous Aquatic Species	2017	United States Geological Survey	HUC-8		Yes	As needed	nas.er.usgs.gov
Facility Registry Service	2016	United States Environmental Protection Agency	Point		Yes	Annually	www.epa.gov/enviro/epa-frs-facilities-state-single-file-csv-download
Airports	2009	Koordinates.com	Point		Yes	None planned	koordinates.com/layer/748-us-airports
MDNR Institute of Fisheries Research catchments		MDNR Institute of Fisheries Research	Polygon	1:24,000		As needed	Please contact Kevin Wehrly
Watershed Boundary Dataset	2017	United States Geological Survey	HUC-12	1:24,000	Yes	As needed	Please contact herrema5@msu.edu for the version downloaded on 03/10/2017

APPENDIX D.

AQUATIC ORGANISMS LISTED AS STATE SPECIES OF GREATEST CONSERVATION NEED (SGCN)

TAXA	COMMON NAME	SCIENTIFIC NAME
Lake fishes	Cisco	*Coregonus artedi*
	Lake Sturgeon	*Acipenser fulvescens*
	Pugnose Shiner	*Notropis anogenus*
	Starhead Topminnow	*Fundulus dispar*
Lake mussels	Eastern Pondmussel	*Ligumia nasuta*
	Elktoe	*Alasmidonta marginata*
	Kidney Shell	*Ptychobranchus fasciolaris*
	Paper Pondshell	*Utterbackia imbecillis*
	Purple Wartyback	*Cyclonaias tuberculata*
	Rainbow	*Villosa iris*
	Round Pigtoe	*Pleurobema sintoxia*
	Slippershell	*Alasmidonta viridis*
	Wavy-rayed Lampmussel	*Lampsilis fasciola*
Stream fishes	Bigmouth Shiner	*Notropis dorsalis*
	Black Redhorse	*Moxostoma duquesnei*
	Brindled Madtom	*Noturus miurus*
	Channel Darter	*Percina copelandi*
	Creek Chubsucker	*Erimyzon oblongus*
	Eastern Sand Darter	*Ammocrypta pellucida*
	Orangethroat Darter	*Etheostoma spectabile*
	Pugnose Shiner	*Notropis anogenus*
	Redside Dace	*Clinostomus elongatus*
	River Redhorse	*Moxostoma carinatum*
	Silver Shiner	*Notropis photogenis*
	Southern Redbelly Dace	*Phoxinus erythrogaster*
Stream mussels	Black Sandshell	*Ligumia recta*
	Clubshell	*Pleurobema clava*
	Deertoe	*Truncilla truncata*
	Eastern Pondmussel	*Ligumia nasuta*
	Elktoe	*Alasmidonta marginata*
	Ellipse	*Venustaconcha ellipsiformis*
	Fawnsfoot	*Truncilla donaciformis*
	Hickorynut	*Obovaria olivaria*
	Kidney Shell	*Ptychobranchus fasciolaris*
	Lilliput	*Toxolasma parvum*
	Northern Riffleshell	*Epioblasma rangiana*
	Paper Pondshell	*Utterbackia imbecillis*
	Purple Wartyback	*Cyclonaias tuberculata*
	Rainbow	*Villosa iris*
	Rayed Bean	*Villosa fabalis*
	Round Hickorynut	*Obovaria subrotunda*
	Round Pigtoe	*Pleurobema sintoxia*
	Salamander Mussel	*Simpsonaias ambigua*
	Slippershell	*Alasmidonta viridis*
	Snuffbox	*Epioblasma triquetra*
	Threehorn Wartyback	*Obliquaria reflexa*
	Wavy-rayed Lampmussel	*Lampsilis fasciola*

APPENDIX E.

AQUATIC ORGANISMS LISTED AS STATE OR FEDERALLY THREATENED OR ENDANGERED IN MICHIGAN

ENTITY	TAXA	COMMON NAME	SCIENTIFIC NAME
Federal	**Mussels**	Clubshell	*Pleurobema clava*
		Northern Riffleshell	*Epioblasma rangiana*
		Snuffbox	*Epioblasma triquetra*
		Rayed Bean	*Villosa fabalis*
State	**Fishes**	Channel Darter	*Percina copelandi*
		Eastern Sand Darter	*Ammocrypta pellucida*
		Cisco	*Coregonus artedi*
		Lake Sturgeon	*Acipenser fulvescens*
		Mooneye	*Hiodon tergisus*
		Northern Madtom	*Noturus stigmosus*
		Pugnose Minnow	*Opsopoeodus emiliae*
		Pugnose Shiner	*Notropis anogenus*
		Redside Dace	*Clinostomus elongatus*
		River Darter	*Percina shumardi*
		River Redhorse	*Moxostoma carinatum*
		Sauger	*Sander canadensis*
		Shortjaw Cisco	*Coregonus zenithicus*
		Silver Shiner	*Notropis photogenis*
		Southern Redbelly Dace	*Phoxinus erythrogaster*
		Creek Chubsucker	*Erimyzon oblongus*
State	**Mussels**	Black Sandshell	*Ligumia recta*
		Clubshell	*Pleurobema clava*
		Eastern Pondmussel	*Ligumia nasuta*
		Fawnsfoot	*Truncilla donaciformis*
		Hickorynut	*Obovaria olivaria*
		Lake Floater	*Pyganodon subgibbosa*
		Lilliput	*Toxolasma parvum*
		Northern Riffleshell	*Epioblasma rangiana*
		Pink Papershell	*Potamilus ohiensis*
		Purple Lilliput	*Toxolasma lividus*
		Purple Wartyback	*Cyclonaias tuberculata*
		Rayed Bean	*Villosa fabalis*
		Round Hickorynut	*Obovaria subrotunda*
		Salamander Mussel	*Simpsonaias ambigua*
		Slippershell	*Alasmidonta viridis*
		Snuffbox	*Epioblasma triquetra*
		Threehorn Wartyback	*Obliquaria reflexa*
		Wavy-rayed Lampmussel	*Lampsilis fasciola*
		White Catspaw	*Epioblasma obliquata perobliqua*

APPENDIX F.

LIST OF FISH PROCESSORS

RECOROAD ID	NAME	ADDRESS	CITY	ZIP-CODE	COUNTY	PHONE
Ffp092320	AFC Sushi at Kroger #409	12731 Saginaw Road	Grand Blanc	48439	Genesee	(810) 695-6384
Ffp116411	AFC Sushi at Kroger #463	3125 John R. Road	Troy	48083	Oakland	(248) 658-1700
Ffp099964	AFC Sushi at Kroger #720	108 W. Highland Road	Howell	48843	Livingston	(517) 552-0126
Ffp102650	AFC Sushi at Kroger #738	4672 State St.	Saginaw	48603	Saginaw	(989) 792-6371
Flp098716	Alcona FFA Chapter (Seasonal)	51 N. Barlow Road	Lincoln	48742	Alcona	(989) 736-8534
Flp089038	Baldwin Fish Farm/Stevenson Express	1435 8th St.	Baldwin	49304	Lake	(231) 745-2040
Flp075100	Barbeaux Fisheries	325 Huron St.	DeTour	49725	Chippewa	(906) 297-5969
Flp069363	BeaRoadsley Fisheries	3994 S. Main Road	Standish	48658	Arenac	(989) 846-4045
Ffp106974	Big Bay De Noc Fisheries	15659 17th Road	Garden	49835	Delta	(906) 644-2200
Ffp106531	Big O Smokehouse	9740 Cherry Valley Ave.	Caledonia	49316	Kent	(616) 891-5555
Ffp061613	Big Stone Bay Fishery Inc.	10975 US-23 Hwy.	Mackinaw City	49701	Cheboygan	(231) 436-4144
Ffp095187	Blis LLC	3759 Broadmoor SE, Ste. D	Grand Rapids	49512	Kent	(616) 942-7545
Ffp056331	Carl & Don Frazier Inc.	Corner Arbor & Main	Naubinway	49762	Mackinac	(906) 477-6027
Flp043011	Diepenhorst G.L. Fisheries	6313 Gleason Road	Saugatuck	49453	Allegan	(269) 857-4641
Flp061527	Express Poultry & Fish Inc.	15038 W. Warren Ave.	Dearborn	48126	Wayne	(313) 584-1020
Flp084180	Fennville Aquaculture Facilities	5293 117th Ave.	Fennville	49408	Allegan	(269) 561-2203
Ffp094049	Fishdock	3040 Lakeshore Dr.	Muskegon	49441	Muskegon	(231) 759-0496
Ffp040651	Glacier Springs Trout Farm	7851 Tyler Road, PO Box 389	Bellaire	49615	Antrim	(231) 533-8332
Ffp036722	Great Lakes Fish & Seafood Inc.	126 W. 7 Mile Road	Detroit	48203	Wayne	(313) 368-6050
Ffp109365	Greenbush Brewing Co.	5885 Sawyer Road	Sawyer	49125	Berrien	(269) 405-1076
Ffp112683	Hissho Sushi at Meijer #46	8650 W. Grand River Ave.	Brighton	48116	Livingston	(704) 926-2200
Ffp000891	Kings Fish Market Inc.	Box 98 Lake St.	Naubinway	49762	Mackinac	(906) 477-6362
Ffp077032	Mackinac Straits Fish Co.	109 Elliott St.	St. Ignace	49781	Mackinac	(906) 643-7535
Ffp094725	Massey Fish Co.	1442 West Road	St. Ignace	49781	Mackinac	(906) 984-2148
Ffp024989	Michigan Brand Inc.	1313 Farragut	Bay City	48708	Bay	(989) 893-9589
Ffp013683	Michigan Food Sales	16901 Harper	Detroit	48224	Wayne	(313) 882-7779
Ffp118667	Moes Roe	15677 17th Road	Garden	49835	Delta	(906) 286-0922
Ffp091177	Northern Lakes Seafood & Meats LLC	12301 Conant	Detroit	48212	Wayne	(313) 368-2500
Ffp110400	Odawa Fishery Inc.	229 S. Huron Ave.	Mackinaw City	49701	Cheboygan	(231) 436-7821
Ffp053839	Ruleau Bros Inc.	W. 521 South Dr.	Stephenson	49887	Menominee	(906) 753-4767
Ffp094579	Sea Fare Foods Inc.	2127 Brewster Ave.	Detroit	48207	Wayne	(313) 568-0223
Flp079085	Serafin Fisheries	3266 Lapan	Pinconning	48650	Bay	(989) 879-4596

RECORD ID	NAME	ADDRESS	CITY	ZIP-CODE	COUNTY	PHONE
Ffp030020	Superior Foods Company	4243 Broadmoor SE	Grand Rapids	49512	Kent	(616) 698-7700
Ffp117526	Sushi Avenue Inc. (Inside Fresh Thyme)	940 Trowbridge Road	East Lansing	48823	Ingham	(651) 294-7000
Ffp109705	Sushi Kabar	1185 Washington Ave.	Holland	49423	Allegan	(248) 379-4801
Ffp118950	Sushi Kabar LLC	15900 W. Michigan Ave.	Marshall	49068	Calhoun	(248) 379-4801
Ffp099069	True World Foods Detroit LLC	11876 Belden Ct.	Livonia	48150	Wayne	(734) 266-1518
Ffp013889	United Fish Dist.	1349 Adelaide	Detroit	48207	Wayne	(313) 567-6533
Ffp044384	Vanlandschoot & Sons Inc. (Seasonal)	1338 Commercial St.	Munising	49862	Alger	(906) 387-3851
Ffp090214	Walters Fisheries	4728 W. 6th St.	Ludington	49431	Mason	(231) 845-1510
Ffp044819	Weyand Fisheries Inc.	471 Biddle	Wyandotte	48192	Wayne	(734) 284-0400
Ffp117935	Whytes Fishery	3260 N. Two Mile Road	Pinconning	48650	Bay	(989) 879-3502
Ffp049795	Wrege Fish Co.	226 Millard, PO Box 2363	Saginaw	48607	Saginaw	(989) 753-8980

APPENDIX G.

NON-INDIGENOUS AQUATIC SPECIES

HUC8 NUMBER	COMMON NAME
4060200	Round Goby
4060200	Ruffe
4060200	Sea Lamprey
4060200	Threespine Stickleback
4060200	Wiper
4070001	Round Goby
4070001	Sea Lamprey
4070001	Threespine Stickleback
4070002	Round Goby
4070002	Sea Lamprey
4070003	Round Goby
4070003	Ruffe
4070003	Sea Lamprey
4070004	Maraena Whitefish
4070004	Round Goby
4070004	Ruffe
4070006	Round Goby
4070006	Ruffe
4070006	Sea Lamprey
4070007	Round Goby
4080101	Goldfish
4080101	Round Goby
4080101	Sea Lamprey
4080102	Round Goby
4080103	Round Goby
4080104	Round Goby
4080201	Asian Swamp Eel
4080201	Goldfish
4080201	Threespine Stickleback
4080202	Round Goby
4080203	Oriental Weatherfish
4080203	Round Goby
4080204	Pirapatinga, Red-bellied Pacu
4080204	Round Goby
4080205	Round Goby
4080206	Goldfish
4080206	Round Goby
4080300	Goldfish
4080300	Little Kern Golden Trout
4080300	Round Goby
4080300	Ruffe
4080300	Sea Lamprey
4080300	Splake
4080300	Threespine Stickleback
4090001	Freshwater Tubenose Goby
4090001	Goldfish
4090001	Round Goby
4090001	Sea Lamprey
4090002	Bigmouth Buffalo
4090002	European Flounder
4090002	Freshwater Tubenose Goby
4090002	Ghost Shiner
4090002	Goldfish
4090002	Pirapatinga, Red-bellied Pacu
4090002	Red Piranha
4090002	Round Goby
4090002	Sea Lamprey
4090002	Threespine Stickleback
4090003	Freshwater Tubenose Goby
4090003	Goldfish
4090004	Bigmouth Buffalo
4090004	Freshwater Tubenose Goby
4090004	Goldfish
4090004	Mummichog
4090004	Round Goby
4090004	Western Mosquitofish
4090005	Goldfish
4090005	Pirapatinga, Red-bellied Pacu
4090005	Red Piranha
4090005	Round Goby
4090005	Zebra Tilapia
4100001	Freshwater Tubenose Goby
4100001	Goldfish
4100001	Round Goby
4100002	Freshwater Tubenose Goby
4100002	Goldfish
4100002	Round Goby
4120200	Bigmouth Buffalo
4120200	Freshwater Tubenose Goby
4120200	Goldfish
4120200	Round Goby
4120200	Western Mosquitofish
7070001	Tiger Muskellunge
4000000	Goldfish
4000000	Margined Madtom
4000000	Suckermouth Minnow
4000000	Tench
4000000	Threespine Stickleback
4000000	Western Mosquitofish
4000000	Westslope Cutthroat Trout
4010302	Sea Lamprey
4020101	Ruffe
4020101	Sea Lamprey
4020101	Threespine Stickleback
4020102	Ruffe
4020102	Sea Lamprey
4020102	Threespine Stickleback
4020103	European Flounder
4020103	Pirapatinga, Red-bellied Pacu
4020103	Ruffe
4020103	Sea Lamprey
4020103	Threespine Stickleback
4020103	Tiger Muskellunge

HUC8 NUMBER	COMMON NAME
4020104	Ruffe
4020105	Sea Lamprey
4020201	Ruffe
4020201	Sea Lamprey
4020201	Splake
4020201	Threespine Stickleback
4020203	Ruffe
4020203	Sea Lamprey
4020300	Brook Silverside
4020300	Round Goby
4020300	Ruffe
4020300	Sea Lamprey
4020300	Threespine Stickleback
4030108	Sea Lamprey
4030108	Western Sand Darter
4030109	Round Goby
4030111	Round Goby
4030111	Sea Lamprey
4030112	Round Goby
4030112	Sea Lamprey
4040001	Round Goby
4040001	Sea Lamprey
4050001	Round Goby
4050001	Sea Lamprey
4050001	Steelcolor Shiner
4050002	Goldfish
4050002	Round Goby
4050002	Sea Lamprey
4050003	Goldfish
4050003	Round Goby
4050003	Wiper
4050004	Goldfish
4050004	Round Goby
4050005	Sea Lamprey
4050006	Goldfish

HUC8 NUMBER	COMMON NAME
4050006	Pirapatinga, Red-bellied Pacu
4050006	Round Goby
4060101	Round Goby
4060101	Sea Lamprey
4060102	Goldfish
4060102	Round Goby
4060102	Sea Lamprey
4060102	Shortnose Gar
4060103	Pirapatinga, Red-bellied Pacu
4060103	Round Goby
4060103	Sea Lamprey
4060104	Round Goby
4060104	Sea Lamprey
4060104	Splake
4060104	Threespine Stickleback
4060105	Cherry Salmon
4060105	Round Goby
4060105	Sea Lamprey
4060106	Margined Madtom
4060107	Round Goby
4060107	Sea Lamprey
4060107	Threespine Stickleback
4060200	European Flounder