MI/DEQ/WRD-15/044

Monitoring Strategy for Michigan's Inland Lakes

Introduction

Michigan's unique geographical location provides its citizens with a wealth of freshwater resources, including over 11,000 inland lakes that are valuable ecological resources and provide tremendous aesthetic and recreational value for the people of Michigan. Economically, inland lakes support a recreational industry valued at $15 billion per year and the value of shoreline property is estimated to be worth $200 billion, generating $3.5 billion in tax revenue.

Comprehensive water quality monitoring is necessary to inform natural resource management, assess inland lake quality, and protect public health. Although the Michigan Department of Environmental Quality (MDEQ) is the lead state agency responsible for monitoring, assessing, and managing the state's surface water and groundwater, effective water resource management is best achieved through partnerships with other state and federal agencies, local governments, tribes, universities, industry, environmental groups, and citizen volunteers. Wherever possible, the MDEQ strives to organize and direct the resources and energies created by these partnerships through a "watershed approach" to protect the quality and quantity of the state's water resources.

In January 1997, the MDEQ completed a monitoring report entitled, "A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters" (Strategy) *(The link provided was broken and has been removed)*. The Strategy was developed specifically to identify the activities and resources needed to establish a comprehensive, state-of-the-art water quality monitoring program, and has guided Michigan's monitoring program implementation. The Strategy defined four monitoring goals: (1) assess the current status and condition of waters of the state and determine whether water quality standards (WQS) are being met; (2) measure spatial and temporal water quality trends; (3) evaluate the effectiveness of water quality prevention and protection programs; and (4) identify new and emerging water quality problems. It consisted of nine interrelated elements: fish contaminants, water chemistry, sediment chemistry, biological integrity, wildlife contaminants, bathing beaches, inland lake quality and eutrophication, stream flow, and volunteer monitoring. The specific objectives of the inland lake quality and eutrophication monitoring component are to:

- Determine the trophic conditions of the inland lakes in the state and identify those not meeting WQS.
- Measure whether inland lake quality in the state is changing with time.
- Compare water quality among waters throughout Michigan.
- Identify causes and sources of water quality problems.
- Determine the effectiveness of the MDEQ's water quality management programs in protecting inland lake quality in the state.
- Identify inland lakes in the state that are high quality waters.
- Detect emerging issues in inland lakes, including the presence of nuisance aquatic species.

The Strategy was updated in 2005 and is currently (2015) being updated.

This document describes ongoing inland lake monitoring and assessment activities by the MDEQ as well as other organizations; identifies the objectives necessary to meet programmatic needs; proposes some additional/expanded projects to ensure objectives are met; and finishes with data management and reporting requirements.

Past and Ongoing Inland Lake Monitoring Activities

There is a great deal of existing monitoring on Michigan's inland lakes, not only by the MDEQ but by many local organizations, other local and state agencies, and multiple federal agencies.

MDEQ

A systematic effort to monitor the quality of Michigan's inland lakes was initiated in 1973 by the Michigan Department of Natural Resources (MDNR) under Section 314 of the federal Clean Water Act. The expectation of sampling significant lakes, defined as lakes 50 acres and greater with a public boat launch, every five years was hampered by lack of funds until the United States Environmental Protection Agency (USEPA) awarded a one-time grant in 1980 that allowed all of the unsampled lakes to be inventoried and classified according to trophic state. During the 1990s, water quality monitoring funding was reduced significantly and federal Clean Water Act Clean Lakes Program funds were eliminated. In 1998, the citizens of Michigan passed a $675 million Clean Michigan Initiative (CMI) bond for environmental, health, and natural resources protection programs and the MDEQ used a portion of these funds to develop the Lake Water Quality Assessment (LWQA) Monitoring Program in partnership with the United States Geological Survey (USGS). From 2001-2010, 729 public access inland lakes greater than 25 acres in size were monitored for baseline water quality conditions and trophic status (Figure 1). In addition, Landsat satellite imagery was used by the USGS to predict the water clarity of approximately 3,000 inland lakes greater than 20 acres in size during five different time frames (Figure 2) (https://www.usgs.gov/media/images/michigan-lake-water-clarity-interactive-map-viewer).

Surface Water Assessment Section (SWAS) staff have completed 17 Total Maximum Daily Loads (TMDL) through 2013 for inland lakes, addressing phosphorus (12) and *E. coli* (5). Follow-up monitoring has been conducted every other year at four lakes with USEPA-approved phosphorus TMDLs to assess progress toward attainment of the goals established in the TMDLs and to measure point source and nonpoint source program effectiveness (Figure 3).

Monitoring for aquatic invasive species (AIS) in inland lakes has recently been initiated. During the 2007 and 2012 National Lakes Assessments, a total of 101 Michigan lakes were surveyed for AIS. The number of AIS found ranged from 0-3 per lake in 2007 and 0-6 per lake in 2012. In addition, the MDEQ surveyed 14 lakes during the 2014 field season to become familiar with AIS sampling methods currently being used in Wisconsin, increase awareness of AIS issues, and collaborate with local groups. Based on the results from the National Lakes Assessments surveys and pilot study, we are currently evaluating how to proceed with AIS monitoring in inland lakes, including lake numbers, locations, and procedures.

The MDEQ has analyzed samples of 30 species of fish from 330 lakes and 93 impoundments since the Fish Contaminant Monitoring Program began in 1981. Prior to 1986 fish tissue monitoring was conducted primarily to address specific problems; since that time the monitoring has been conducted more broadly in an effort to evaluate the status of contaminant levels in fish statewide. Since 1986 the MDEQ has analyzed fish from an average of 30 lakes and impoundments annually. The MDEQ relies, to a large extent, on the Fisheries Division of the MDNR to collect fish samples during that agency's regular annual survey work. The MDEQ generally requests ten samples of a top predator species (walleye, northern pike, largemouth bass, or smallmouth bass). Depending on the water body, the MDEQ will also request a bottom-feeding species (generally common carp). At a minimum, fish fillet samples will be analyzed for mercury; if a bottom feeder is collected or if there is reason to believe the water body has been contaminated by chlorinated organic contaminants (e.g., proximity to a

legacy pollution source), the samples will also be analyzed for PCBs, chlorinated pesticides such as DDT, and a series of other industrial chemicals. The MDEQ also regularly analyzes contaminant levels in whole fish samples from seven inland lakes and five impoundments (Figure 4). These fixed stations have been sampled every three to four years since 1990, and the results are used to determine temporal trends in mercury, PCBs, DDT, and chlordane. The Michigan Department of Health and Human Services uses the sampling results and issues consumption advisories, where appropriate, designed to protect human health.

Sediment chemistry was monitored in partnership with Michigan State University at 47 inland lakes from 1999 to 2010, using CMI funds, to assess temporal trends in contaminant inputs into lakes (Figure 5). Annual reports of the sampling results from each lake were prepared and are available. The sediment core samples collected for this project were analyzed for mercury, trace metals (cadmium, chromium, copper, lead, nickel, and zinc), total PCBs, phosphorus, and organochlorine pesticides such as DDT.

Wildlife contaminant monitoring is another element of the 1997 monitoring strategy that is funded with CMI grants. The bald eagle and herring gull projects were started in 1999 and 2002, respectively. Bald eagle and herring gull samples are analyzed for bioaccumulative contaminants of concern such as mercury, PCBs, and chlorinated pesticides (e.g., DDT, DDE, and DDD). Herring gull eggs are also analyzed for dioxins and furans. While this effort is not specific to inland lakes is does allow for comparisions of contaminants and reproductive success of bald eagles at inland waters, including lakes, compared to the Great Lakes (Figure 6).

Local Agencies/Volunteers

Volunteer monitoring of Michigan's inland lakes was started by the MDNR as the Self-Help Program in 1974, and was expanded in 1992 when the MDNR and Michigan Lake and Stream Associations formed a cooperative agreement. In 2003, former Governor Jennifer Granholm created, by Executive Order, the Michigan Clean Water Corp (MiCorps), which includes the volunteer Cooperative Lakes Monitoring Program (CLMP) and is supported by CMI funds. The CLMP is administered by the MDEQ and Michigan Lake and Stream Associations and is operated under contract by the Great Lakes Commission, Huron River Watershed Council, and Michigan State University's Department of Fish and Wildlife. In recent years volunteers from about 200 lakes per year are enrolled and trained for the CLMP Program. Adequate secchi disc, phosphorus, and chlorophyll data to determine trophic state are collected from slightly more than 100 lakes per year (Figure 7). Significantly fewer volunteers participate in the temperature and dissolved oxygen profile, aquatic plant identification and mapping, and the exotic plant watch elements of the CLMP.

Beginning in 2001, the MDEQ annually awarded monitoring grants to local governments, watershed organizations, and university scientists to address local water quality issues. Several of these grants focus on inland lake monitoring, including trophic status, pathogens, internal phosphorus cycling, AIS, and algal toxins. The final grants were awarded in 2015, as the funding source (CMI bond funds) is almost exhausted.

Since 2003, the MDEQ has provided CMI grant funding to local health departments to support and augment beach monitoring at inland lakes throughout Michigan. Public beaches have been identified at 495 sites on inland lakes throughout the state (Figure 8). In 2012, monitoring was conducted at 163 inland lake public beaches in 33 counties. Exceedance of *E. coli* WQS were reported at 16 percent of the beaches. The number of inland beaches monitored since 2007

has ranged from a high of 269 to a low of 153. The monitoring typically yields several cases each year where contaminant sources are identified and remediation efforts are initiated.

County drain commissioners are typically tasked with maintaining legally established water levels at inland lakes. Lake water levels are monitored to confirm compliance with the court orders at varying frequencies and the results are maintained by county officials.

Other State Agencies

In 2002, the MDNR, Fisheries Division, initiated a statewide Status and Trend Program with a statistically-based design and standardized sampling methods for public inland lakes ten acres and larger. Public inland lakes are those with public access sites as well as lakes with pay ramps or lakes that are connected to another water body that can be accessed by the public; private lakes are those where access is restricted to the landowners living around the lake. The lakes are stratified by size and fisheries management unit (8 units), which allows for statewide and regional watershed assessments of fisheries, lake habitat, and water chemistry. The number of lakes surveyed per year varies depending upon individual management unit priorities but, after 12 years, more than 500 lakes have been surveyed with the status and trend protocols. Recent annual effort has been slightly more than 25 lakes per year. MDEQ involvement has been limited to paying for the analysis of the water chemistry samples with CMI funds.

The MDNR, Fisheries Division, also conducts creel surveys at inland lakes throughout Michigan to estimate fishing effort as well as catch and harvest rates for various species. Creel surveys were conducted at 58 inland lakes from 2000-2006 (Project No F-81_R-7, Study No. 230646).

In 2013, a cooperative effort between the MDEQ, MDNR, Michigan Department of Agriculture and Rural Development, and Michigan Department of Transportation led to the development of *Michigan's Aquatic Invasive Species State Management Plan 2013 Update* (https://www.michigan.gov/-/media/Project/Websites/invasives/Documents/Response/egle-ais-smp-public-review.pdf). The AIS management plan focuses on prevention, detection, and management. AIS monitoring at inland lakes is conducted by MDNR staff during routine sampling and is becoming more of a focus for MDEQ staff in recent years. AIS monitoring has become a standard add-on activity, especially for the nationally sponsored assessments of lakes and rivers/streams. AIS monitoring at inland lakes is also conducted by volunteers in the CLMP and the anglers monitoring network. The MDNR, Wildlife Division, received grant funds in 2010 to begin an early detection response project focused on aquatic invasive plant species. A pilot AIS early detection project was conducted in 2014 by MDEQ staff at 15 inland lakes.

Federal Agencies

Since 2005, the USEPA has sponsored national aquatic resource surveys. These national assessments focus on inland lakes every five years (i.e., 2007, 2012). The stratified random selection design of the National Lakes Assessment surveys at over 900 randomly selected lakes and reservoirs across the nation are designed to help the USEPA provide regional and national statistically valid estimates of the condition of lakes, as well as state-scale assessments for those states who participate in the surveys. The MDEQ coordinated the sampling of 50 Michigan lakes for the 2007 survey, and conducted sampling at 53 Michigan lakes in 2012, which allows for state scale assessments (Figure 9). The next National Lakes Assessments survey will be conducted in 2017.

Monitoring of inland lake water levels is currently conducted by the USGS in partnership with other agencies and organizations at 11 locations throughout Michigan. Water levels are continuously recorded at these sites with real time and historic data available at the USGS's Web site.

In addition to the LWQA partnership effort with the MDEQ that involved monitoring at 729 public access lakes, the USGS Michigan Science Center conducts more intensive monitoring to address specific issues at inland lakes. They recently completed the sampling necessary to develop a water and nutrient budget for Silver Lake in Oceana County, which has recently been plagued with algal blooms.

Trophic state monitoring at selected inland lakes in three of Michigan's National Parks Service properties is conducted by the National Park Service. The National Park Service is also partnering with the USGS on a study to characterize Harmful Algal Blooms (HAB) toxins at inland lakes in the three parks. United States Forest Service staff are conducting a soil acidification study in a watershed that is part of one of the four National Forests in Michigan. Three inland lakes are being monitored as part of this climate change investigation.

Regulated Facilities/Permits

National Pollutant Discharge Elimination System (NPDES) permits are issued to municipalities and industries that discharge effluent to the surface waters of Michigan. To demonstrate compliance with WQS, many of these permits contain requirements for effluent monitoring as well as monitoring ambient inland lake water quality parameters either at intake or outfall structures. NPDES permits authorize the discharge of effluent to about 75 inland lakes or to streams and wetlands in close proximity to inland lakes. The volume of effluent is monitored as well as other parameters and compounds dependent upon the type of facility. While ambient water quality data are not routinely monitored, permit reissuance, depending upon the type of facility, often requires submission of ambient water quality data in conjunction with the permit application. At least seven inland lakes have intake structures where NPDES permits stipulate, at a minimum, the monitoring of ambient temperature.

The MDEQ, Water Resources Division (WRD), issues permits for a variety of activities that alter the bed or shorelines of inland lakes. The individual permits will at times contain special monitoring conditions for management projects that have specific objectives and permittees may be required to monitor water quality, biological, or physical parameters. Examples include permits for lake aeration, lake augmentation wells, suction dredging of aquatic plants, and maintenance drawdowns of water levels.

In 2013, aquatic nuisance control staff issued 2,624 permits and certificates of coverage for treatments of ponds, marinas, inland lakes, streams, wetlands, and portions of the Great Lakes. The treatments are aimed at the control of invasive aquatic vegetation as well as the control of nuisance levels of native aquatic vegetation. The program staff conducts minimal monitoring, usually less than ten inland lakes per year, where whole or partial lake vegetation surveys along with secchi disc measurements are conducted before and/or after treatments. The permittee may also be required to conduct whole or partial lake vegetation surveys; monitor basic water quality parameters such as dissolved oxygen, clarity, nutrients and/or the concentration of the chemical being applied; conduct genetic analysis of watermilfoil; and provide a treatment report that includes specific details about the product(s) used, target species, efficiency and/or selectivity of the treatment, and impacts to threatened and endangered plant species.

Inland Lake Monitoring In 2015 and Beyond

A. Objectives

The current goals of the MDEQ, WRD, are to:

- Enhance Recreational Waters
- Ensure Consumable Fish
- Protect and Restore Aquatic Ecosystems
- Ensure Safe Drinking Water
- Protect Public Safety

At a minimum, the MDEQ must protect all of the designated uses specified in Michigan's WQS, including agriculture; navigation; industrial water supply; warmwater fishery; other indigenous aquatic life and wildlife; partial body contact recreation; and fish consumption. All surface waters of the state are designated and protected for total body contact recreation from May 1 to October 31. In addition, all inland lakes identified by the Director of the MDNR in the publications entitled, "Coldwater Lakes of Michigan" (1976) and "Designated Trout Lakes and Regulations" (1998) are designated and protected for coldwater fisheries. The biennial Integrated Report submitted by the MDEQ to the USEPA is structured to facilitate reporting of attainment and nonattainment of these designated uses at all water bodies throughout Michigan.

To assess progress towards achieving the goals listed above, the MDEQ, WRD, has developed a number of "Measures of Success" related to Inland Lakes. These include:

1. Percent of monitored beaches with no closures or advisories due to unacceptable levels of *E. coli* during the recreational season.
2. Mercury concentrations in the 90th percentile of length normalized walleye, northern pike, or largemouth bass from selected sites in the Great Lakes and inland waters.
3. PCB concentrations in the 90th percentile of lipid normalized carp fillets (site dependent) from selected sites not impacted by legacy pollution.
4. Total phosphorus concentration in the TMDL lakes (Lake Allegan, Lake Macatawa, Ford Lake, and Belleville Lake).
5. The number of water bodies restored between 2012 and 2017. Results will be provided every two years to coincide with updates to Michigan's water quality nonattainment list.
6. The number of causes of water body impairments eliminated between 2012 and 2017. Results will be provided every two years to coincide with updates to the water quality nonattainment list.
7. By 2017, improve water quality conditions in five 12-digit Hydrologic Unit Code watersheds.
8. Increase in number of shoreline protection permits issued for natural shoreline designs.

To achieve our monitoring goals, the MDEQ's inland lake water quality monitoring objectives are largely consistent with those identified in the 1997 monitoring strategy, with minor modifications:

OBJECTIVE 1: Assess the status of trophic conditions, water quality, and habitat of inland lakes.

OBJECTIVE 2: Determine whether inland lake trophic conditions, water quality, and habitat are changing with time (i.e., trend assessment).
OBJECTIVE 3: Support watershed, lake management, and regulatory programs and determine their effectiveness.
OBJECTIVE 4: Identify high quality inland lakes.
OBJECTIVE 5: Identify inland lakes that are not meeting WQS, including those affected by nuisance or harmful algal blooms.
OBJECTIVE 6: Identify emerging problems in inland lakes, including the presence and impacts of AIS.

B. *Monitoring Activities*

There are a number of ongoing monitoring projects related to inland lakes, which we propose to continue with little modification since they have been designed to meet specific programmatic needs and are consistent with monitoring goals and objectives. After each project description below, we have identified which of the six objectives listed above are addressed by that activity and the designated uses that are evaluated or protected for attainment of WQS by the activity.

- CLMP: The use of volunteers makes this program the most cost-effective method for monitoring hundreds of inland lakes on an annual basis with standard protocols. The associated environmental awareness created with the volunteers often produces local efforts to preserve and protect Michigan's lake resources.
    - Objectives 1, 2, 3, 4, 5, and 6
    - Designated use: other indigenous aquatic life and wildlife

- TMDL lake sampling: WRD staff will continue to monitor TMDL lakes (Lake Allegan, Lake Macatawa, Ford Lake/Bellevue Lake) in even-numbered years. The primary purpose of this effort is to determine whether water quality is improving in response to TMDL implementation.
    - Objectives 2 and 3
    - Designated use: other indigenous aquatic life and wildlife

- Targeted monitoring: The WRD solicits monitoring requests from a variety of internal and external stakeholders each year, and determines which requests will be acted upon based on the number of requests, watershed priorities, and available resources. Depending on the project, the actual sampling may be conducted by WRD staff or our contractors.
    - Objectives 1, 3, 4, 5, and 6
    - Designated use: varies depending upon request

- National Lakes Assessment: The USEPA is responsible for assessing the quality of the nation's water resources. Each year, over a five-year cycle, a specific water body type is the focus of this national effort. Inland lakes were assessed in 2007 and 2012, and are scheduled for another assessment in 2017. We propose that the WRD participate in the 2017 National Lakes Assessments and add lakes as needed to conduct a statewide assessment.
    - Objectives 1, 2, 4, 5, and 6
    - Designated use: other indigenous aquatic life and wildlife

- Fish Contaminant Monitoring: The WRD arranges the collection of fish from inland lakes each year for tissue contaminant analysis. The number of lakes from which fish are collected varies, but typically averages about 30 lakes. Most of the collection is done by the

MDNR, Fisheries Division, as part of its standard survey work. Criteria for lake selection include lack of historical information, outdated data, or if data are needed for a special project. Fish are also collected every three to four years from seven inland lake sites and analyzed as whole fish for the temporal trend element of the Fish Contaminant Monitoring Program.
    - Objectives 1, 2, 3, 4, 5, and 6
    - Designated use: fish consumption

- Beach Monitoring: The WRD provides funding to county health departments to monitor public beaches throughout Michigan, including those on inland lakes. Between 2008 and 2013, the total number of monitored inland lake beaches ranged from 153-269. In 2013, 174 beaches were assessed in 35 counties. Beaches are selected by local health departments based on public access and volume of use by the public.
    - Objectives 1, 3, 4, 5, and 6
    - Designated uses: partial and total body contact recreation

- NPDES permits: The NPDES Program issues permits for discharges to surface waters (including inland lakes), which contain limits and special conditions, as appropriate. These permits sometimes also include monitoring requirements and studies needed to comply with federal and state WQS and Treatment and Technology-Based Standards.
    - Objective 3
    - Designated uses: all, as applicable, except navigation

- Aquatic Nuisance Control: The Aquatic Nuisance Control Program issues permits for the control of aquatic nuisance organisms in inland lakes. These permits sometimes require the applicant to design and implement studies to monitor impacts and effectiveness of the permit program.
    - Objectives 3 and 6
    - Designated uses: all, as applicable, including navigation

In addition to the "routine," ongoing activities listed above, the following items represent new or expanded "non-routine" lake monitoring projects:

- Satellite remote sensing: The WRD has worked with the USGS in recent years to use satellite remote sensing technology to predict water clarity. This effort has produced five date sets from 2002, 2003-2005, 2007-2008, 2009-2010, and 2011, that include, on average, 3,000 inland lakes greater than 20 acres. The predictive models used for this project require Secchi disk transparency data throughout Michigan. Historically, only the field measurements of MiCorps volunteers and USGS staff have been used. The USGS measurements of Secchi transparency were obtained during the LWQA at public access lakes and was completed in 2010. Model development involves using 20-25 Secchi measurements for each of 14 satellite scenes that cover the entire state of Michigan. Therefore, the continued success of the modeling effort will require a more collaborative approach that will seek to use additional data collected by the MDEQ, WRD; MDNR, Fisheries Division; Tip of the Mitt Watershed volunteers; National Park Service; Tribes; and other organizations that sample lakes. A new joint funding agreement with the USGS was initiated on June 1, 2014, that will generate statewide Trophic State Index predictive models from data collected in 2014 as well as 1999-2000. The combination of 1999-2000 and 2014 data sets will result in a 15-year record of trophic state predictions, a sufficient number of years to establish a record of statewide trophic status trends that will be analyzed. The MDEQ is contributing $65,000 to the total cost of $75,000, with the USGS providing the

remainder. The need for additional assessment with this cost-effective approach will be determined pending the outcome of the current study.
    - Objectives 1 and 2
    - Designated use: potentially could be used as a screening level assessment at lakes where other information is lacking; other indigenous aquatic life and wildlife

- Inland Lake Status and Trends: During the past 15 years staff of the MDEQ, WRD, and MDNR, Fisheries Division, have met on multiple occasions and discussed the value of better coordination of stream and lake monitoring activities, particularly status and trend monitoring efforts. In 2011, a collaborative team was formed and charged with exploring opportunities for collaboration between the Fisheries Division and WRD monitoring programs. Collaborative inland lake monitoring was identified by the team as a high priority task that would benefit both agencies. Since 2007 the WRD has funded the analysis of water samples, primarily for trophic state determination, collected at 20 to 30 lakes per year as part of the inland lake status and trends monitoring effort of the MDNR, Fisheries Division. A pilot project was conducted by SWAS biologists in 2014 at 7 of the 26 inland lakes sampled by the MDNR, Fisheries Division, to determine the feasibility of adding additional water quality, habitat, and aquatic vegetation parameters. We propose to expand our level of participation in 2015 by collecting water quality samples in the spring and early summer at all the status and trend lakes sampled by the MDNR, Fisheries Division. The spring turn-over sampling will allow for comparisons of water quality data with results obtained at the 729 public access lakes sampled during the LWQA. In addition, during the early summer sampling event at all of the lakes, shoreline habitat data, limited aquatic vegetation surveys (protocols established during LWQA surveys at public access lakes in the 1980s and again from 2001-2010), AIS survey (primarily for aquatic plants), and potentially, sampling for harmful algal toxins will be done to complement the fish data collected at the status and trend lakes monitored by the Fisheries Division. The collection of an additional summer sample for trophic state determination will more accurately characterize trophic state. Continued funding for the analysis of late summer water quality samples collected by the MDNR, Fisheries Division, as well as the analysis of spring and early summer water samples collected by the MDEQ will cost approximately $25,000 per year, assuming 25 lakes are sampled per year.
    - Objectives 1, 2, 4, and 5
    - Designated use: other indigenous aquatic life and wildlife, Fisheries Division data is used to determine attainment of either warmwater or coldwater fishery as appropriate

- AIS: The WRD initiated an early detection pilot project in 2014 for AIS organisms at 15 lakes. The pilot project was continued in 2015 at several more lakes. The specific details of additional AIS monitoring at inland lakes will be determined after the results of the pilot project are compiled and analyzed. To the extent possible, AIS monitoring will be incorporated into the existing and proposed monitoring activities described in this document. It is possible that additional lakes may be sampled specifically to fulfill AIS objectives. The WRD filled a limited-term position to develop an AIS monitoring strategy and will work with other monitoring specialists to incorporate AIS monitoring into lake and stream monitoring efforts. Until that work is done, it is not feasible to estimate resource requirements (staff time or funding) needed for this activity.
    - Objective 6

- Water Withdrawal Program Support: The Water Use Advisory Council established several work groups, including an inland lake Adverse Resource Impact work group. The Adverse

Resource Impact work group concluded that additional information on water level (average levels as well as ranges of natural variability) and lake morphology for inland lakes, which are vulnerable to impacts of direct water withdrawals, is needed. The work group recommended that the MiCorps develop protocols for collection of this data by volunteers. Historically, inland lake water level monitoring has been conducted by the USGS with support from the MDEQ. An extensive amount of historic data has not been catalogued or entered into a database. Future efforts to monitor inland lake levels should involve working with the USGS to take advantage of their expertise and working to utilize the historic data to prioritize future monitoring efforts.

  - Objective 3

- HABs: The MDEQ and Michigan Department of Health and Human Services currently have a work group addressing issues related to algal bloom monitoring, response, and reporting. In 2015, the WRD will monitor a mix of randomly selected and targeted inland lakes to measure the geographical extent of HABs in Michigan; evaluate the timing and frequency of samples needed to accurately characterize the occurrence and duration of algal blooms and HAB toxins; and lay the foundation for a more comprehensive monitoring approach in 2016, including the identification of technological options to assist with HAB assessment.
  - Objectives 1, 3, 5, and 6

- Consider expanding the scope of the remote satellite sensing work from just modeling water clarity to include additional water quality parameters such as chlorophyll *a* and potentially other parameters such as nutrients and blue green algae. The cost for each additional modeled parameter is unknown and will require either the collection of additional samples or greater collaboration with other lake monitoring efforts throughout Michigan. Variable parameters, such as algal abundance, will likely require sampling the same day as satellite images are recorded in order to develop an accurate model.
  - Objectives 1, and 2

C. *Indicators*

Table 1. Routine indicators monitored by various programs of the MDEQ, WRD, at inland lakes.

Issue	Indicator	Monitoring Activity/Program
Aquatic Invasive Species	Aquatic Invasive Species	• Aquatic Invasive Species Staff • Cooperative Lakes Monitoring Program • National Lakes Assessment • Fisheries Division Status and Trend
Aquatic Macrophytes/Algae	Emergent, Floating, and Submergent Aquatic Plants	• Fisheries Division Status and Trend • Aquatic Nuisance Control Staff • National Lakes Assessment
Harmful Algae	Toxin Concentrations	• Fisheries Division Status and Trend • National Lakes Assessment
Water Chemistry	Total Phosphorus	• Cooperative Lakes Monitoring Program • National Lakes Assessment • TMDL Lakes - Follow-up • Fisheries Division Status and Trend
	Orthophosphorus	• TMDL Lakes - Follow-up
	Nitrogen, Ammonia	• Fisheries Division Status and Trend • National lake Assessment • TMDL Lakes - Follow-up
	Other Nitrogen Species (Nitrate, Nitrate + Nitrite, Nitrite, Kjeldahl Nitrogen)	• Fisheries Division Status and Trend • National lake Assessment • TMDL Lakes - Follow-up
	Chlorophyll *a*	• Cooperative Lakes Monitoring Program • National Lakes Assessment • TMDL Lakes - Follow-up • Fisheries Division Status and Trend
	Secchi Depth/Clarity	• Cooperative Lakes Monitoring Program • National Lakes Assessment • TMDL Lakes - Follow-up • Fisheries Division Status and Trend Satellite Sensing-USGS

Issue	Indicator	Monitoring Activity/Program
Water Chemistry	Hardness	• Fisheries Division Status and Trend • National Lakes Assessment
	Cations (Calcium, Magnesium)	• Fisheries Division Status and Trend • National Lakes Assessment
	Anion, Chloride	• Fisheries Division Status and Trend • National Lakes Assessment
	Other Anions (Sodium, Potassium, Sulfate)	• Fisheries Division Status and Trend • National Lakes Assessment
	Total Dissolved Solids	• Fisheries Division Status and Trend • National Lakes Assessment
	Field pH	• Cooperative Lakes Monitoring Program • National Lakes Assessment • TMDL Lakes - Follow-up • Fisheries Division Status and Trend
	Field Temperature	• Cooperative Lakes Monitoring Program • National Lakes Assessment • TMDL Lakes - Follow-up • Fisheries Division Status and Trend
	Field Dissolved Oxygen	• Cooperative Lakes Monitoring Program • National Lakes Assessment • TMDL Lakes - Follow-up • Fisheries Division Status and Trend
	Field Conductivity	• Cooperative Lakes Monitoring Program • National Lakes Assessment • TMDL Lakes - Follow-up • Fisheries Division Status and Trend
	Alkalinity	• National Lakes Assessment • TMDL Lakes - Follow-up • Fisheries Division Status and Trend
	Total Organic Carbon	• National Lakes Assessment
	Dissolved Organic Carbon	• National Lakes Assessment
	Total Suspended Solids	• National Lakes Assessment • TMDL Lakes - Follow-up

Issue	Indicator	Monitoring Activity/Program
Bacteria	*E. coli*	• Beach Monitoring
Biological Integrity	Macroinvertebrate Community	• National Lakes Assessment
	Fish Community	• Fisheries Division Status and Trends
	Zooplankton Community	• National Lakes Assessment
Fish Contaminants	Hexachlorobenzene	• Fish Contaminant Monitoring
	gamma-BHC (Lindane)	• Fish Contaminant Monitoring
	Aldrin	• Fish Contaminant Monitoring
	Dieldrin	• Fish Contaminant Monitoring
	4,4'-DDE; 4,4'-DDD; 4,4'-DDT	• Fish Contaminant Monitoring
	2,4'-DDE; 2,4'-DDD; 2,4'-DDT	• Fish Contaminant Monitoring
	Total DDT	• Fish Contaminant Monitoring
	Heptaclor Epoxide	• Fish Contaminant Monitoring
	Mercury	• Fish Contaminant Monitoring
	Selenium	• Fish Contaminant Monitoring
	Oxychlordane	• Fish Contaminant Monitoring
	Chlordane *(alpha-, gamma-)*	• Fish Contaminant Monitoring
	Dieldrin	• Fish Contaminant Monitoring
	cis-Nonachlor	• Fish Contaminant Monitoring
	Styrene, (octachloro-, hexachloro-, heptachloro-, pentachloro-)	• Fish Contaminant Monitoring
	Heptachlor	• Fish Contaminant Monitoring
	Terphenyl	• Fish Contaminant Monitoring
	Toxaphene	• Fish Contaminant Monitoring
	Mirex	• Fish Contaminant Monitoring
	PBB (FF-1, BP-6)	• Fish Contaminant Monitoring
	Total PCB (congener method)	• Fish Contaminant Monitoring
Habitat	% Hardened Shoreline	• Cooperative Lakes Monitoring Program • Fisheries Division Status and Trends
	% Riparian Turf or Beach	• Cooperative Lakes Monitoring Program • Fisheries Division Status and Trends
	Riparian/Greenbelt Width	• Cooperative Lakes Monitoring Program • Fisheries Division Status and Trends

Issue	Indicator	Monitoring Activity/Program
Habitat	%Riparian/Greenbelt	• Cooperative Lakes Monitoring Program • Fisheries Division Status and Trends
	Riparian/Greenbelt Vegetation Density	• Cooperative Lakes Monitoring Program • Fisheries Division Status and Trends
	% Littoral with Emergent Vegetation	• Cooperative Lakes Monitoring Program • Fisheries Division Status and Trends
Wildlife Contaminants	Mercury	• Bald Eagles • Herring Gulls
	Organochlorine Contaminants: Dichloro-diphenyltrichloroethane (DDT) and its metabolites	• Bald Eagles • Herring Gulls
	Hexachlorobenzene (HCB)	• Bald Eagles • Herring Gulls
	alpha-hexachlorocyclohexane (*alpha*-HCH)	• Bald Eagles • Herring Gulls
	gamma-hexachlorocyclohexane (*gamma*-HCH) Heptachlor	• Bald Eagles • Herring Gulls
	Heptachlor Epoxide	• Bald Eagles • Herring Gulls
	Chlordane *(alpha-, gamma-)*	• Bald Eagles • Herring Gulls
	Dieldrin	• Bald Eagles • Herring Gulls
	Toxaphene	• Bald Eagles • Herring Gulls
	20 PCB Congeners	• Bald Eagles • Herring Gulls

D. Data Management

- The WRD must develop and/or utilize an inland lake database for water quality, physical parameters that are measured in the field, and stores trophic state calculations for individual lakes. The database should be populated with not only current information but historic information that has been collected by SWAS staff. The database will be developed and maintained by SWAS staff with relevant information available via the MiSWIMS database.

- The existing inland lake file is extensive and has not been adequately cataloged to determine what data/reports exist. The WRD will inventory those files and scan historic inland lake reports and management plans from the old Land and Water Management Division. To warehouse the information, we need to add the reports to the existing reports database to ensure access by WRD staff and the public. This effort will require the use of additional staff, which could include our contractor (Great Lakes Environmental Center), interns, or Senior Environmental Employees.

E. Reporting

- CLMP: Continue to produce an annual summary report listing the participating lakes and parameters that were monitored. Trophic state determinations are reported individually for Secchi transparency, phosphorus and chlorophyll *a*. Since not all volunteers collect adequate data for all three trophic state indicators, the overall trophic state has not historically been reported. A new procedure is being developed to report results for each lake in a fact sheet style summary of current year results along with historic data displayed as trends.

- TMDL Lake Sampling: The WRD will continue to update WRD metrics and develop reports after sampling every other year to document progress toward achieving the goal established by the approved TMDL.

- Targeted Monitoring: Project results will be presented in staff reports prepared either by MDEQ staff or our contractors.

- National Lakes Assessment: Similar to the 2007 National Lakes Assessment, the WRD will analyze the Michigan-specific data collected for the 2012 National Lakes Assessments and prepare a report on the status and trends of Michigan's inland lakes. In addition, individual fact sheets will be prepared for each lake.

- Fish Contaminant Monitoring: A staff report will continue to be prepared annually by the WRD.

- Beach Monitoring: WRD staff will continue to prepare a beach monitoring report on an annual basis.

- NPDES Permits: Monitoring results can be retrieved from the discharge monitoring reports submitted by each facility.

- Aquatic Nuisance Control Permits: The number of permits issued annually will be reported and any reports produced by applicants will be available upon request.

- Satellite Remote Sensing: The USGS will continue to publish technical reports and provide internet access to the results via the Michigan Lake Water Clarity Interactive Map (https://www.usgs.gov/media/images/michigan-lake-water-clarity-interactive-map-viewer).

- Inland Lake Status and Trends: Individual fact sheets summarizing the water quality and habitat data collected by the SWAS will be prepared for each lake surveyed during the Fisheries Division collaborative status and trend inland lake assessments. Results will be compared to the medians and range of values documented at the 729 public access lakes surveyed as part of the LWQA. Status and trend reports will be prepared by the WRD every five years that summarize results on a statewide basis as well as by the Fisheries Division Management Units.

- AIS: Options for monitoring and reporting are still being developed. The results of AIS monitoring likely will be presented in the other reports described in this section or a separate report will be considered that is focused on AIS.

- Water Withdrawal Program Support: All monitoring data collected by volunteers involved in the CLMP are presented in an annual report and stored in a database maintained by MiCorps staff.

F. Resource Requirements: For New or Expanded Monitoring Projects

- Collaboration with the Fisheries Division Inland Status and Trend will require $25,000 to $30,000 for lab analysis of the samples collected in the spring and summer by the MDEQ and the summer samples collected by the MDNR. MDEQ staff time associated with the planning, sampling, data management, and report writing is estimated to be 1,200 hours per year.
- Plans for the surveillance and sampling of harmful algae at a statewide scale are still being developed. Coordination and collaboration with other state and federal agencies, local health departments, and universities will be necessary to efficiently address this rapidly emerging issue. To the extent possible, harmful algae monitoring will be conducted through the existing and newly expanded monitoring activities presented above.
- Remote satellite sensing technology continues to evolve to additional water quality parameters beyond just water clarity. The technology can potentially be used at a statewide scale to characterize nutrients, chlorophyll *a*, and cyanobacteria abundance. Details of additional projects are being considered and the technology could be used as a key component of the overall plan to assess harmful algae throughout specific regions of the state. If this type of assessment is pursued, we would likely have to provide funding to a federal partner (e.g., USGS, National Oceanic and Atmospheric Administration), university, or a private contractor.
- The specific details of AIS monitoring, surveillance, and early detection at inland lakes are being developed and continue to evolve as level of effort and funding of AIS staff is taken into consideration.
- Historic inland lake files from the former Land and Water Management Division contain many reports that were produced with Section 314 funds in the 1980s and into the early 1990s. Many of the reports contain not only water quality data but data characterizing aquatic macrophytes, zooplankton, algae, lake habitat, and watershed uses, and include plans for lake management. A simple inventory of the files does not exist. The files are unorganized because of staff changes, reorganizations, and multiple physical moves.

The reports and data are not in an electronic format that can be shared or utilized. It is estimated that about 0.25 full time equivalents of staff time is needed to organize and scan the files in order to make the reports and data available.

- The Water Use Advisory Council established several work groups, including an inland lake Adverse Resource Impact work group. The Adverse Resource Impact work group concluded that additional information on water level (average levels as well as ranges of natural variability) and lake morphology for inland lakes, which are vulnerable to impacts of direct water withdrawals, is needed. The work group recommended that MiCorps develop protocols for collection of this data by volunteers. Historically, inland lake water level monitoring has been conducted by the USGS with support from the MDEQ. An extensive amount of historic data has not been catalogued or entered into a database. Future efforts to monitor inland lake levels should involve working with the USGS to take advantage of their expertise and working to utilize the historic data to prioritize future monitoring efforts. Staff are currently evaluating options and the required resources for collecting additional lake level information as well as utilizing the historic information collected by the USGS. The Fisheries Division is in the process of developing and adopting protocols for creating lake bathymetric maps utilizing the latest technology available from several companies. Estimated costs and resource needs for these efforts are still unknown and will largely depend upon the level of effort that is deemed necessary to protect Michigan's inland lake resources.

Report by: Mike Walterhouse, Environmental Quality Specialist
Surface Water Assessment Section
Water Resources Division

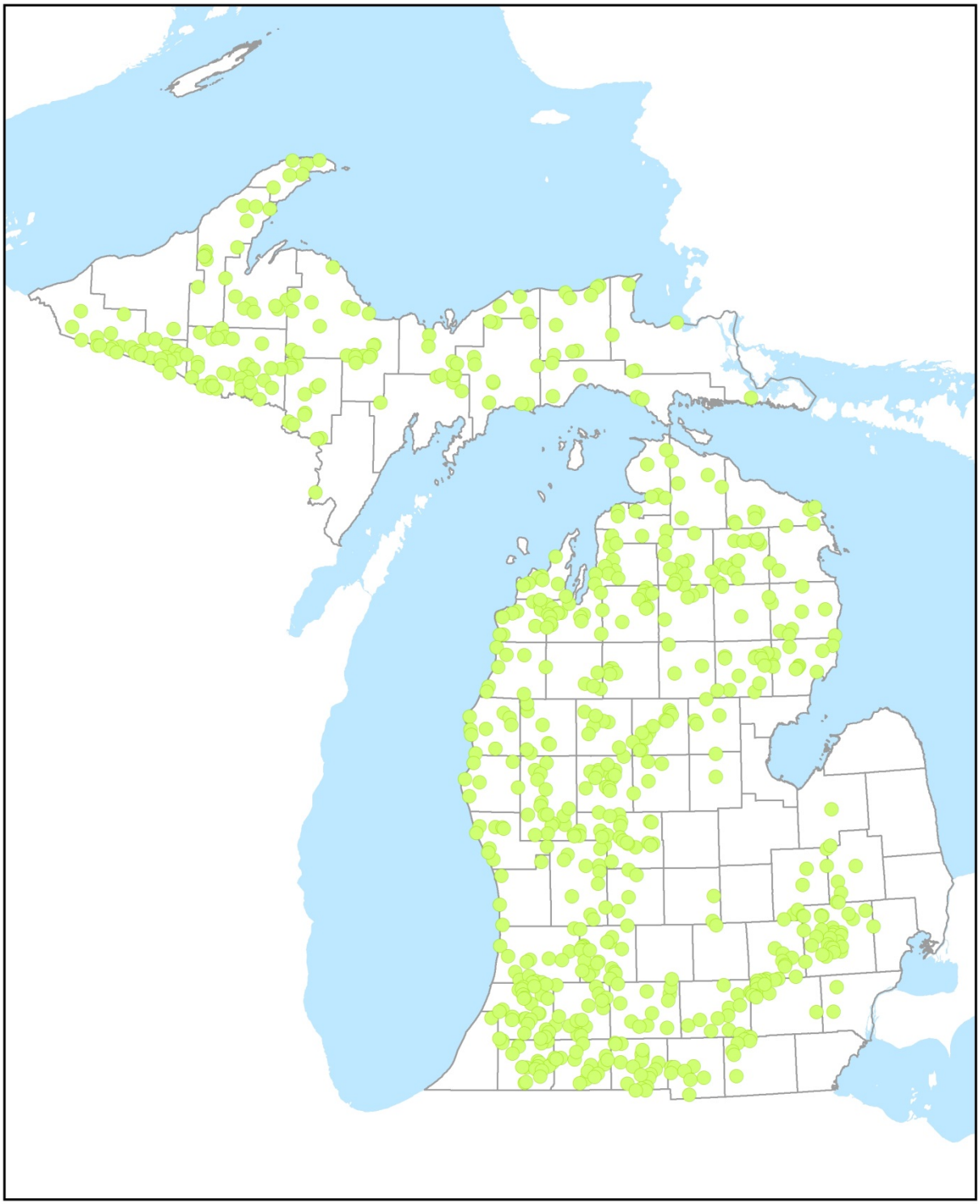

Figure 1. Location of the 729 public access lakes sampled from 2001-2010 for the LWQA partnership with the USGS.

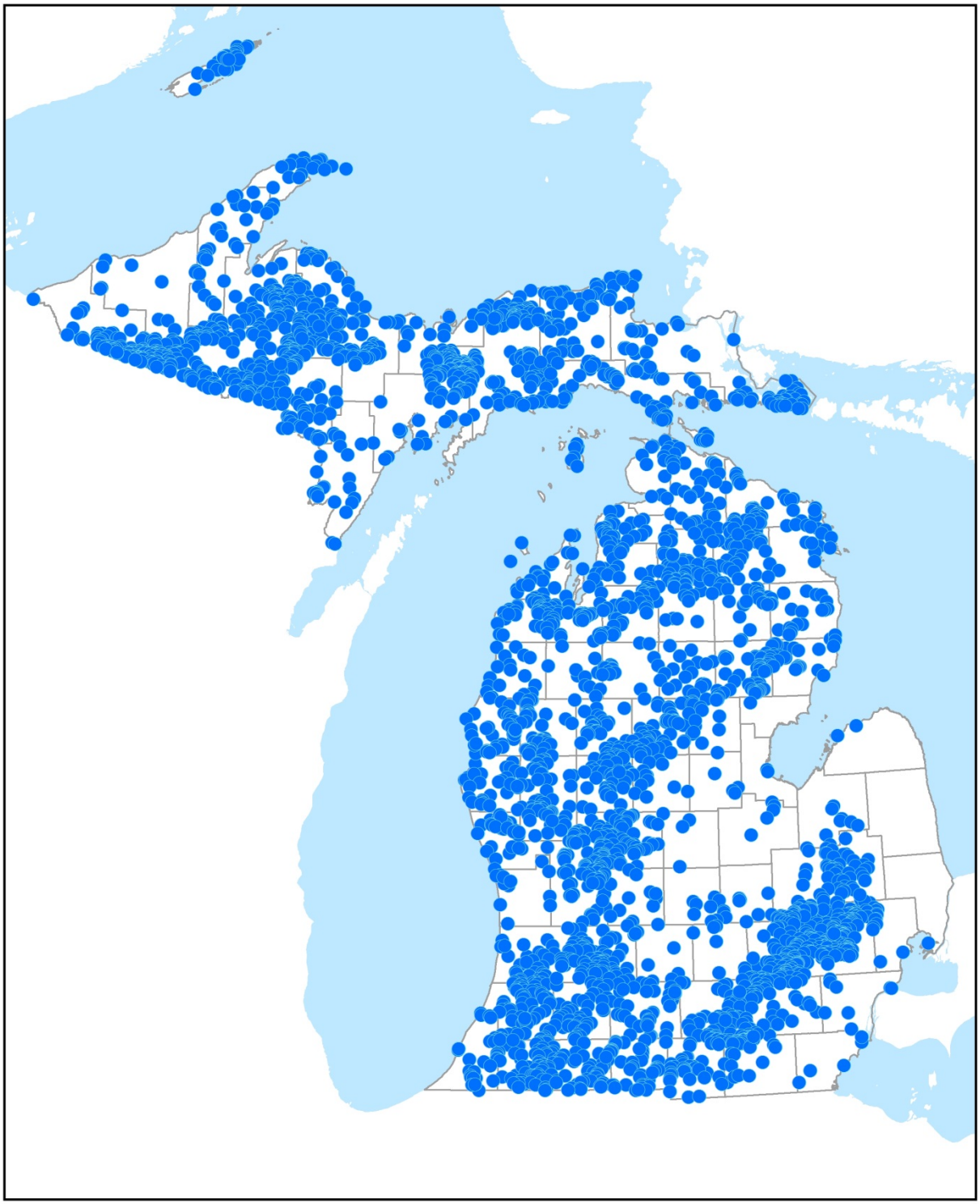

Figure 2. Michigan inland lakes greater than 20 acres where at least one water clarity prediction has been made since 2002.

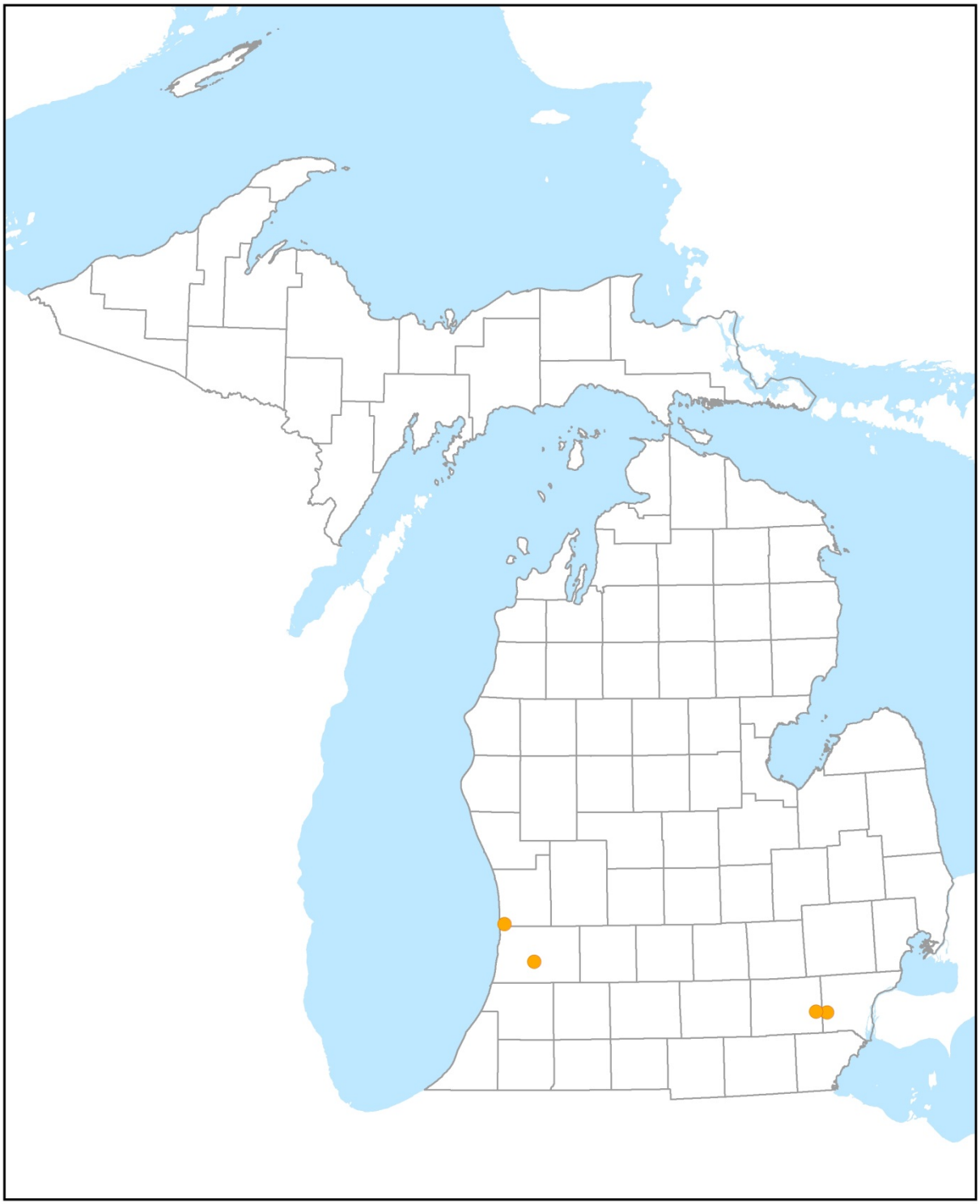

Figure 3. Michigan inland lakes where phosphorus TMDLs have been established and monitoring is conducted during even-numbered years.

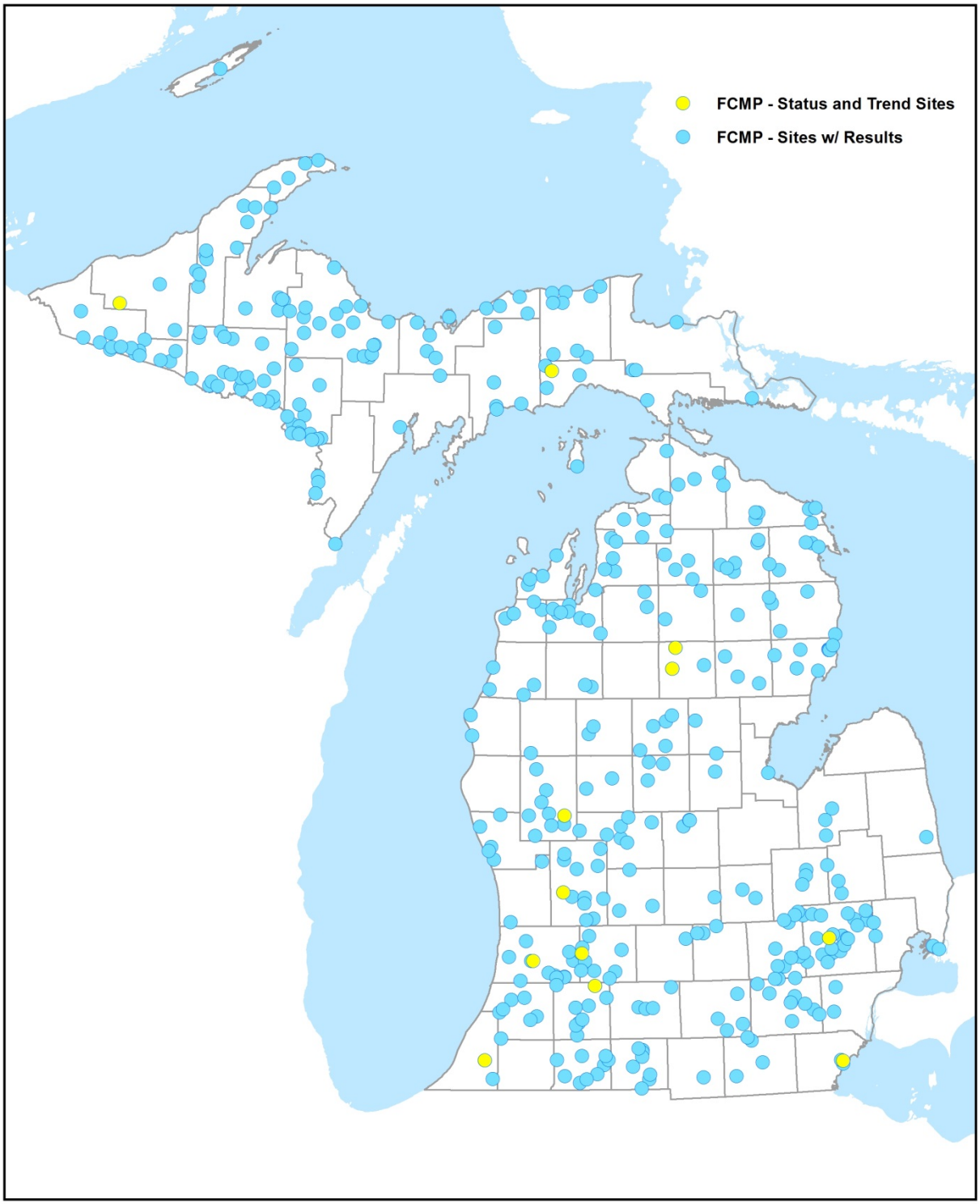

Figure 4. Michigan inland lakes where fish have been analyzed for contaminants, 423 targeted lakes and 12 fixed temporal trend lakes, since 1981.

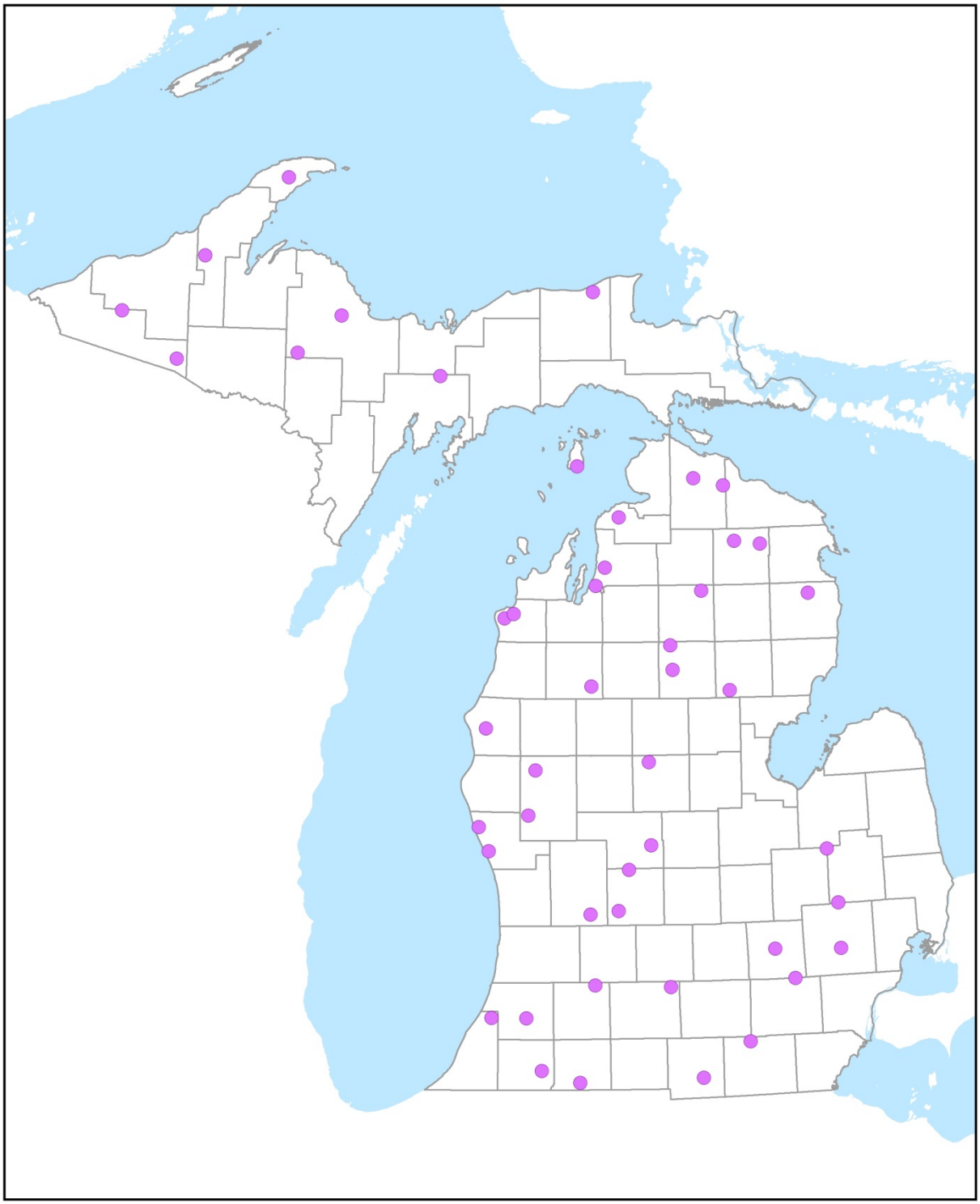

Figure 5. Michigan inland lakes where sediment chemistry monitoring was conducted from 1999-2010.

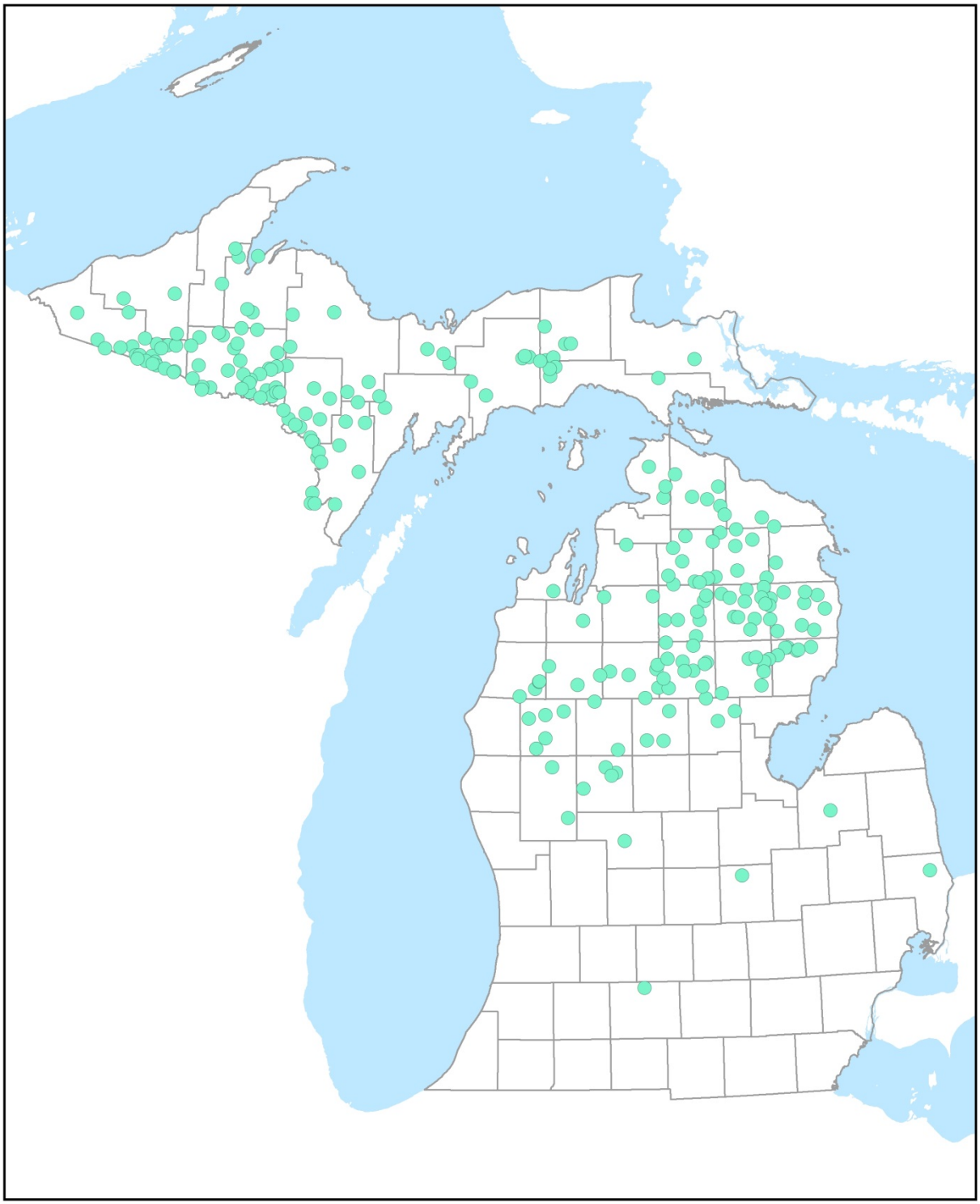

Figure 6. Location of inland bald eagle territories where plasma from eaglets has been analyzed at least once since 1999.

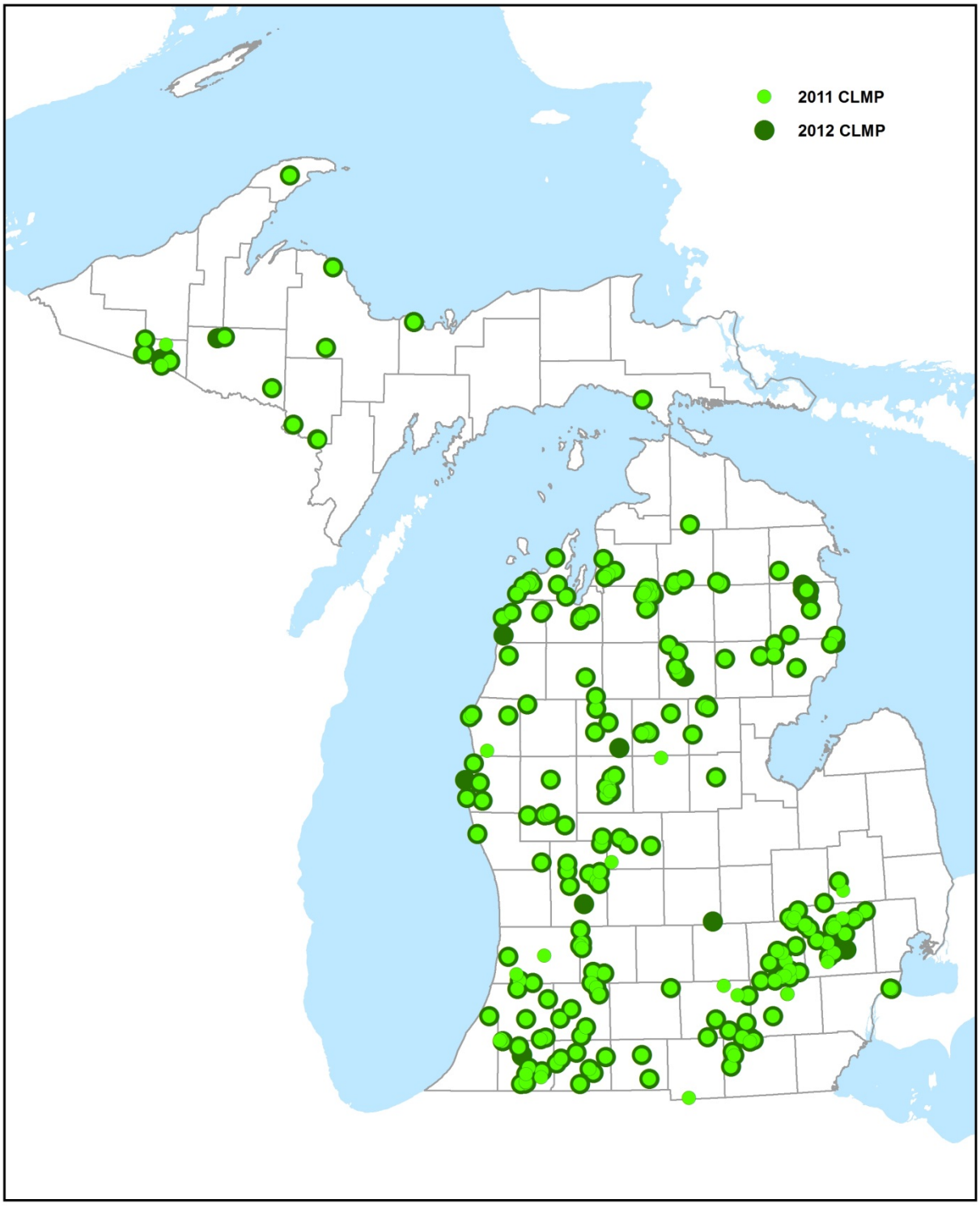

Figure 7. Michigan inland lakes where CLMP volunteers collected adequate data for trophic state determination in 2011 and 2012.

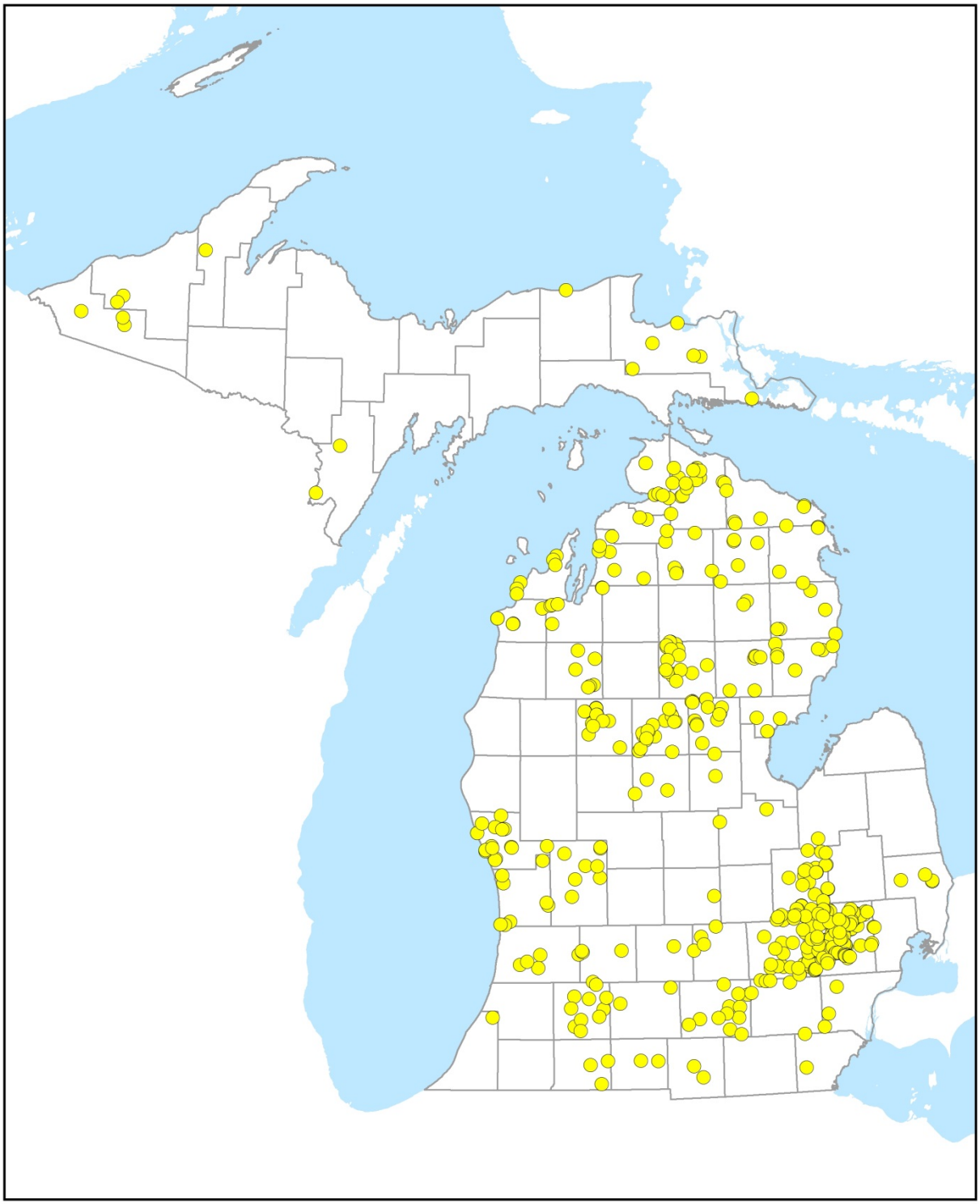

Figure 8. Distribution of 495 sites where public beaches have been identified at Michigan's inland lakes.

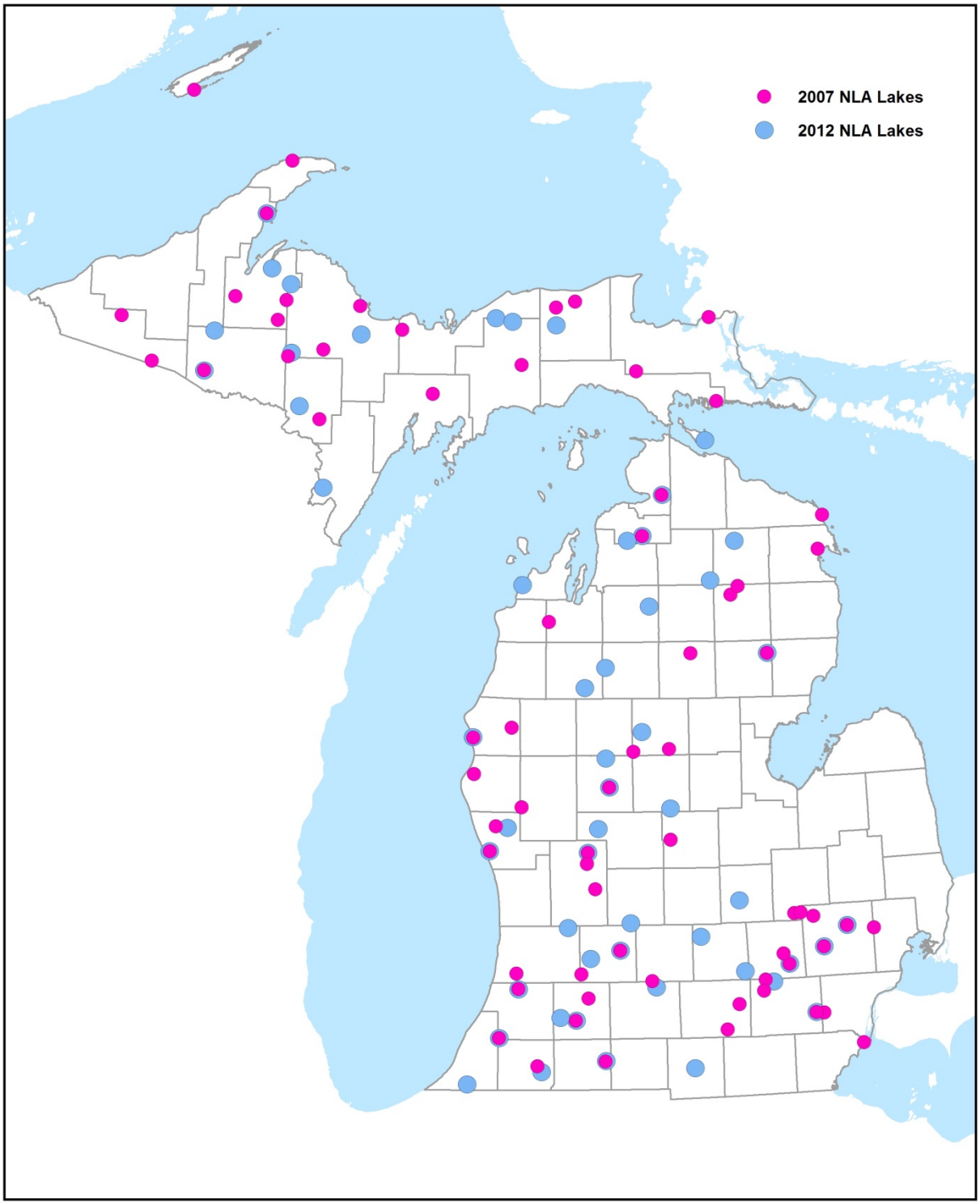

Figure 9. Randomly selected Michigan inland lakes sampled during the USEPA-sponsored National Lakes Assessments, 2007 and 2012.