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Management Plan for Inland Trout in Michigan

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Management Plan for Inland Trout in Michigan

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Introduction

This plan focuses on the ecology and management of inland trout populations that primarily reside in rivers and inland lakes of Michigan. Brown Trout *Salmo trutta* and Brook Trout *Salvelinus fontinalis* are the primary species of interest in streams, though resident Rainbow Trout *Oncorhynchus mykiss* occur in a few waters, such as the upper Au Sable River and several tributaries to the Manistee River, most notably the Pine River. Inland lakes with suitable water quality conditions are (or could be) managed for any of several trout species, including Brook Trout, Brown Trout, Rainbow Trout, Lake Trout *Salvelinus namaycush*, Atlantic Salmon *Salmo salar*, and splake *Salvelinus fontinalis x S. namaycush*, a hatchery-based hybrid of Brook and Lake trouts. These species share similar characteristics, but they differ in their suitability for specific fishery management purposes. This report does not cover adfluvial salmonids, such as Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *Oncorhynchus kisutch*, migratory Rainbow Trout (steelhead), or Brown Trout that reside in the Great Lakes and migrate inland from the Great Lakes to spawn. Likewise, the report does not cover steelhead, which occasionally remain in streams as “resident” trout and do not migrate out to the Great Lakes.

The intent of this document is to provide an overview of inland trout habitats in Michigan, the biology and ecology of inland trout populations, and management activities directed towards inland trout and their habitats. This report provides the foundation for current and future management of inland trout fisheries in Michigan’s inland lakes and streams. It is not meant to be time-constrained, but rather a template to follow to ensure successful management of the state’s diverse inland trout resources.

Goals, Key Issues, and Actions

Overall Goal

The overall goal is to provide (1) a diverse portfolio of inland trout fishing opportunities for anglers; (2) trout populations that are self-sustaining whenever possible; (3) the judicious use of hatchery-produced fish; and (4) waters managed with an array of objectives. This array of objectives includes provision of high angler catch rates of trout, quality-sized trout, harvest opportunities, geographically well-dispersed fisheries (within the constraints of natural environmental conditions), opportunities to recruit new and retain anglers, and aesthetically-pleasing and productive environments for trout fishing.

To support the overall goal, the Michigan Department of Natural Resources (MDNR) Fisheries Division seeks to maintain or improve the quality of inland trout fishing opportunities in full partnership with the anglers and citizens of Michigan by (1) protecting and enhancing existing trout populations and the environmental conditions upon which they depend, and (2) improving technical information and outreach on these important species.

Specific Management Goals

Specific management goals for inland trout reflect the guiding mission statements for both MDNR and MDNR Fisheries Division. The MDNR is committed to the conservation, protection, management, use, and enjoyment of the state's natural resources for current and future generations. Fisheries Division's mission is to protect and enhance populations of fish and other forms of aquatic life, aquatic ecosystems and local habitats, and to promote optimum use of these resources for the benefit of the people of Michigan. This plan embeds these overall mission statements into our direction for inland trout populations.

We list five major goals below. For each goal, we identify key issues (in *italics*) that prevent attainment of the goal, reiterate why each issue is important (in **bold**), and recommend actions to best address the issue. Sections of this document providing supportive information for key issues and recommended actions are identified at the end of each, using one-letter abbreviations as follows: Background (B); Regulations (R); Status of fisheries (S); and Habitat concerns, restoration, and partnerships (H). Issues and actions listed below are not prioritized. Actionable efforts may be detailed in plans associated with Fisheries Division's Strategic Plan and other local-scale documents. An abbreviated listing of key issues and recommended actions by plan goal occurs in Appendix A.

Goal 1. Ensure that adequate technical information is available for managing Michigan's coldwater fisheries.

Key issues, supporting information, and recommended actions:

1. *Insufficient creel data are available for assessing fishing effort, catch, harvest, and suitability of regulations for trout lakes and streams. **Creel data allow managers to better weigh the benefits against the costs of different management actions.*** Seek partners and funding to expand collection of creel data on inland trout waters and develop novel survey techniques to assess low-use or remote areas. Periodically survey trout anglers to characterize their behaviors, preferences, and opinions. R, S.
2. *The number of surveys conducted on streams to document status and trends of inland trout populations has declined over the years due to funding cutbacks. **Stream survey data are key for understanding how coldwater resources vary around the state and are changing through time, and for providing the basis for making management decisions.*** Seek partners

- and funding to increase the annual number of surveys dedicated to monitoring trout populations in streams through the random and fixed-site components of the Status and Trends Program. S.
3. *Considerable recent information on Michigan trout populations from Status and Trends Program surveys, trout fisheries (e.g., angler effort), and trout angler behaviors and preferences (e.g., Carlson and Zorn 2018) have become available since the last time population models were constructed to assess effects of sportfishing regulations on inland trout populations. **Effective trout fishing regulations are based upon models that include current, Michigan-specific information on trout population biology and fishery attributes (e.g., angling pressure, harvest practices, hooking mortality, etc.).*** Update existing models or create new models to assess the effects of various sportfishing regulation scenarios on inland trout populations prior to the next statewide review of inland trout regulations for Michigan. B, R, S.
 4. *Fisheries Division currently does not receive information from inland fishing guides who are not charter captains or who conduct excursions in nonreportable waters, which makes it impossible to estimate the biological and economic effects of this industry. **Managers need to have an understanding of all users of trout resources.*** Work with partners and the legislature to develop a system for documenting activities of fishing guides who work on inland waters, similar to current Great Lakes charter boat reporting system. R, S.
 5. *Limited data and tools are available to support and inform trout management in inland lakes. **By ensuring survey information is comparable statewide, standardized sampling protocols contribute to more efficient and effective management decisions, especially when staff capability for sampling is limited.*** Develop and implement a standardized protocol for assessing trout populations in inland lakes. B, R, S.
 6. *There is a scarcity of data on biological and economic effects of opening designated trout streams to fishing during the traditional closed period. **Information is needed to weigh the benefits against the risks of extended season fishing.*** Work with universities and other partners to gather pre- and post-regulation change data on streams that are open to extended season fishing. R, S.
 7. *Insufficient data are available to describe both natural and excessive sediment movement in stable Michigan streams. **Excess sedimentation is considered a major impairment of streams, but distinguishing natural and excessive levels is not clear for many Michigan trout streams that drain sand-dominated landscapes.*** Work with universities and other partners to gather sediment data in Michigan streams and develop bedload and suspended sediment rating curves for a variety of stream types in Michigan. B, H.
 8. *Additional data are needed for characterizing instream fish habitat on trout streams throughout Michigan. **Guidance is needed to determine if and what types of trout habitat is lacking on individual stream reaches.*** Work with MDNR Fisheries Division's Research Section, universities, and other partners to gather information using a standardized sampling protocol and geospatial framework on key instream trout habitat parameters for all trout stream types in Michigan. B, S.
 9. *Insufficient streamflow (discharge) data are available for Michigan trout streams, particularly for unimpounded headwater streams. **Stream discharge controls channel processes, shapes stream habitats, and influences reproductive success, growth, survival, and population trends of trout.*** Stream discharge data is needed statewide for a variety of trout research, management, and resource protection purposes. Work with U.S. Geological Survey (USGS) and other partners, using published USGS methods, to establish flow gages on stable, nonimpounded trout streams. B, S.
 10. *Insufficient continuous water temperature data are available for Michigan trout streams. **Water temperature varies on daily, seasonal, annual, and longer time scales, and has major influences on trout distribution, abundance, growth, and survival.*** Work with

USGS, citizen scientists, and other partners to establish water temperature monitoring sites on trout streams where data are currently unavailable. Develop predictive water temperature models as decision-support tools and to fill data gaps. B, S.

11. *Improved streamflow models that incorporate glacial drift thickness as a variable are not available at this time. Such models would especially improve groundwater input and streamflow predictions for Upper Peninsula (UP) streams, since drift thickness is only a few feet to nonexistent in many areas. **Maps showing areas of groundwater inflow allow managers to locate stream reaches that may provide important thermal refuge habitat for trout.*** Develop improved Darcy groundwater velocity models that incorporate drift thickness. Update statewide streamflow predictions using this and other data layers. B, H.
12. *Statewide information needed for prioritizing rehabilitation efforts on road-stream crossings and dams on trout streams is lacking. **Dams and poorly-designed road-stream crossings have major negative effects on trout populations and habitats.*** Continue working with county road commissions, partners, and citizen scientists to develop statewide information using standardized protocols on road-stream crossings and dams on trout streams to enhance prioritization of resources. B, H.
13. *Decision-support tools based on standardized statewide surveys are needed to support management of stream habitats and trout populations. **Science-based management of trout streams requires quantitative evaluations of stream habitats and trout population characteristics.*** By the end of 2019, develop a decision-support tool, which uses standardized stream survey and other appropriate data to quantitatively describe typical values for important stream habitat attributes, fish population abundance, and trout growth in any type of stream in any region of Michigan. Such values can serve as benchmarks or targets for local-scale management plans and actions and provide insights into the potential for any type of Michigan trout stream. B, R, S.
14. *Limited MDNR Fisheries Division Research Section staff time is available for investigating and providing science-based input on issues pertaining to inland trout management. **Adequate Research Section staffing is needed to provide thoughtful, science-based input on inland trout management issues.*** Allocate commensurate level of Research Section staff time and resources to trout-related issues. S.

Goal 2. Protect, rehabilitate, and enhance coldwater habitat on Michigan waters.

Key issues, supporting information, and recommended actions:

1. *Trout stream habitat improvement effort and results vary considerably across Michigan's coldwater resources. **A common understanding of stream processes and effectiveness of habitat improvement techniques is needed for groups involved in trout habitat projects.*** Develop and institute a "Trout Stream Habitat Improvement 101" course for partners. This will provide up-to-date information on appropriate techniques and evaluation components. Information will be communicated on a level understandable to the casual angler and general public and held on some regular basis around the state. B, H.
2. *Some sand traps that are/were performing as designed are not cleaned or maintained on a routine basis. **Properly designed sediment traps are not effective unless they are cleaned out regularly.*** Fisheries Division, other agencies, Nongovernmental Organizations (NGOs), and citizen scientists should clearly identify properly functioning sediment traps and work together to find ways to maintain them more frequently. B, H.
3. *Some Michigan trout streams lack adequate instream cover to promote and maximize healthy fish and aquatic organism populations. **Adequate instream cover is needed for trout streams to achieve their trout-holding potential.*** Fisheries Division, other government agencies,

- NGOs, and citizen scientists should identify trout streams where instream habitat is inadequate. Fisheries Division will take a proactive approach in leading rehabilitation efforts to include assisting in planning appropriate measures and providing grant opportunities to promote such activities. B, H.
4. *Many trout streams are affected in a variety of ways (but especially thermally) by dams. A list of dams prioritized by relative negative effects will guide dam removal efforts and funds to where the benefit to cost ratio is highest.* Identify dams that negatively affect coldwater habitats and species. Seek support and funding for removal of dams where the benefits of dam removal outweigh the costs of dam maintenance and effects on the trout stream. B, H.
 5. *Barriers to trout passage including dams, lake level control structures, poorly designed road-stream crossings, and natural logjams prevent or reduce movements and migrations of trout among spawning, refuge, nursery, and growth habitats, thus reducing or eliminating trout populations. Enabling movements of fish to key spawning, refuge, and growth habitats increases the size of trout population that a stream can potentially support.* Identify key fish passage barriers in tributaries to coldwater lakes and in trout streams and rivers using a standardized protocol. Work with various nonprofit organizations and through partnerships to remove priority barriers or ameliorate their effects. B, H.
 6. *Improperly designed road-stream crossings or ones that are degraded often debilitate trout streams by adding excessive sediments to the streams, preventing passage of aquatic organisms, or warming the water. Apply limited road-stream crossing funding to locations where the benefit to cost ratio to trout populations is highest.* Identify poorly-designed road-stream crossings using a standardized protocol and work with other partners and entities to replace poorly-designed road-stream crossings or rectify the excessive input of sediments. B, H.
 7. *Riparian land uses affect fisheries habitat along coldwater streams and lakes, yet enforcement of existing land use rules is lacking and development of more appropriate measures to protect nearshore habitat is needed. Healthy trout populations require properly managed and protected riparian zones.* Actively protect coldwater stream and lake corridors using established Michigan Department of Environmental Quality (MDEQ) rules and the MDNR Natural River Program zoning processes. Improve monitoring of coldwater riparian zones by using partners and citizen scientist information on potential land use issues and violations to augment MDNR and MDEQ information. H.
 8. *Excessive sedimentation, due largely to non-point-source runoff, negatively affects many of Michigan's trout waters. Elevated rates of sediment delivery into trout streams can cover productive spawning gravels and fill pool habitats used by trout.* Improve working relationships between state agencies and county drain commissions to protect coldwater streams that are designated drains. Work with local governments, MDEQ, and other entities to reduce non-point-source runoff into trout streams. B, H.
 9. *Human-caused bank erosion still occurs frequently along our inland trout lakes and rivers. Target efforts to treat bank erosion to locations where human-caused detrimental effects of excess sedimentation are greatest.* Continue identifying excessive bank erosion sites from land development and other human-caused activities using a standardized protocol with the data collected by other government agencies, partners, and citizen scientists. Improve degraded site conditions at the highest priority sites. H.
 10. *Numerous human activities ranging from local to landscape scales have the potential to adversely affect coldwater habitats (and biota), and input from Fisheries Division staff is needed to ensure resources are protected. Continued cooperation with regulatory partners and education of the public about these issues are critical to protection of Michigan's trout streams.* MDNR Fisheries Division must continue to review and comment on relevant MDEQ and U.S. Army Corps of Engineers permits and MDNR activities/permits (e.g.,

compartment reviews, oil and gas lease reviews, land transactions, etc.) from a fisheries-based perspective. Evaluate the long-term effects of human activities on trout streams to allow a proactive approach to their future management. Use media and contacts with other groups to highlight the importance of healthy aquatic environments not only for trout, but also for all aquatic species, citizens, and future generations. B, H.

Goal 3. Protect, maintain, and enhance Michigan’s coldwater fisheries and aquatic communities.

Key issues, supporting information, and recommended actions:

1. *Trout populations in small streams may be vulnerable to overexploitation during the spawning season and when these streams are key thermal refugia for trout populations in larger systems. **The majority of Michigan’s inland trout populations are maintained through natural reproduction, so adequate protection is critical.*** Maintain seasonal harvest closures on trout streams where this is a concern. B, R.
2. *Human development and changes in land use typically have negative effects on trout populations through their influence on the hydrology and instream habitat. **Michigan trout populations rely on high quality instream habitat and watersheds with minimal human effects.*** Work with MDEQ, local units of government, and informed members of the public to ensure that protection of trout streams is a priority when land use changes and development are proposed. H.
3. *Various invasive species have entered State of Michigan waters and are prolific, but relatively few of them have entered our coldwater rivers. **Coldwater fishes are highly vulnerable to some invasive species.*** Develop and implement a strategy to detect the presence of invasive species in our coldwater systems, to quantify their current effects, and to prevent further invasions. Continue to develop methods to supplement standard fisheries techniques for detecting invasive species in trout waters. Work with angling groups and other partners to educate anglers about proper disinfection techniques and provide wader-washing stations at key access points to prevent the spread of invasive species. S, H.
4. *Changing climate and habitat conditions require continued assessment of the suitability of habitats for wild and stocked trout. **Coldwater fish communities, especially those in habitats where thermal conditions approach species’ tolerances, are highly susceptible to environmental changes.*** Continue to refine and implement the Status and Trends Program to assess coldwater systems to ensure that wild trout populations are properly protected and that hatchery trout are stocked judiciously. Explore additional methods to supplement standard fisheries techniques (e.g., remote sensing, citizen scientist, and eDNA). B, S, H.
5. *Effectiveness of habitat improvement techniques for enhancing trout populations in inland streams varies among streams due to differences in their hydrologic and physical characteristics. **A “one size fits all” approach to stream habitat improvement will not work for Michigan trout streams, and tailored, cost-effective techniques are needed.*** Develop and implement a strategy to work with universities, other partners, and citizen scientists to better understand stream processes and habitat influences on inland stream trout populations and to determine appropriate habitat improvement techniques for different types of trout streams in Michigan. Fully evaluate habitat improvement techniques to better understand the cost/benefit of those techniques and their utility in meeting stated goals and objectives. B, H.
6. *An attempt to re-introduce Arctic Grayling seems appropriate, given improvements in our understanding of Michigan river habitats, advances in knowledge of imprinting of salmonids, and recent Arctic Grayling reintroduction successes in Montana. **This native species still exists at some locations on the North American landscape and has a legitimate place within Michigan’s borders.*** Assess feasibility of Arctic Grayling reintroduction in select tributaries on an experimental basis. B.

Goal 4. Provide a variety of fishing opportunities for inland trout in Michigan.

Key issues, supporting information, and recommended actions:

1. *Fisheries Division receives frequent complaints, particularly from new trout anglers, that trout fishing regulations are too complicated. **Complicated regulations may frustrate veteran anglers and reduce recruitment of new trout anglers.*** Investigate opportunities to simplify lake and stream trout fishing regulations, while protecting trout populations and meeting the management objectives of each regulation type. Use news releases and social media to help anglers better understand the MDNR Fishing Digest. B, R.
2. *A segment of the angling population seeks more waters with gear restrictions, size restrictions, and catch-and-release regulations. **When used judiciously, special regulations can create unique fishing opportunities for trout.*** Evaluate the feasibility on selected waters and discuss the use of special regulations for individual lakes and streams where the productivity and fishery potential exists and the public supports such management action. B, R.
3. *Fishing currently is prohibited on the majority of streams during fall-early spring, and opportunities may exist for allowing catch-and-release angling for inland trout without adversely affecting populations. **A segment of the angling population is interested in catch-and-release fishing for inland trout during fall and early spring.*** Consider and evaluate providing geographically-dispersed catch-and-release fishing opportunities for inland trout on streams using approaches that protect trout populations and do not further complicate angling regulations. This can be accomplished by reclassifying select Type 1 waters as Type 4. B, R.
4. *The introduction of nontrout species into lakes, by anglers, can degrade or eliminate trout fisheries. **Lakes with suitable habitat conditions for trout are a rare resource, and it typically is not feasible to completely remove introduced unwanted fish species after they are established in a lake.*** Maintain bait restrictions on single species or trout-dominated lakes (e.g., Type A and D waters) and locations where excessive hooking mortality could prevent management objectives from being met. Work with education and outreach staff to produce materials to inform the public of the biological and economic issues with introducing nontrout species into trout lakes. B, R.
5. *Regulations limiting harvest from streams may be important for rehabilitating some migratory trout populations, such as coaster (adfluvial) Brook Trout. **Migratory trout often exhibit rapid growth, and protection of these populations could increase fishing opportunities for trophy trout.*** If experimental fishing regulations prove effective in rehabilitating coaster Brook Trout, evaluate options for incorporating a coaster-friendly regulation into one of the existing regulation types and evaluate similar options for other known migratory trout populations. B, R.
6. *Trout fishing regulations were last reviewed on a statewide basis in 2008-2010. **Trout fishing regulations should be reviewed periodically because scientific knowledge and angler preferences and behavior change over time.*** Conduct a comprehensive review of Michigan's trout regulations with staff and constituents using a decision-support system that includes all available trout biology information, angler preference data from monthly and other creel surveys, and enhanced population models. R.

Goal 5. Communicate with anglers and nonanglers to promote the recreational, ecological, and cultural value of Michigan's coldwater fisheries.

Key issues, supporting information, and recommended actions:

1. *It is relatively easy to communicate with organized sportfishing groups. However, it is much more challenging to provide information to and receive feedback from anglers who are not part of any organized group. **Good trout management requires an understanding of***

Michigan's entire trout angling clientele and the balance among different types of trout anglers. Continue meetings with the CRSC and other angler groups. Conduct periodic surveys of a random or representative sample of inland trout anglers to evaluate angler behavior and preferences and the economic effects of inland trout fishing. R, S.

2. *There is trend for anglers to use electronic devices (e.g., smartphones) to check fishing regulations as opposed to hard copies of the Fishing Guide. **Smartphone apps may represent an efficient way to provide many trout anglers with the most current fishing regulations.*** Develop smartphone applications that help anglers identify fishing regulations where they plan to or are fishing on a particular stream or lake. R.
3. *Coldwater streams and lakes that harbor trout are a fragile resource and always at risk of poor habitat management from a well-meaning but uninformed public. **Informing citizens that trout populations are highly vulnerable to degradation of habitat and water quality is an ongoing need.*** Inform anglers and citizens of status of Michigan's inland trout resources via media updates, and by maintaining and enhancing existing online trout stream data viewers. Work with local chambers of commerce, informed members of the public, and other organizations to promote stewardship of trout waters and trout fishing along with the importance of maintaining public access to these waters. S, H.
4. *Trout management involves a blending of biological and social values, and often, information is skewed or mismanaged as it is transferred among regulatory agency, stakeholder groups, and anglers. **Unbiased information exchange fosters better decision-making.*** Maintain complete transparency between the Fisheries Division, NGOs interested in coldwater resources, and all trout anglers through information sharing, stakeholder meetings, and statewide committees. Empower the public through partnerships and comanagement to take general ownership in state trout resources. Increase the amount and type of Fisheries Division fisheries and habitat information that is publicly available online and encourage other entities to do the same. Encourage anglers and stakeholder groups to directly access MDNR's online data viewers so they can see information first-hand, and not form their opinions based solely on second-hand information or other people's opinions. R, S, H.

Background

Distribution of Trout Waters in Michigan

Michigan was totally covered by ice during the Wisconsin glacialiation of the Pleistocene Epoch, and following retreat of the glaciers, was totally ice-free about 10,000 years ago (Dorr and Eschman 1993). Remnants of glacial activity are the defining features of Michigan as the state is almost entirely covered by glacial drifts (up to 1000 feet deep in places), and has over 78,000 miles of streams, many following former glacial drainage paths, and over 11,000 lakes that are five or more acres in size.

A primary key to the distribution of trout is the availability of sufficiently cold and well-oxygenated water. This means that trout can persist only in certain stream and lake habitats. Lakes have to be sufficiently deep or have direct groundwater flows to provide these temperatures, and possess high dissolved oxygen levels. Streams need to receive large inputs of groundwater to maintain cold summer water temperatures and warmer winter temperatures.

Michigan's landscape contains various types of glacial deposits and soil textures because of its glacial history (Albert et al. 1986). Glacial features include end and ground moraines containing particles ranging in texture from clay to boulders, glacial outwash plains and channels consisting of coarse sands and gravels, and flat glacial lakebeds of clay (Figure 1). This glacially patchy landscape causes many Michigan streams to not show the typical upstream to downstream changes seen among

trout streams in other regions of the country, namely cold, high-gradient creeks draining mountains, which coalesce and transition into warm, low-gradient rivers (Hawkes 1975; Vannote et al. 1980). Rather, some streams have warm headwaters and cooler lower reaches; others are cold upstream and warm downstream, and others alternate between thermal states depending upon characteristics of the landscape (Zorn et al. 2002). Hydrologic conditions in Michigan reach their extremes for streams draining small catchments (a catchment is the entire area of land that contributes to the river's flow at a particular location), and range from extremely stable, groundwater fed rivers draining deep sand and gravel deposits to hydrologically flashy tributaries draining clay or bedrock deposits. Using 90% exceedance flow yield (the streamflow rate or discharge value exceeded by the stream during 90% of the year divided by its catchment area) as an index for hydrologic stability, Michigan streams show approximately a million-fold range in values between the most stable and most flashy streams (Zorn et al. 2002). Some of Michigan's groundwater-fed trout streams, such as the Jordan, Au Sable, and Manistee rivers in the northcentral Lower Peninsula (LP), are among the most hydrologically stable streams in the United States (Zorn and Sendek 2001).

The understanding of relationships among Michigan's glacial features, topography, and groundwater inputs has improved significantly in the last two decades. This has enabled the MDNR Fisheries Division to better understand and explain where conditions are suitable for trout, and contributed to better management and protection of trout streams across Michigan. Michigan trout streams are cooled, and their flows stabilized, by large inputs of groundwater associated with deep deposits of coarse-textured glacial drifts (Wiley et al. 1997). Outwash deposits have exceptionally high hydraulic conductivities, which in combination with elevation head differences provided by adjacent end moraines can provide high rates of groundwater input to nearby channel segments (Hendrickson and Doonan 1972). Use of data on surficial geology and soil types (hydraulic conductivity) and slope (hydraulic head) in a GIS environment enabled researchers to model groundwater loading to stream channels throughout Michigan (Wiley et al. 1997; Baker et al. 2003), and produce fairly accurate maps of groundwater inputs to stream channels in the LP where glacial deposits are quite thick (Wiley et al. 1997; Baker et al. 2003). Inclusion of glacial drift thickness in these models is needed to improve groundwater input predictions for the UP, because drift thickness is only a few feet to nonexistent in many areas.

Looking at the correspondence between Michigan's surficial geology (Figure 1) and the occurrence of coldwater streams in Michigan (Figure 2), spatial relationships among surficial geology, coldwater streams, and trout distributions within the state are quite apparent. Surface geology also strongly affects land-use patterns in Michigan, as these coarse-textured deposits were ill-suited for agriculture, and ultimately these lands reverted to forests (Figure 3). Finer-textured geology, warmer streams, more agriculture, and the majority of Michigan's population occur in the southern third of the state.

The distribution of trout waters in Michigan follows the patchiness of Michigan's surficial geology (Figure 4). From a summary of 1:24,000 (i.e., 1 foot on map equals 24,000 feet) scale stream network data, Michigan possesses an estimated 78,816 miles of stream, 29,538 miles of which have characteristics to support trout and are legally classified as "Designated Trout Streams" (Anonymous 2015). Previous, coarser (1:100,000) scale map summaries identified about 36,000 miles of streams, of which approximately 19,200 miles were identified as "Designated Trout Streams". The distribution of self-sustaining trout waters as measured by the percent of the state's total stream miles for this class in each MDNR Fisheries Division management unit were estimated as follows: Central Lake Michigan (40%), Northern Lake Huron (22%), Northern Lake Michigan (14%), Southern Lake Michigan (9%), Southern Lake Huron (7%), Western Lake Superior (5%), Eastern Lake Superior (3%), and Lake Erie (<1%) (Seelbach et al. 1997; T. Zorn, MDNR Fisheries Division, unpublished data).

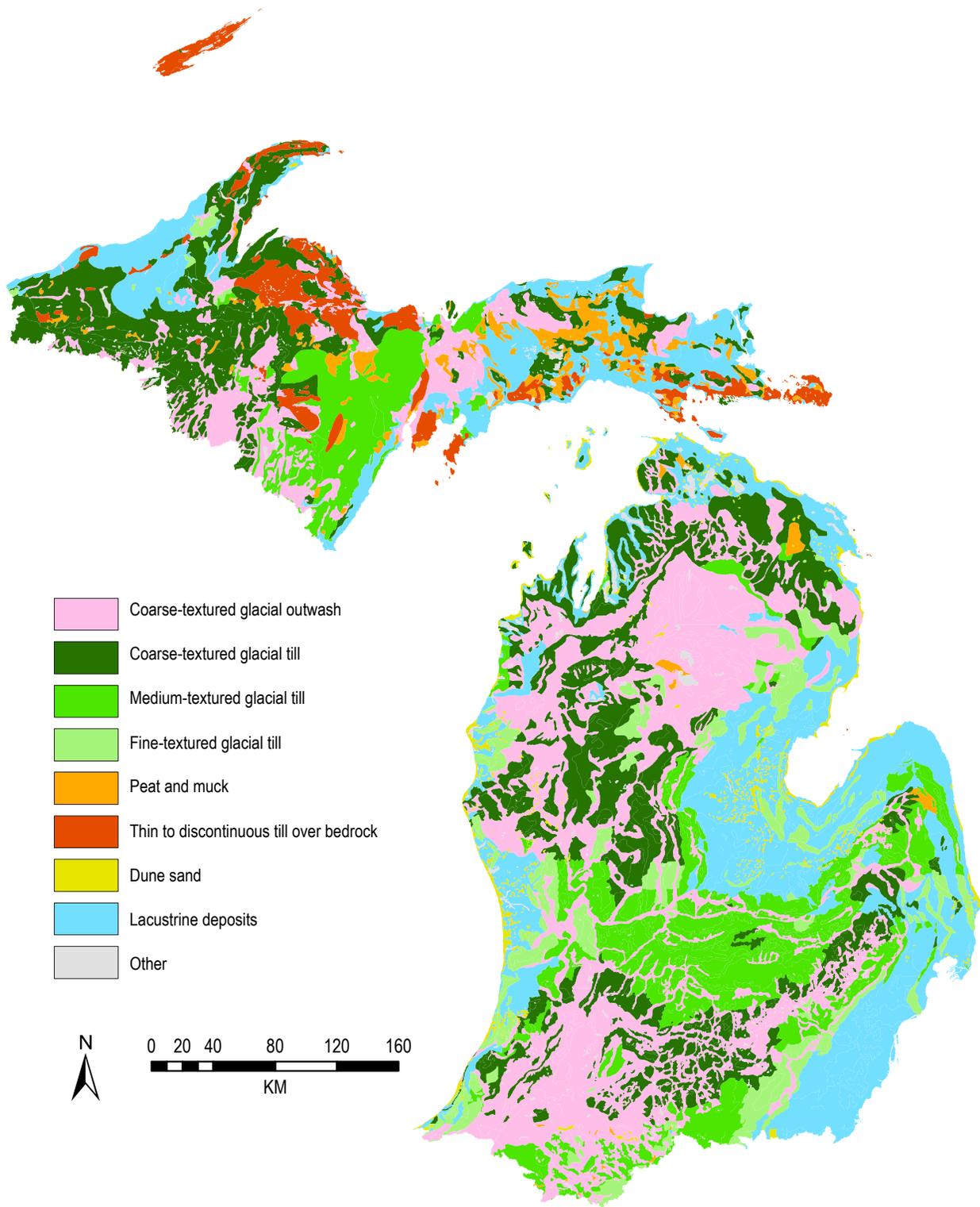


Figure 1.—Map of surface geology of Michigan. Michigan trout streams are cooled and their flows stabilized by large inputs of groundwater associated with catchments dominated by coarse-textured glacial outwash and tills.

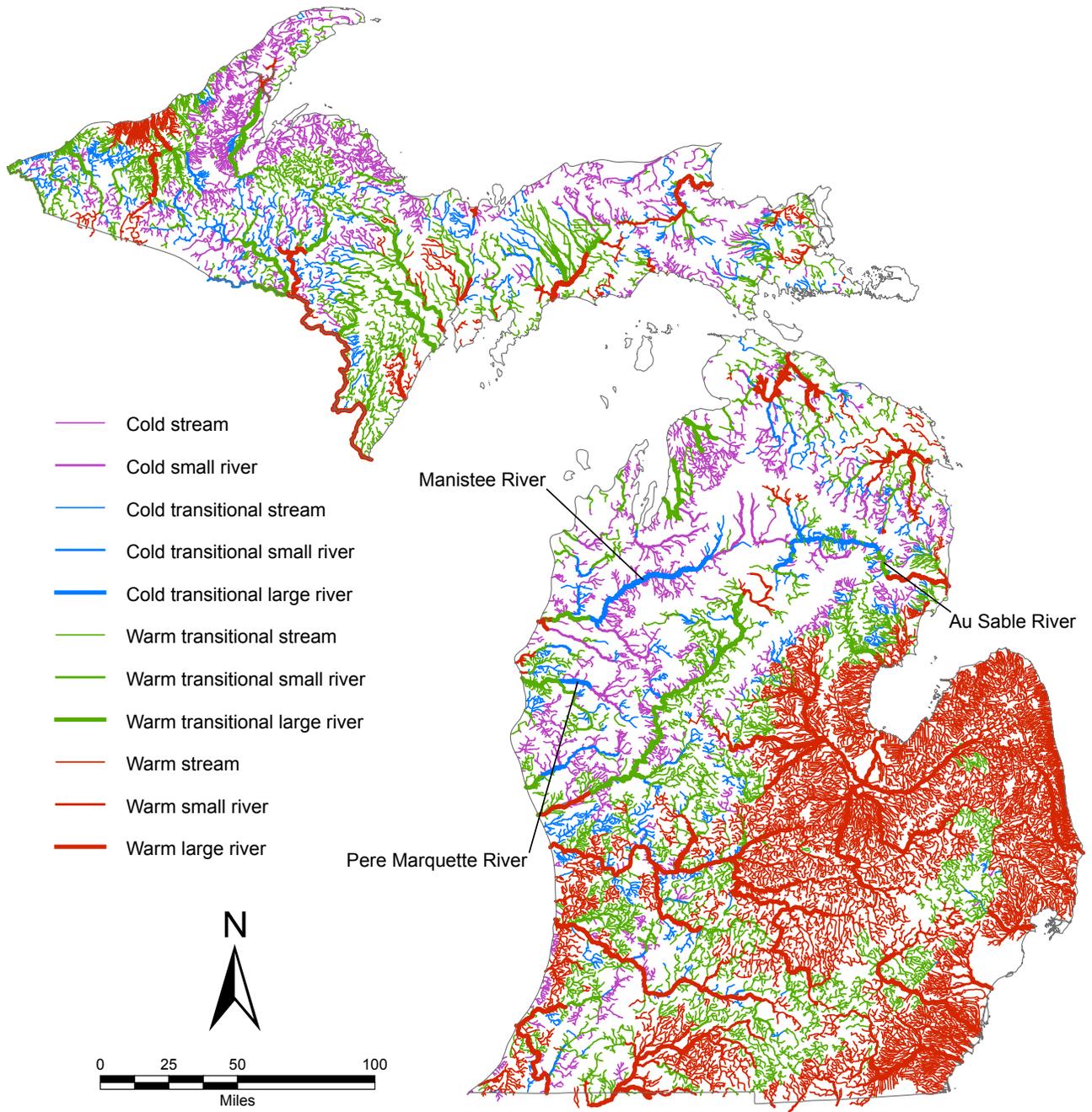


Figure 2.—Stream classification map of Michigan, showing locations of three prominent trout streams (Zorn et al. 2008).

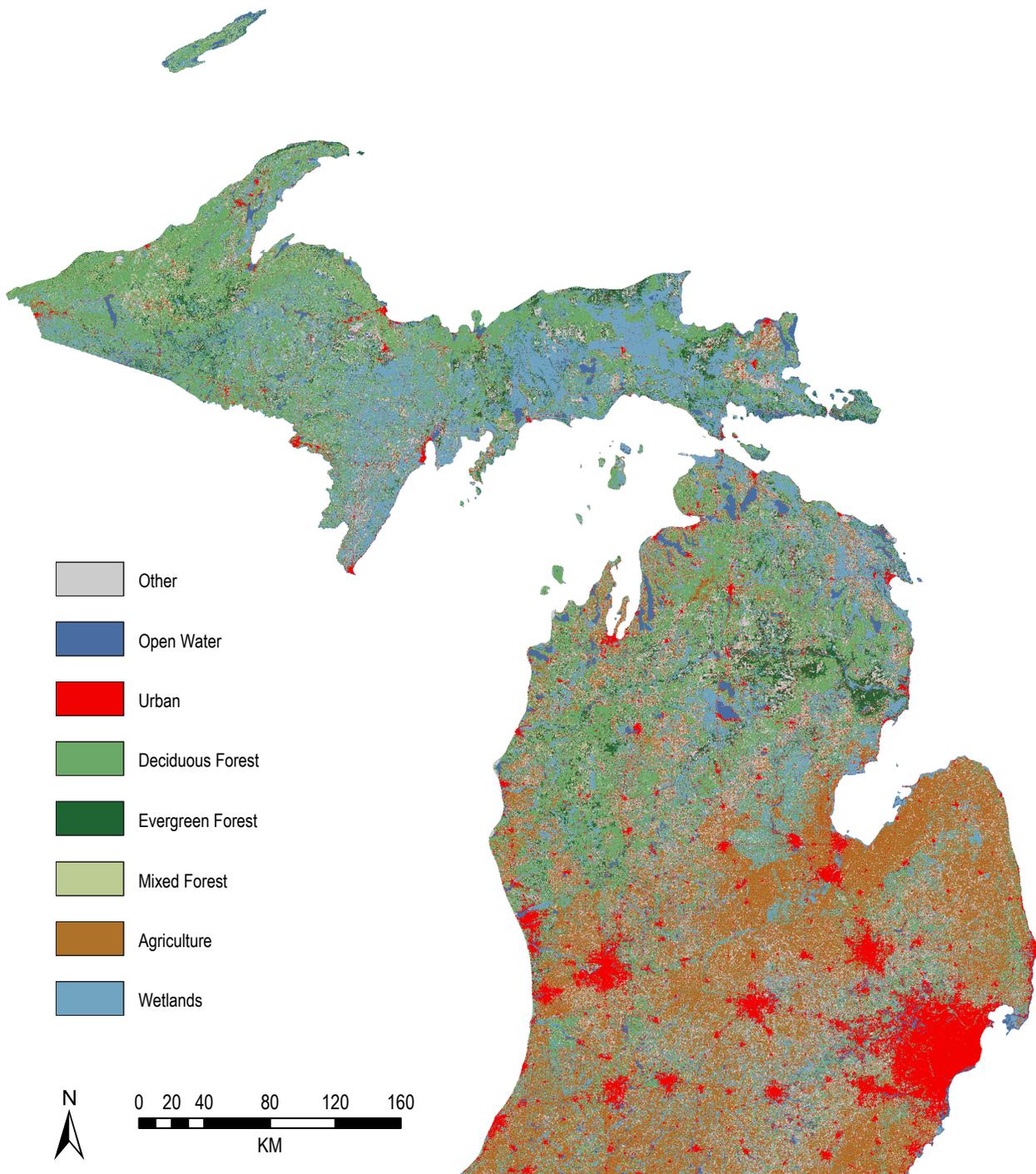


Figure 3.—Map of 2011 land use and land cover for Michigan.

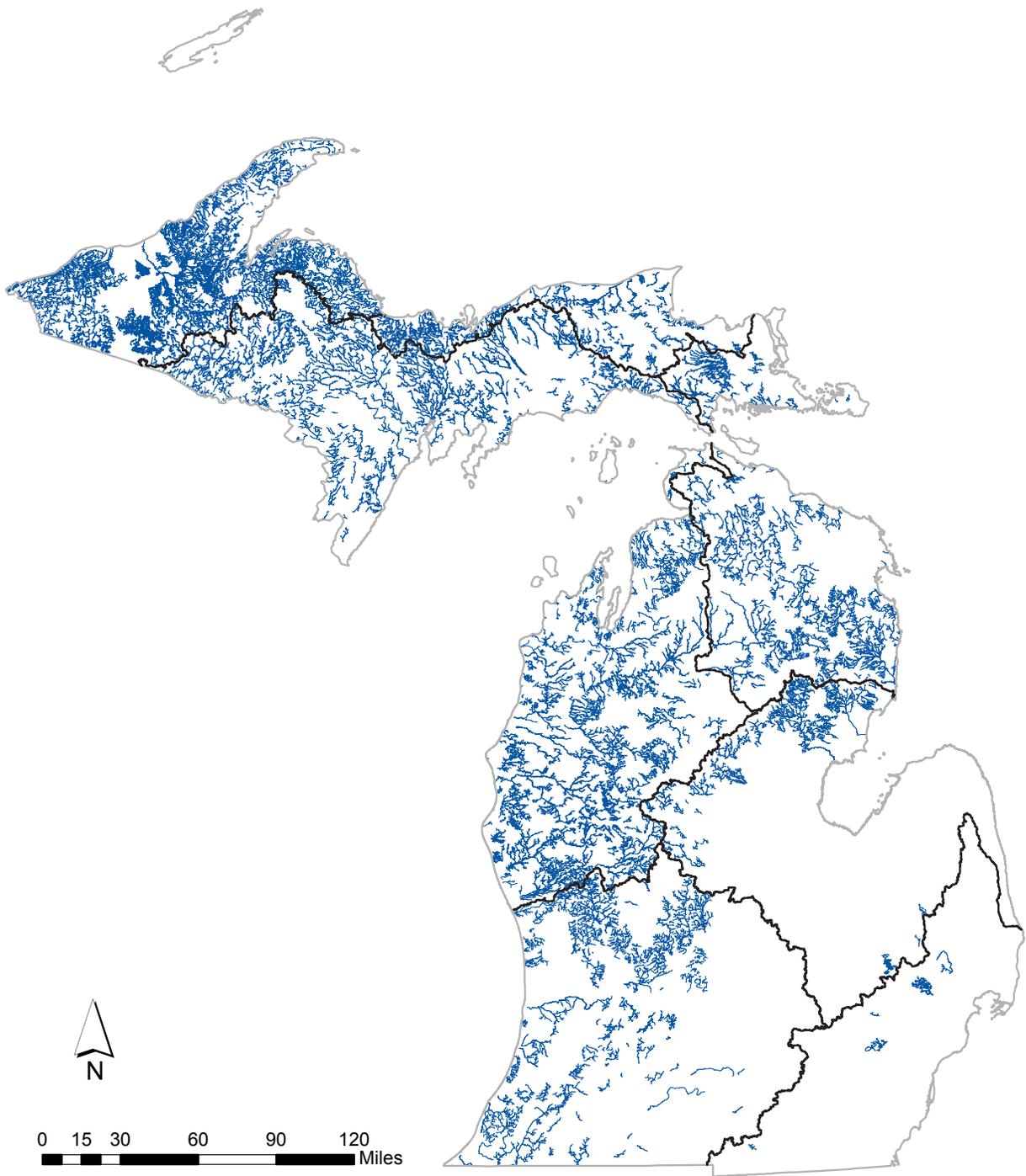


Figure 4.—Map of designated trout streams and MDNR Fisheries Division management unit boundaries (outlined in black).

Marginal trout streams generally have lower groundwater inputs and are too warm to sustain naturally-reproducing trout populations year-round over many years. However, they often have trout due to stocking, immigration, or during seasonal periods of cold-cool temperatures when trout take advantage of enhanced food production occurring in warmer reaches. About 40% of Michigan's trout stream mileage consists of marginal trout streams (T. Zorn, MDNR Fisheries Division, unpublished data). The distribution of marginal trout waters as measured by the percent of the state's total stream miles for this class in each MDNR Fisheries Division management unit were estimated as follows: Southern Lake Michigan (24%), Western Lake Superior (23%), Northern Lake Michigan (15%), Central Lake Michigan (15%), Southern Lake Huron (11%), Northern Lake Huron (10%), Eastern Lake Superior (1%), and Lake Erie (1%) (Seelbach et al. 1997; T. Zorn, MDNR Fisheries Division, unpublished data).

History of Michigan's Inland Trout Fisheries

In addition to native Brook and Lake trouts, Arctic Grayling *Thymallus arcticus* was one of the most notable species residing in Michigan's inland lakes and streams. Arctic Grayling are believed to have occurred in most major rivers in the northern two thirds of the LP of Michigan (Vincent 1962; Figure 5). In the UP, records of Arctic Grayling only occur for the Otter River, in the Sturgeon River drainage on the western side (Vincent 1962), although there is uncertainty about whether these were native populations.

Arctic Grayling were heavily exploited by anglers. For example, in Michigan's Au Sable River, it was easy for anglers to catch more than 100 pounds of Arctic Grayling daily (Huggler 1981), and anglers often did not reel in their catch until five fish were hooked at once (Day and Donahue 1951). A small commercial fishery that shipped grayling to the Chicago area was believed to exist in some parts of Michigan (Vincent 1962). Angling for the species made Michigan a popular tourist location in the Midwest, especially once railroad lines were extended into the region (Mershon 1923). Overexploitation from intense fishing pressure is believed to have caused initial declines in Arctic Grayling populations throughout the LP (Vincent 1962; Tingley 2010). For example, reductions in the distribution of Arctic Grayling in the Au Sable River due to overfishing may have started as early as the mid-1870s (Vincent 1962).

Unregulated logging also wreaked havoc on Arctic Grayling. Nearly the entire State of Michigan was deforested during 1860-1900, and as much land as possible was drained and converted to farming (Whelan 2004). During the logging period, rivers were the major transportation systems for moving logs to sawmills, and log drives (mass movements of cut logs) occurred on nearly every stream in the state. Log drives required construction of temporary splash dams on streams to create a flood surge in spring for carrying logs downriver over rapids and riffles. These log-laden floods loaded massive amounts of sediment into stream channels, and required large-scale desnagging and blasting operations to remove long-existing (naturally-occurring) logjams that impeded downstream transport of logs. For example, logjams on the Manistee River were extensive enough (up to five miles long) that some included Native American portage routes and were used as river crossings for horses and livestock (Whelan 2004; Rozich 1998). Lumber mill operations, usually near the river mouth, required additional dams to generate mechanical energy for running saws, and further fragmented streams. Isolation and degradation of stream habitats due to poor forestry practices and dams for lumber or other industry likely contributed to the extirpation of Arctic Grayling from Michigan's LP by around 1905, and from the UP rivers by 1935 (Westerman 1974).



Figure 5.—Watersheds with reliable historical records of Arctic Grayling (Vincent 1962).

Brook Trout are native to streams in the UP and the northernmost portion of the LP (Figure 6). Correspondence reprinted in Mershon (1923) identifies Brook Trout as native to coastal streams in the tip of the LP, with most contributors to this book and other sources stating this species was found from the Jordan River northward along the Lake Michigan shoreline, with one individual (Seymour Bower) indicating the range was from the Boardman River (near Traverse City) north. Similarly, Mershon (1923) indicates the range on the Lake Huron shoreline extended south to the vicinity of Hammond Bay and Rogers City, with exact location uncertain. As Arctic Grayling populations declined, stocking of hatchery-reared Brook Trout increased. Stocking began in 1879, when 12,000 Brook Trout fry were stocked into six southwestern Michigan streams. The first planting of 20,000 Brook Trout fry into the Au Sable River occurred in 1885, following the State Board of Fish Commissioners conclusion that Arctic Grayling had disappeared from the river (Westerman 1974). Brook Trout stocking expanded the species range to the extent that the 1885-1886 report from the fish commissioners reported that “now the streams of every county in the state but three, whose waters are not suited to this fish, furnish excellent trout fishing” (Westerman 1974).

Rainbow Trout stocking was also initiated during this period, with the first plant going into the Au Sable River in 1876, and additional stockings of McCloud River (California) strain Rainbow Trout into more rivers in subsequent years (Westerman 1974). By 1904, Rainbow Trout could be caught in about 50 counties in Michigan (Westerman 1974).

In 1883, Fred Mather, superintendent of the New York State Fish Commission, obtained 100,000 Brown Trout eggs from Baron Lucius von Behr, president of the German Fishing Society. The von Behr Brown Trout came from both mountain streams and large lakes in the Black Forest region of Baden-Württemberg (Behnke 2007). On April 11, 1884 a portion of the hatched fry were planted into the Baldwin River, a tributary of the Pere Marquette River in northwest LP (Westerman 1974). This was the first stocking of Brown Trout into a public water body in North America (Behnke 2002). In 1885, the U.S. Fish Commission received 100,000 Brown Trout eggs from Loch Leven, Scotland, sent by Sir James Gibson Maitland, of the Howietown Fishery, Shropshire. Of these, 43,000 eggs came to Michigan, and the hatched fry were stocked into LP streams and inland lakes. By the close of the 1896 stocking season over 1.7 million Brown Trout had been stocked into Michigan waters.

Overexploitation, landscape-scale habitat degradation, and potentially competition with expanding nonnative trout populations ultimately led to extirpation of Arctic Grayling (Mershon 1923; Vincent 1962; Tingley 2010). However, reestablishment of self-sustaining Arctic Grayling populations has been a long-standing desire of many Michigan biologists and anglers with the first attempts using stocked fish occurring in the 1870s. Most recently, the MDNR attempted to reintroduce Arctic Grayling by stocking various waters with them during 1987–1990, but the attempt was unsuccessful due in part to health issues with the hatchery-reared fish, limited understanding of the suitability of receiving waters for Arctic Grayling, low numbers stocked in each water, and an exceptionally warm summer in 1988 (Nuhfer 1992). Since then, the State of Montana has successfully reintroduced Arctic Grayling to streams (some co-inhabited by Brook and Brown trouts) using innovative rearing techniques, and our understanding of Michigan rivers and salmonid imprinting processes (e.g., Dittman et al. 2015) has notably improved. Thus, another attempt to reintroduce Arctic Grayling into Michigan streams where they historically occurred seems worthwhile.

Biology of Trout in Michigan Streams and Inland Lakes

General habitat use

Brook and Brown trouts generally inhabit small to medium sized streams, and lakes with suitable coldwater habitat. Both species occur throughout much of Michigan, with Brown Trout being more prevalent in the LP and Brook Trout more prominent in the UP (Figure 6; Figure 7). When the two species

co-occur, Brown Trout often out-compete Brook Trout (Zorn and Wiley 2010); higher Brook Trout numbers may occur closer to spring-fed, headwater reaches where summer water temperatures are colder and less than optimal for Brown Trout. Naturally-reproducing, stream-resident populations of Rainbow Trout occur in only a few streams (e.g., upper Au Sable River near Stephan Bridge, Sharon Rapids area on the Manistee River, and the Pine River, a tributary of the Manistee River), though juvenile offspring from migratory Rainbow Trout (steelhead) can be found in many coldwater tributaries with access to the Great Lakes (Figure 8). Brook, Brown, or Rainbow trout are sometimes stocked into coldwater stream reaches or lakes where habitat conditions required for natural reproduction are lacking.

Some inland lakes have naturally-reproducing populations of Lake Trout, but most inland lakes with Lake Trout are stocked because Lake Trout do not reproduce successfully in them (Table 1; Figure 9). One inland lake (Rush Lake – Marquette County) has a relic Lake Trout population that has sustained itself without any human intervention (Chavarie et al. 2016). Self-sustaining populations of Lake Trout also exist in Elk and Torch lakes (Antrim County). The Elk Lake population appears to be a remnant of a now extirpated native Lake Michigan population and was established by either natural colonization or stocking progeny of historical Lake Michigan populations (Jonas et al. 2017).

Splake are often stocked into lakes with over-abundant fish populations (e.g., stunted Yellow Perch *Perca flavescens*), where fishery management objectives typically include creation of a splake fishery and improving growth of prey fish (Table 1; Figure 9). Natural reproduction has not been shown to occur for splake, since they are a hatchery-based hybrid of Brook and Lake trouts. However, multiple fisheries agencies have observed spermiating male and spent female splake on Lake Trout spawning reefs during surveys in Lake Superior (Feringa et al. 2016). In addition, Behnke (2002) stated that splake were “fertile and may reproduce in nature”, and Becker (1983) noted that splake were “less fertile than either of the parent species”.

Top-quality stream trout habitats in Michigan share a number of key attributes. First, they have stable daily and seasonal flow patterns, with substantial inputs of groundwater to maintain year-round temperatures suitable for trout growth and survival. In addition, their waters are sufficiently fertile, due to watershed geology and land use, to support productive and diverse insect communities that, in turn, support abundant populations of healthy trout. They have sufficient channel gradients (dropping five or more feet per mile) to provide a diversity of riffle, run, and pool habitats. Good trout streams have an abundance of clean gravel that is not intermixed with sand for spawning trout, and other coarse substrates, including large woody debris, for aquatic insect production. Unlike the gravel-cobble dominated trout streams that drain more mountainous regions, Michigan’s groundwater-dominated trout streams typically drain sand-dominated landscapes that include patches of gravel-cobble substrates. Large woody debris and large riparian trees were historically and still are key channel forming and controlling agents in these sand-based systems. Some studies (e.g., Trimble 2004) suggest that reforestation of the landscape and riparian habitats over time may also be changing substrate and channel habitat conditions in streams, potentially reducing their suitability for trout. Excess sand sediment in trout streams can have strong negative effects on trout growth, abundance, and survival (Alexander and Hansen 1988; Waters 1995), and adverse effects of sand on trout reproduction may persist for decades (Nuhfer 2004). Good trout streams have pool habitats that are deep (deeper is better), with log complexes that provide shade, depth, diverse velocities, and hiding cover for large trout. Studies of fish responses to habitat created by large pieces of wood throughout North America (e.g., Roni et al. 2015) and in Michigan (e.g., Zorn and Nuhfer 2007a; Wills and Dexter 2011) suggest that when other aspects of habitat are suitable, trout and salmon densities respond positively to increased woody habitat in stream reaches. Spawning, growth, and refuge habitats needed over the course of a trout’s lifetime may be separated by many miles, so it is imperative that trout can freely move throughout a river system to access each type of habitat when needed.

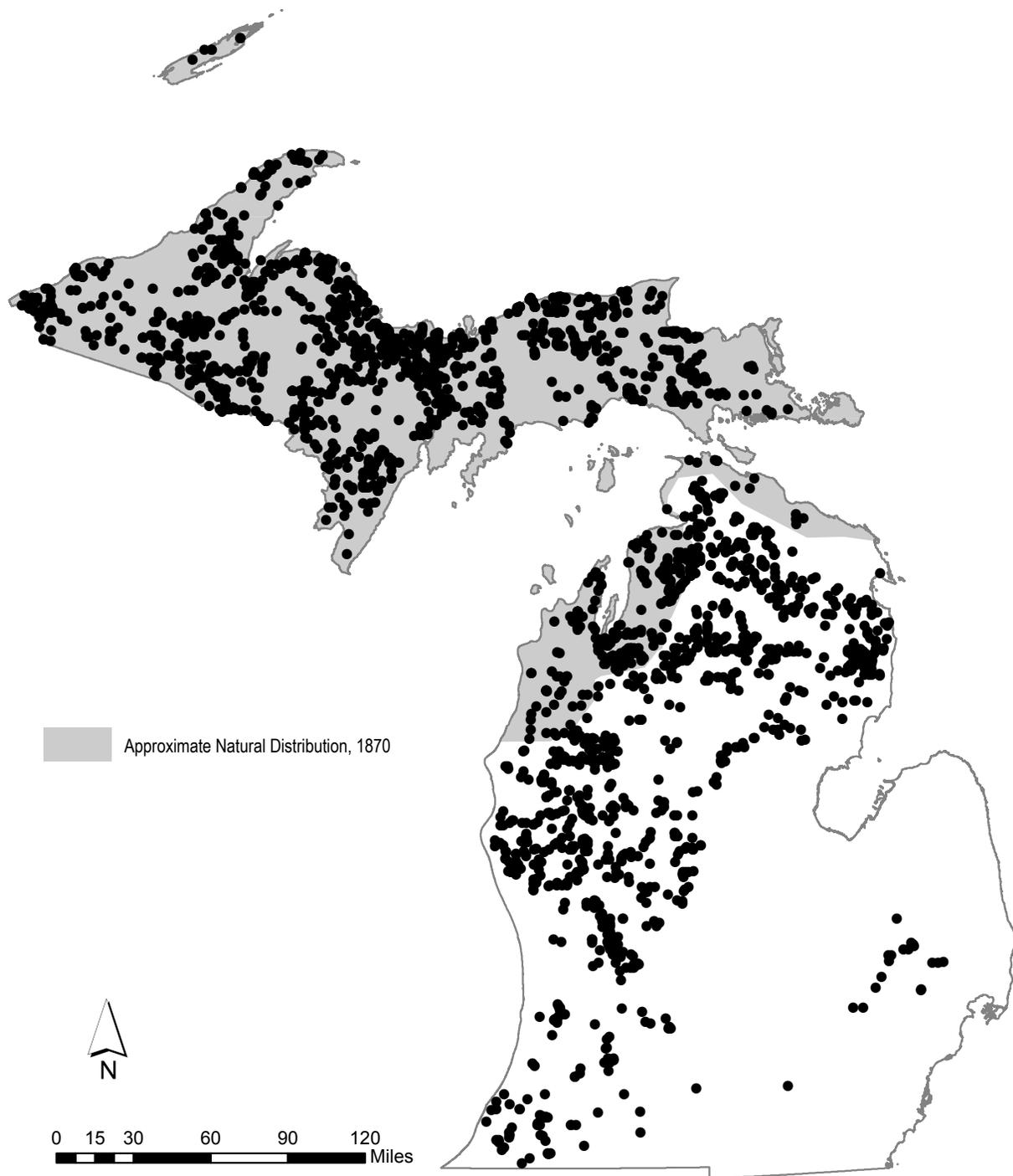


Figure 6.—Brook Trout occurrences in Michigan streams and inland lakes from MDNR Fisheries Division surveys and Bailey et al. (2004). Shaded area indicates estimated natural distribution of Brook Trout in 1870. Brook Trout had been introduced into many rivers south of the Jordan River in the northwestern Lower Peninsula by this time (Vincent 1962).

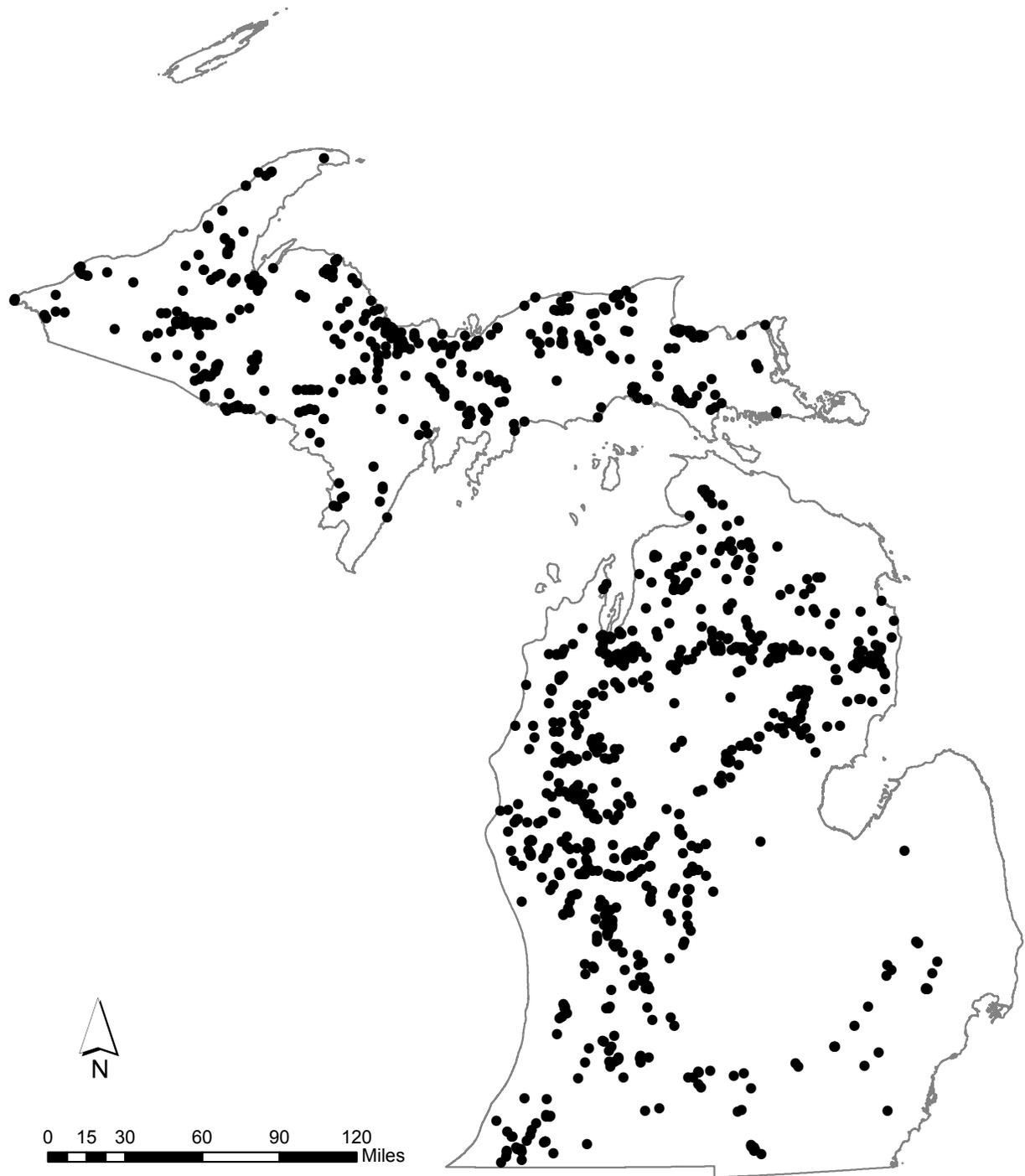


Figure 7.— Brown Trout occurrences in Michigan streams and inland lakes from MDNR Fisheries Division surveys and Bailey et al. (2004).



Figure 8.—Rainbow Trout occurrences in Michigan streams and inland lakes from MDNR Fisheries Division surveys and Bailey et al. (2004). Many occurrences in streams are for migratory Rainbow Trout (steelhead) from the Great Lakes.

Table 1.–Inland lakes in Michigan with fisheries for stocked Lake Trout, wild Lake Trout, or splake.

Lake name	County	Stocked	Wild	Splake
Deer Lake	Alger	x		
Elk Lake	Antrim		x	
Torch Lake	Antrim		x	
Gull Lake	Barry	x		
Crystal Lake	Benzie	x		
Beatons Lake	Gogebic	x		
Clark Lake	Gogebic		x	
Duck Lake	Grand Traverse	x		
Green Lake	Grand Traverse	x		
Lake Gerald	Houghton	x		
Roland Lake	Houghton	x		
Lake Ottawa	Iron	x		
Golden Lake	Iron	x		
Chicagon Lake	Iron	x		
Big Blue Lake	Kalkaska	x		
North Blue Lake	Kalkaska	x		
Lake Fanny Hooe	Keweenaw	x		
Glen Lake	Leelanau	x		
North Lake Leelanau	Leelanau	x		
Ives Lake	Marquette		x	
Sporley Lake	Marquette	x		
Sundstrom Lake	Marquette	x		
Maceday Lake	Oakland	x		
Higgins Lake	Roscommon	x		
Big Spring	Schoolcraft	x		
Lake Alice	Baraga			x
Thumb Lake	Charlevoix			x
Imp Lake	Gogebic			x
Moon Lake	Gogebic			x
Golden Lake	Iron			x
Lake Ellen	Iron			x
Lake Fanny Hooe	Keweenaw			x
Belle Lake #1	Luce			x
Perch Lake	Luce			x
Pretty Lake	Luce			x
Tank Lake	Luce			x
Lake Arfelin	Marquette			x
Sporley Lake	Marquette			x
Twin Lake	Marquette			x
Avalon Lake	Montmorency			x
Clear Lake	Montmorency			x
Maceday Lake	Oakland			x
Mirror Lake	Ontonagon			x



Figure 9.—Inland lakes managed specifically for trout using Type A through F regulations.

Temperature and groundwater

One of the most distinguishing features of trout is their intolerance for warmwater temperatures. A national-level study (Eaton et al. 1995) identified the following maximum weekly average temperatures that could be tolerated by Michigan species of stream trout: Brook Trout (72.1°F), Brown Trout (75.4°F), and Rainbow Trout (75.2°F). Looking at average July temperatures where trout were most abundant in Michigan's UP and northern LP, Zorn et al. (2008) found a pattern of thermal preferences, with Brook Trout having the lowest preference (62.2°F), and Brown Trout (63.4°F) and Rainbow Trout (64.2°F) showing slightly higher preferences. When thermal conditions are stressful in summer, trout seek relief in deeper waters of lakes or spring-fed stream reaches, as has been documented for Brook Trout in the UP's Ford River (Hayes et al. 1998). Data on trout abundance and average July stream temperatures for several hundred Michigan streams shows that as temperatures increase, a stream's potential for supporting Brook or Brown trouts declines (Figure 10; Zorn et al. 2009). The preferred temperature for both Lake Trout (Stewart et al. 1983) and splake (Becker 1983) is estimated to be about 50°F.

In addition to warm summer temperatures limiting trout populations, work on steelhead (Seelbach 1986) and Brown Trout (Zorn and Nuhfer 2007a) in Michigan rivers suggests that winter severity can also adversely affect trout abundance, growth, and survival. Winter can be especially stressful due to day-to-day variability in flow, water temperature, and changes in ice conditions, which can include anchor ice, surface ice, frazil ice from supercooled water, hanging dams, ice cover break-up, and ice jams (Brown et al. 2011). Such conditions are harmful to trout eggs and fry in redds, as well as to juvenile and adult trout. Effects of winter temperature and flow conditions on trout are poorly understood, in part due to the relative paucity of winter studies and complexities involved with them.

Because of their thermal requirements, the distributions of inland trout in Michigan are limited primarily to streams classified as cold or cold-transitional (Figure 2), slightly warmer reaches if connected to these colder streams, and inland lakes that are deep enough to contain sufficiently-cold, well-oxygenated water year-round (Figure 9). Trout streams in Michigan retain sufficiently cold conditions in summer through large inputs of groundwater. The temperature of groundwater is generally equal to the average annual air temperature of the region, and can differ by up to 9°F between the coldest and warmest areas of the state (Albert et al. 1986). Groundwater inputs to streams are indexed by a stream's low-flow yield, defined as the amount of flow the stream has during low-flow conditions divided by its drainage area. Minimum low-flow yield (cubic feet per second of flow per square mile of drainage area) values for trout streams typically range from 0.2 ft³/mi² for smaller watersheds to 0.6 ft³/mi² for larger streams (Zorn et al. 2009). Low-flow yield values have been estimated for Michigan streams, and have been used in describing species composition of stream fish communities (Zorn et al. 2002), assessing the suitability of individual waters for stream trout (Zorn et al. 2009), and assessing responses of stream reaches to flow reduction (Zorn et al. 2012).

Reproduction

Brook, Brown, and Rainbow trouts typically spawn in streams, and show similar spawning behaviors. If necessary, trout will migrate several to many miles from elsewhere in the river system or lakes to find suitable spawning habitat (Becker 1983; Clapp et al. 1990). Brook and Brown trouts usually spawn from late October to early December, with peak spawning occurring in early November. Stream-resident Rainbow Trout in Michigan spawn during March and April in the Pine and upper Manistee river watersheds.

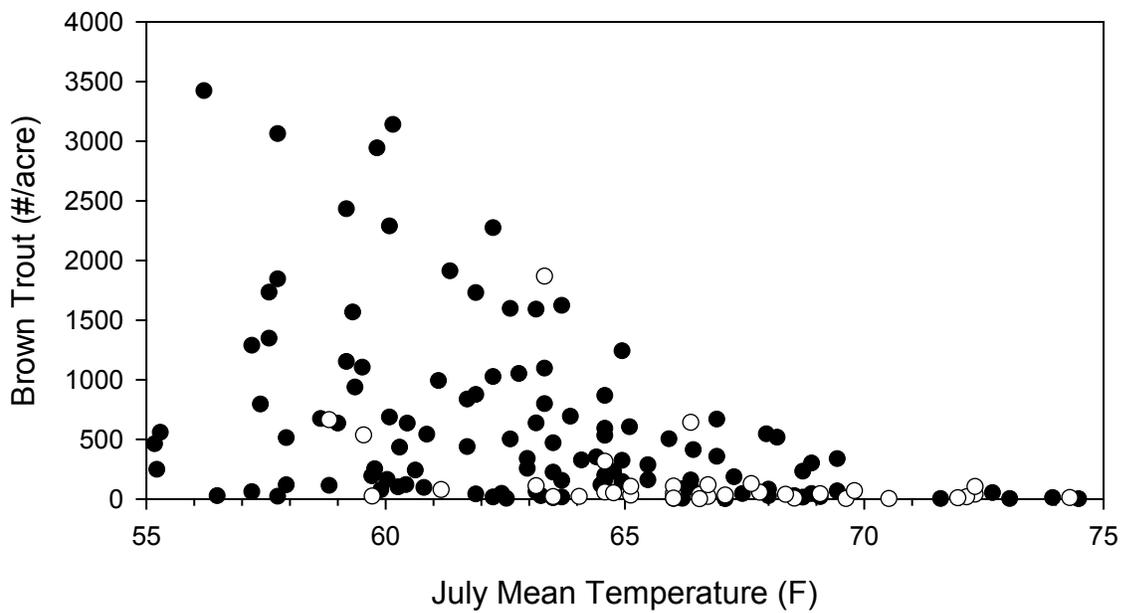
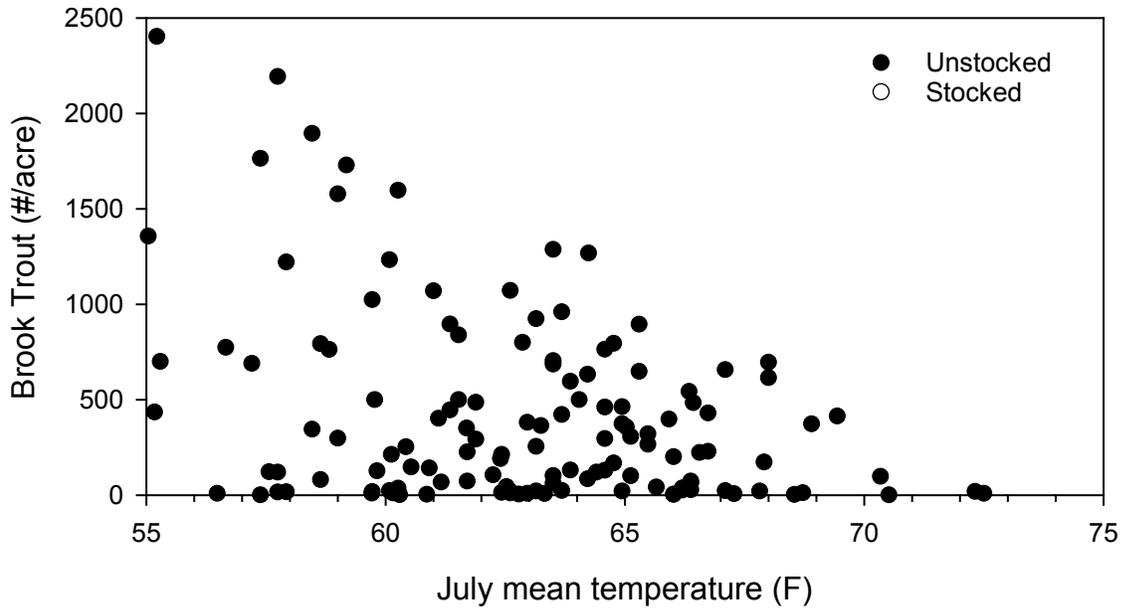


Figure 10.—Relationships between July mean water temperature and Brook and Brown trout density. Each dot represents observations from an individual stream location. The decline in the maximum trout density observed as stream temperatures increase indicates that the potential of a river reach for supporting trout decreases as stream conditions warm.

Trout need specific habitat conditions for spawning to be successful. In streams, trout typically spawn over gravel substrates, with larger individuals spawning over coarser-sized gravels. Good trout spawning areas have pea- to quarter-sized gravel with low embeddedness, meaning that there is open pore space between the gravel particles for oxygenated water to flow through while eggs are incubating. Gaps between gravel particles also allow hatched fry to grow in safety, being surrounded by gravel, and provide protection from higher and potentially lethal current velocities above the streambed. Where gravel is unavailable, spawning may occur on sand or hard clay substrate, but the proportion of eggs surviving to the fry stage is much lower (Becker 1983). In bedrock-dominated watersheds, such as Canadian Shield streams, Brook Trout preferred to spawn in the limited suitable locations where groundwater entered the river channel (Curry and Noakes 1995). However, no preference was evident in streams draining glacial drifts, presumably because they provided suitable water quality conditions along much of their length (Curry and Noakes 1995). Thus, we might expect a similar contrast in spawning-site selection by Brook Trout in Michigan, since watersheds of LP and most UP trout streams are dominated by glacial drifts, while some watersheds have considerable bedrock (e.g., western UP). Becker (1983) summarized observations of Brown, Brook, and Lake trouts spawning over shoals and reefs of various depths in lakes where currents kept eggs oxygenated, and mentioned observations of Brook Trout spawning on lake bottoms where upwelling water (spring seepage) provided oxygen necessary for eggs and fry to develop.

When spawning in streams, a female trout excavates a saucer-shaped nest in the gravel by “cutting” into the streambed with her belly and caudal fin, lays eggs, which are fertilized by the male, and then covers the fertilized eggs with gravel by cutting into the streambed. The eggs incubate and hatch under the gravel during winter for Brook and Brown trouts, with each fry obtaining nutrients from its yolk sac. Once the yolk sac is fully absorbed, the fry wriggles up out of the gravel and emerges above the streambed. Emergence generally occurs between April and May in most Michigan streams and is governed by water temperature, with colder temperatures slowing the process and leading to later emergence (Crisp 1988). Newly-emerged fry are weak swimmers and highly vulnerable to current velocity conditions and predators. This period is critical for stream trout, and if flows are high or fry cannot readily access low-velocity habitats, typically along the stream edge or areas off the main channel, their likelihood of survival is low. These effects have been demonstrated on Michigan trout streams (Nuhfer et al. 1994; Zorn and Nuhfer 2007b), where flow conditions are very stable and channel gradients low, as well as trout waters that are fed by mountains and have more variable flow conditions and steep gradients (e.g., Strange et al. 1992; Cattaneo 2002; Lobón-Cerviá 2004).

The regional-scale effect of flow on trout reproductive success is critically important, because the number of age-0 trout produced is a key predictor of the abundance of trout at older ages and strongly influences population trends over time (Zorn and Nuhfer 2007a). This highlights the importance of maintaining natural flow conditions that limit human-caused high stream runoff events and low-velocity, natural habitats along stream edges for age-0 trout. In addition to reproductive success influencing abundance of trout at older ages, potentially important factors include summer and winter water temperatures, food availability, channel habitat characteristics, density of competing fish, and levels of predation and angler harvest (Zorn and Nuhfer 2007a).

Growth

While adequate reproduction is key to supporting large populations of stream trout, the growth rate of trout also has an important influence on the availability of quality trout for anglers. Water temperature conditions and food availability are two major factors influencing the growth of fish (Brett 1979; Diana 1995), and where temperatures are ideal and food is abundant, spectacular trout fishing can be had. Such is the case in portions of the Bighorn River (Montana), Green River (Utah), and Bow River (Alberta), where upstream reservoirs provide downstream water temperature and nutrient conditions that support abundant populations of large, fast-growing trout (Nuhfer 1988). The fertility of these

and other western U.S. trout streams is enhanced by the geology of their watersheds, anthropogenic (human-caused) nutrient inputs, reservoir influences, and abundant coarse substrates and exposure to sunlight for algal and aquatic insect production. Studies in small Michigan streams have highlighted the dominant effects of temperature on trout growth, through its direct influence on fish metabolism, as well as its positive influence on food (aquatic invertebrate) availability (Hinz and Wiley 1998).

A river's or region's water quality acts to constrain that system's potential for producing trout. Michigan's groundwater-influenced streams are hydrological jewels, though they have low to moderate productivity, owing to the geology and largely forested land cover of watersheds they drain. Michigan streams are relatively nutrient-poor, with phosphorus concentrations typically less than 0.03 mg/L (e.g., Zorn and Sendek 2001; Cwalinski et al. 2006) and relatively low alkalinity values. Using a national-scale relationship between total alkalinity and trout production (Kwak and Waters 1997) and measured total alkalinity values of Michigan streams (Zimmerman 1968; Zorn and Sendek 2001), trout streams in southeastern Minnesota were estimated to have 1.4 times higher trout production than major branches of the Au Sable River and 2.4 times more trout production than many tributaries to Lake Superior in Marquette and Baraga counties. McFadden et al. (1963) noted that Brown Trout from infertile (i.e., low alkalinity) streams were older at first sexual maturity and produced fewer eggs because of smaller average size than trout from fertile streams. They concluded that in waters of low basic productivity, production of fewer eggs per adult trout and reduced overall levels of reproduction kept Brown Trout populations in equilibrium with a less productive environment. More recent studies on the Au Sable River also associated reductions in nutrient inputs to streams with declines in trout abundance, growth, and survival (Merron 1982; Zorn and Nuhfer 2007a).

In addition, many Michigan streams have a preponderance of low-gradient reaches and sandy substrates that offer patchy spawning habitat and limited availability of larger food items (e.g., forage fish and large invertebrates) for high densities of large trout (Alexander and Hansen 1988). Thus, while Michigan streams have outstanding water supplies, they do not offer unlimited growth and reproduction potential for trout. For example, Brown Trout in Montana's Beaverhead, Bighorn, and Madison rivers are 14 to 15 inches long once fish reach age-3 (Nuhfer 1988), while age-3 Brown Trout in Michigan's Au Sable River are 12 to 13 inches long in late summer (MDNR Fisheries Division, unpublished data). Lower densities of larger Brown Trout in Michigan streams partly result from fish needing an additional year to attain 15 inches, and natural mortality claims a considerable portion of the year class before they reach that age (Nuhfer 1988). Natural mortality alone annually claims about 50–80% of each year class of Brown Trout in Michigan (Zorn and Nuhfer 2007a); total annual mortality for Brook Trout is often over 80% (McFadden et al. 1967; Zorn and Nuhfer 2007a). Lower densities of large trout means fewer spawners, less egg deposition for future trout generations, and lower trout abundance overall compared to more fertile systems.

There is considerable variation in growth among trout in rivers throughout Michigan, due to differences in water temperatures, nutrients, and habitat conditions (Table 2). Looking at stream survey data from 25 MDNR status and trends fixed sites, the average length of age-2 Brown Trout in late summer ranged from 8.2 inches for the West Branch Sturgeon River (northern LP) to 11.5 inches for the North Branch Manistee River (MDNR Fisheries Division, unpublished data).

Additional variation in trout growth occurs within individual river systems, especially those with seasonal connections to productivity hotspots, such as the occasional beaver pond, inland lakes or ponds, warmer (more productive) reaches, or exceptionally deep pools (>20 feet deep). Brook and Brown trouts in such environments typically grow more rapidly and are considerably heavier than trout spending their entire lives in streams (Table 2). Reasons for this include the ability to vertically migrate to select depths that provide the most suitable temperature, lower energetic costs compared to dealing with the velocity of the stream's current, and potentially higher availability of prey fish and large invertebrate or vertebrate prey. Even more striking are the sizes attained by stream trout (i.e., Brown Trout, steelhead, and coaster Brook Trout) that migrate to and from the Great Lakes.

Table 2.—A) Mean length at age and annual growth increment (calculated) from status and trends surveys at randomly selected stream reaches and fixed site streams. Mean lengths are means of individual surveys where a mean length at age value was calculated from at least five fish. Annual growth increments were calculated as the difference between the mean length-at-age for a species and its mean length at age when fish were one year younger. The number of surveys used in calculating each mean length at age value is shown. Surveys were conducted between July and September. B) Mean length at age for August–September and annual growth increment data for trout in Michigan inland lakes from Schneider et al. (2000) occur further down. BKT = Brook Trout, BNT = Brown Trout, RBT = Rainbow Trout, LAT = Lake Trout, and SPL = splake.

Age	Mean length at age (in)			Annual growth increment (in)			Number of surveys		
	BKT	BRN	RBT	BKT	BRN	RBT	BRK	BRN	RBT
Random site surveys									
0	2.9	3.0	2.4	2.9	3.0	2.4	22	23	15
1	5.9	6.5	5.8	3.0	3.5	3.5	37	35	20
2	7.6	9.3	8.2	1.7	2.8	2.4	18	27	5
3	9.3	11.9		1.7	2.7		1	22	
4		15.3			3.4			6	
Fixed site surveys									
0	3.1	3.1	2.5	3.1	3.1	2.5	118	134	82
1	6.1	6.6	6.0	3.0	3.4	3.5	143	145	107
2	8.2	9.5	8.6	2.2	2.9	2.6	90	133	18
3	9.1	12.4	12.0	0.9	2.9	3.3	7	100	1
4	11.9	15.1	15.2	2.8	2.6	3.3	1	51	1
5		18.4			3.3			13	
6		21.1			2.7			3	

Age	Average length (in) for August–September					Annual growth increment to age				
	BKT	BRN	RBT	LAT	SPL	BKT	BRN	RBT	LAT	SPL
1	8.1	10.1	9.7	7.9	10.9					
2	10.7	13.6	12.8	11.9	13.2	2.6	3.5	3.1	4.0	2.3
3	13.3	17.0	15.8	15.4	15.6	2.6	3.4	3.0	3.5	2.4
4	15.9	20.4	18.8	18.7	17.9	2.6	3.4	3.0	3.3	2.3
5	18.4	23.8	21.8	21.5	20.2	2.5	3.4	3.0	2.8	2.3
6		27.2		24.0	22.5		3.4		2.5	2.3
7				26.2	24.8				2.2	2.3
8				27.9	27.2				1.7	2.4
9				29.3					1.4	

The differences in water fertility between Michigan and other regions, as well as among river and lake habitats, highlight the importance of the habitat conditions to fish growth within a water body. Genetic effects of trout strain on growth are most apparent when side-by-side growth comparisons are made within a water body (Wills 2005; Nuhfer and Wills 2012), but strain effects on growth are relatively minor compared to habitat influences (e.g., river vs. lake).

Stocked Lake Trout and splake often grow well in inland lakes (Table 2). For example, average length-at-age values for naturally-reproducing Lake Trout in Elk Lake are: age-3, 18.0 inches; age-4, 21.1"; age-5, 23.0"; age-6, 24.1"; age-7, 25.9"; and age-8, 26.9" (J. Jonas, MDNR, unpublished data). These data suggest similar growth trajectories between stocked Lake Trout populations and this naturally-reproducing population.

Maturation

The age at which inland trout mature and spawn differs by species. In Michigan's Platte River, 100% of resident male Brown Trout were mature when they reached age-3 or 10.0 inches, and 100% of females were mature at age-4 or 12.0 inches (Taube 1976). Percent maturity and fecundity (number of eggs per fish) values for resident female Brown Trout in the Platte River from Taube's study were age-1 (16% and 279 eggs/fish), age-2 (77% and 493), age-3 (88% and 766), age-4 (100% and 1,382), and age-5 (100% and 1,601). Taube (1976) also noted that egg size was positively correlated with a fish's length and age. Becker (1983) noted that in southern Wisconsin, some male Brown Trout were mature by October when they were 20 months old and 12 inches long, but in northern Wisconsin, they generally did not mature until after their third summer of life.

Brook Trout mature earlier, especially when food resources are limited. In Lawrence Creek, Wisconsin, 5% of males matured at the end of their first summer of life, the smallest mature fish being about 3.5 inches long (Becker 1983). Most females (about 80%) mature as yearlings, at minimum lengths of about 5 inches (Becker 1983). McFadden et al. (1967) noted similar maturity patterns for Brook Trout in Hunt Creek, Michigan, with males initially maturing at 5 inches (the largest age-0 males) and females at age-1 and 5 inches. Fecundity (number of eggs per fish) values for some inch groups of female Brook Trout in their study were 7-inch (354 eggs/fish), 9-inch (668), 11-inch (1,144), and 13-inch (1,721). We could not locate similar data for stream-resident Rainbow Trout in Michigan rivers or Wisconsin (i.e., Becker 1983). Maturity and fecundity data are usually not collected on trout stream surveys since they typically occur well outside of trout spawning periods.

Little is known about when Lake Trout mature in inland lakes, though Becker (1983) noted that male Lake Trout in Lake Superior first matured at age-4 (20 inches) and females at age-5 (24 inches). In Elk Lake, 46% of female Lake Trout were mature at age-4 (22 inches) and 71% of males were mature at age-4 (22 inches) (J. Jonas, MDNR Fisheries Division, unpublished data).

Movements

Stream trout in Michigan are known for migrating on a daily basis while foraging, and on a seasonal basis as they move into spawning, overwintering, or refuge habitats (Clapp et al. 1990; Hayes et al. 1998; Diana et al. 2004). In coastal areas, populations of Brown, Rainbow, and Brook trouts migrate from the ocean to freshwater rivers to spawn. Adfluvial populations, which migrate from lakes to spawn in rivers, occur for each of these species in Michigan. Great Lakes adfluvial Rainbow Trout are called "steelhead", and adfluvial Brook Trout are referred to as "coasters" (Great Lakes adfluvial populations are not the focus of this report). Anything that blocks or reduces the movement of trout between spawning, refuge, and growth habitats has the potential to limit the abundance and viability of the population as a whole. Barriers may include human-made dams of all sizes, poor water-quality conditions, improperly-sized or -installed culverts at road-stream crossings, stream channelization projects, and occasionally beaver

dams. With over 2,500 dams and more than 67,000 road-stream crossings in Michigan, addressing the negative effects of barriers is a major issue for managers of inland trout.

Mortality, predation, and competition

Trout are subject to many causes of death, and those sources of mortality vary throughout their lives. A large portion of mortality occurs in the earliest stages of a trout's life. Trout eggs are preyed upon by trout and other fishes as they are being released by spawning females, and eggs may also be consumed by small fishes and invertebrates during the incubation phase. Developing eggs may be smothered by sedimentation, which reduces the flow of oxygen into redds and blocks interstitial spaces that fry need to move through when emerging from redds (Nuhfer 2004). Developing eggs and fry may be killed by floods that destroy nests, or damaged by icing of the streambed (i.e., anchor ice) during extremely cold weather. Groundwater inputs to spawning areas are best for limiting ice effects. Fry that survive to emerge from redds are subject to velocity conditions above the streambed and many are washed away, especially when flows at emergence are above average (Nuhfer et al. 1994). Excessively warm summer or cold winter conditions also lead to death of trout, especially age-0 fish, which are more vulnerable than older-aged trout because of higher metabolism rates and less able to move to better habitats in the river system (Seelbach 1986; Zorn and Nuhfer 2007a).

As trout grow older and larger, the sources of mortality change as a new suite of predators come into play. For example, Alexander (1976) documented predation on Brook and Brown trouts in northcentral LP lakes and streams by several species of birds (American Merganser, Belted Kingfisher, Great Blue Heron, Common Loon, American Bittern), mammals (mink, otter, raccoon), and one reptile (water snake). In addition, larger trout prey on small trout. For example, Westerman (1974) noted that Brown Trout compete closely with Brook Trout (both spawn in the fall and inhabit similar stream types), stating that the Brown Trout has the edge since it is more carnivorous, grows much larger, is more aggressive (monopolizing choice pools and holding positions), and is more wary of anglers. He stated that "there are small [Michigan] streams where the Brown Trout has taken over to the complete exclusion of the Brook Trout" (Westerman 1974). Fausch and White (1981) documented behavioral dominance of Brown Trout over Brook Trout in a Michigan stream, and negative influences of Brown Trout density on Brook Trout age classes were apparent in both the Au Sable River (Zorn and Nuhfer 2007a) and statewide analyses of Brook Trout distribution and abundance (Zorn et al. 2004; Zorn and Wiley 2010).

Various abiotic and biotic factors cause considerable mortality of older trout in streams. Annual survival rates of trout, as defined by the percentage of trout that survive from one year to the next, in Michigan streams average about 30%, typically ranging between 25% and 35% per year (Table 3). Average annual survival was lower for Brook Trout (24%) than Brown Trout (34%), which are generally considered the more wary and crepuscular (active during lower light conditions) species. Trout density, availability of instream woody habitat, predator abundance, and trout size were associated with annual increased survival rates of older-aged trout in the Au Sable River (Zorn and Nuhfer 2007a). In addition, trout of all ages are vulnerable to various types of disease and parasites. For example, studies in Wisconsin suggest wild Brook Trout populations are being reduced by gill lice *Salmincola edwardsii* infestations and Brown Trout interactions, both of which are increasing due to warmer stream temperatures that have occurred in recent years (Mitro 2016). Brook Trout infested with gill lice may occur in many Michigan streams, having been observed in Hunt Creek (P. Muzzall, Michigan State University, personal communication; G. Whelan, MDNR Fisheries Division, personal communication; and T. Zorn, personal observation), and documented in Honey Creek (Kent County), Fish Creek (Montcalm County), and the Au Sable River (Crawford County).

Table 3.—Average percent (%) annual survival estimates for Brook and Brown trouts from status and trends fixed site surveys. Values shown are averages from surveys where calculated survival was greater than 0 and less than 1, and the number of surveys used to compute individual survival values by age are shown. Average values by age for both species combined and overall averages by species are also shown. BKT = Brook Trout and BNT = Brown Trout.

Age		Annual survival (%)			Number of surveys	
From	To	BKT	BRN	Averages	BKT	BRN
0	1	27.4	33.0	30.2	68	78
1	2	19.6	44.7	32.1	72	74
2	3	22.8	40.1	31.5	25	69
3	4	24.9	38.3	31.6	2	60
4	5		24.7	24.7		32
5	6		38.9	38.9		11
6	7		16.7	16.7		1
Averages		23.7	33.8	28.7		

As trout grow larger, they become less vulnerable to many predators, though humans remain an important source of trout mortality. In addition to human-induced changes to the landscape and stream habitats, which can increase mortality, impair trout reproductive success, and reduce population levels over the long term, angling harvest and fishing techniques also lead to death of trout. Several researchers have estimated hooking mortality (i.e., the percentage of hooked trout that die after release) for fish captured using various types of fishing gear. Summarizing results from over twenty studies on trout and salmon, Wydoski (1977) found that hooking mortality averaged 25% for anglers using live bait, 6% for those using spinners and other artificial lures, and 4% for anglers fishing with artificial flies. Of these studies, only two involved wild trout caught on artificial lures or flies in a stream (Shetter and Allison 1955; 1958), and both were conducted in Michigan. The overall percent hooking mortality of stream trout using flies, artificial lures, and worms from the Shetter and Allison studies were as follows: Brook Trout (flies- 2.0%, lures- 2.6%, worms- 42.4%); Brown Trout (flies- 0.0%, lures- 1.5%, worms- 20.3%); and Rainbow Trout (flies- 5.8%, lures- 6.3%, worms- 35.4%). A more recent study in Maryland (Pavol and Klotz 1996) used similar procedures to Shetter and Allison. They produced similar results for flies and lures with Brown Trout (and flies with Brook Trout), but found 8.7% hooking mortality for Brook Trout using lures. Nuhfer and Alexander (1992) reported 8.3% hooking mortality for trophy wild Brook Trout caught on treble-hooked lures in three Michigan lakes. Schill (1996) noted that hooking mortality from bait angling can be substantially reduced if bait anglers “actively” fished bait (without a slack line) and cut the line on fish that were deeply hooked, leaving the hook in the fish. Mortality after 72 hours for 199 wild Brook Trout and Brown Trout caught in a Wisconsin stream by active baitfishing was 4.5% (DuBois and Kuklinski 2004).

Use of barbless hooks has been promoted to reduce hooking mortality, but Schill and Scarpella’s (1997) review of many studies indicated that barbless hooks did not reduce hooking mortality for fly- or lure-caught trout. They concluded that there was no biological basis for imposing barbed hook restrictions on fly or lure anglers. They suggested “possible merit” to the use of barbless hooks by bait anglers intent on releasing trout since they make it easier to unhook fish.

Competition among individuals of a year class is also an important source of mortality. Aggressive territorial behavior among salmonid fry or parr for limited suitable foraging space within a stream reach can result in emigration or mortality of fish, and ultimately sets an upper limit on the numbers of fish that a reach can support (Chapman 1966; Bachman 1984). Reduced survival when fish density is high and increased survival when density is low, known as density-dependent survival, is well-documented for stream trout in Michigan and elsewhere (Chapman 1966; Elliott 1994; Grossman et al. 2012). For example, in Michigan's Au Sable River, a negative relationship between trout density and survival when high densities led to low survival to the following fall was seen in all age classes of Brown and Brook trouts (Zorn and Nuhfer 2007a).

Competition with migratory salmonids can also lead to substantial changes in resident trout populations. For example, MDNR (Nuhfer et al. 2014) experimentally introduced migratory Rainbow Trout (steelhead) into a portion of Hunt Creek to assess how the creek's resident Brown Trout population would respond. Annual survival of age-0 Brown Trout declined significantly when juvenile steelhead were present, which led to the density of age-1 and older Brown Trout declining to levels that were nearly half of those that existed prior to the introduction of steelhead. Competition was especially notable in Hunt Creek because of its stable, dense population of age-0 Brown Trout (Nuhfer et al. (2014). Such effects may be less likely to occur in streams where age-0 trout densities are lower or more variable. Peck (2001) also noted decreased survival of age-0 Brown and Brook trouts as a result of increased steelhead populations in a Lake Superior tributary. Interestingly, some larger Michigan streams, such as the Pere Marquette and Little Manistee rivers, have the capacity to produce and sustain some of the highest densities of large resident Brown Trout observed in the state, despite the presence of dense populations of juvenile steelhead (Tonello 2005; MDNR Fisheries Division, unpublished data). Often, other key factors such as water temperature will regulate the outcome of competitive interactions between fish species (De Staso and Rahel 1994). For example, White Suckers may appear to be out-competing trout in a stream because they are more abundant, when in actuality, the stream is marginally warm for trout and better suited to White Suckers, which tolerate warmer summer water temperatures than trout (Zorn et al. 2009).

Fishing Regulations

History and Overview of Trout Fishing Regulations

The need for regulations to protect Michigan's trout populations from excessive angler harvest was formally acknowledged in 1873, when the poor condition of the state's fisheries prompted the Michigan Legislature to establish the first Board of Fish Commissioners. George H. Jerome, Michigan's first Superintendent of Fisheries, reported in 1875:

That waters once abounding with fish can become barren by excessive, or ill-timed, or barbarous fishing, or all together, is too obviously, painfully true. ...Go where we will, lakes streams and rivers, which scarcely a generation ago gave great joy and profit to riparian owner and general angler, now scarcely excite their thought or notice. ...Laws, too, prescribing closure times and regulating the utensils and methods of capture, whether by seine or weir, or spear or hook, grow out of the very necessities of the case and can no more be dispensed with than can the rudder be detached from the ship and she ride on in safety. [Jerome 1875]

In 1881, the first regulation was adopted for trout in Michigan streams, a 6-inch minimum size limit (MSL) for Brook Trout and Arctic Grayling (Clark et al. 1981). Beginning in 1889, the open fishing season for trout was set from May through August. The first "special regulation" was enacted in 1901 – an increase of the MSL to 8 inches on the Au Sable River. In 1903, the statewide MSL was increased

to 7 inches for Brook, Brown, and Rainbow trouts, Atlantic Salmon, and Arctic Grayling, and the daily possession limit was set at 50 trout (Clark et al. 1981). Other landmark events in Michigan's trout regulations history include the implementation of the first flies-only rule on the North Branch Au Sable River in 1907 and the designation of several trout lake and stream types in 2000. More detailed histories of fishing regulation changes can be found in Clark et al. (1981) and Borgeson (1974). Despite many regulation changes and evaluations on individual waters, and reductions in trout bag limits over time, the basic structure of fishing regulations remains similar to what it was over 100 years ago.

The principal types of fishing regulations are as follows: daily possession limits (also known as creel limits or bag limits), seasonal fishing and harvest closures, gear or fishing method restrictions, and size limits. The daily possession limit is the total number of caught fish that may be retained in one day. Possession limits are useful for preventing individuals from harvesting more fish in a day than the general public feels would be reasonable, and contribute to a more equitable distribution of fish among the angling public. Possession limits also can be effective for regulating a fish population if set low enough that many anglers reach the limit. In Michigan, the 2016 daily possession limit on most lakes and streams is five trout, with no more than three trout being longer than 15 inches.

Fishing and harvest closures occur on most Michigan streams from October 1 to the last Saturday in April, in large part to protect Brown and Brook trouts, which congregate on spawning riffles in fall and are more vulnerable to anglers. In Michigan, most trout streams have been closed to fishing during fall-early spring since 1873. Other states (e.g., Wisconsin, Minnesota, and Pennsylvania) prohibit harvest of trout on the majority of streams during roughly the same portion of the year, suggesting a region-wide strategy of protecting spawning Brook and Brown trouts. Anecdotally, these harvest seasons appear to have broad public acceptance. However, some anglers have expressed interest in expanding catch-and-release fishing opportunities on all or a subset of Michigan trout streams outside of the standard harvest season. There are two mechanisms by which such activity could affect trout populations: (1) released fish could perish due to hooking mortality, and (2) wading anglers could damage trout eggs that are incubating in spawning gravels (Roberts and White 1992). Insufficient data are available to quantify potential effects of extended season fishing on trout populations in particular stream types. Thus, fisheries managers have adopted a precautionary approach regarding seasonal closures. Small streams in Michigan typically have the standard harvest and seasonal fishing closures; whereas, some larger rivers or streams with stocked trout populations are open to fishing all year (see *Current Trout Stream Regulation Types*).

Recreational fishing gear or method restrictions are used to enforce principles of fair chase, assuring that fish are captured individually and with sufficient difficulty. For example, hook size restrictions are used to prevent illegal snagging, while other limits (e.g., number of fishing lines, hooks, etc.) are intended to reduce angler efficiency. Gear or method restrictions are also used to reduce mortality of fish that are not legally harvestable or of legal size and voluntarily released. For example, use of live bait is not allowed on river reaches designated as "flies only" or "artificial lures only" where high catch rates of quality or trophy trout are the objective because multiple studies have demonstrated that hooking mortality is much higher with live bait than with artificial lures and flies (Shetter and Allison 1955; Shetter and Allison 1958; Wydoski 1977; Pavol and Klotz 1996). Other less commonly applied gear and method restrictions include limits on the number of points per hook (treble vs. single hooks) and barbless hook requirements (Nuhfer and Alexander 1992; Schill and Scarpella 1997). Restrictions are also used to prevent the spread of potentially invasive bait species or diseases into waters where they are not desired.

A MSL requires anglers to release fish that are not large enough to be legally harvested. The best MSL for a particular fishery depends upon the level of fishing effort, growth and survival rates of trout, the vulnerability of the species to angling, and whether protection is needed to assure there are enough spawners to saturate spawning habitats. MSLs have been shown to be effective in lowering angling mortality of trout populations (Shetter 1969; Hunt 1970). In his work on Brook Trout in Lawrence Creek,

Wisconsin, Hunt (1970) evaluated the effects of size limits, possession limits, and gear restrictions and noted that, “The size limit, if wisely applied is the best single regulation for preventing excessive angler harvest of Brook Trout populations. The size limit applies to every trout caught, and it can be related to a rather stable biological parameter, growth rates of trout populations.” The MDNR Fisheries Division has focused predominantly on selecting the appropriate MSLs for each species and stream.

Although less common than MSLs, protected slot limits have been implemented on streams both within and outside of Michigan. A slot limit was in place on the Au Sable River from Burton’s Landing to Wakeley Bridge during 1979-1983. The slot limit did not fulfill the objectives of increasing growth rates of trout and increasing abundance of large Brown Trout in the treatment reach; however, interpretation of the results was complicated by changing environmental conditions and the short duration of the study (Clark and Alexander 1985). Snook and Dieterman (2014) summarized the results of creel surveys conducted on southeastern Minnesota streams with varying regulation types. They concluded that “Anglers were clearly not fishing longer, catching more or larger sizes of trout, or were more satisfied on stream areas with protected slot regulations than anglers fishing general regulation areas.” Computer simulations by Power and Power (1996) suggested that slot limits outperformed MSLs in producing quality and trophy Brook Trout. However, the MSLs used in the simulations were lower than the current MSLs on Michigan trout streams. Computer simulations using trout population data from Michigan streams could be used to predict the effects of various MSLs or protected slot limits on harvest and abundance of trout of different size classes, and simulations should be part of any decision-support software used to evaluate regulations.

In most instances, the purpose of fishing regulations is to reduce fishing mortality, which includes harvest and hooking mortality of released fish. Management of trout populations in Michigan streams is complicated by the scarcity of data on fishing effort and harvest for nearly all of our streams, especially our smaller ones. It is exceptionally difficult and expensive to estimate fishing effort and harvest on trout streams due to many factors, including the sheer number of trout streams in Michigan, multiple access points along rivers, and agency staff limitations. Furthermore, changes in angler behavior (e.g., percent of legal-sized trout that were released) over time limit usefulness of older harvest estimates in predicting effects of proposed regulation changes on stream trout populations. Out of necessity, our assumptions regarding fishing mortality in a particular stream often are based on creel data from other streams, age structure data from electrofishing surveys, observations by biologists or conservation officers, or anecdotal reports from anglers. Revenue from the restructuring of fishing license fees in 2014 has allowed MDNR to expand the inland creel program to assess some of the data gaps for a very limited number of inland trout streams. For example, creel surveys recently have been completed on the Au Sable River and on four trout streams in the UP with experimental Brook Trout regulations.

Current Trout Stream Regulation Types

Sportfishing regulations are determined by a mixture of biological, social, and economic considerations. Thus, Michigan’s trout stream regulations represent an effort to optimize trout population characteristics, in particular trout abundance and growth potential, while taking angler preferences and demographic factors into account including the availability of stream trout fisheries in the area and potential angling pressure. In addition, MDNR strives to make regulations understandable and avoid unnecessary complexity. One strategy that has been employed to make regulations more understandable for trout anglers is the classification of the vast majority of Michigan trout streams into one of four standard regulation types (Figure 11).

All types of natural and artificial baits may be used on stream Types 1-4			Minimum Size Limit (inches)			Daily Possession Limit
Stream Type (Colors below are indicated accordingly on the maps online.)	Fishing Season	Possession Season	Brook Trout	Brown Trout	Atlantic, Chinook, Coho & Pink Salmon, Lake Trout, Rainbow Trout (Steelhead), Splake	All Trout and Salmon
1 (Approx. 1,400 streams)	Last Sat. in Apr. - Sep. 30	Last Sat. in Apr. - Sep. 30	7"	8"	10"	5 fish, but no more than 3 trout 15" or greater
2 (14 streams)	Last Sat. in Apr. - Sep. 30	Last Sat. in Apr. - Sep. 30	10"	12"		
3 (60 streams)	Open All Year	Open All Year	15"	15"		
4 (130 streams)	Open All Year	Last Sat. in Apr. - Sep. 30 for Brook Trout, Brown Trout, and Atlantic Salmon Open all year for all other Trout and Salmon	7"	10"		

Figure 11.—Overview table of sportfishing regulations for trout and salmon in Type 1 through Type 4 streams from MDNR’s 2016-2017 Michigan Fishing Guide.

Most reaches of Michigan trout streams are classified as Type 1. These account for about 1,400 reaches measuring 26,000 miles (Figure 12). Type 1 waters are generally small, spring-fed streams with stable flows, cold summer temperatures, and are often difficult to fish because of dense riparian vegetation. Many have self-sustaining populations of relatively slow-growing trout, while others serve as critical seasonal coldwater refuges for faster-growing trout that seasonally forage in larger, more productive (but thermally-marginal) rivers. Some Type 1 stream reaches are stocked. Type 1 reaches are often narrow and most effectively fished with bait or spinners because streamside vegetation makes fly-casting difficult. Trout in Type 1 reaches are protected during the spawning season, as fish may concentrate when spawning areas are limited and could be especially vulnerable to experienced anglers. The fishing and possession seasons on Type 1 streams are identical, beginning on the last Saturday in April and extending through September 30. Of the four major regulation types, Type 1 reaches provide the greatest opportunity for harvest. The MSLs in Type 1 streams are 7 inches for Brook Trout and 8 inches for Brown Trout. The Rainbow Trout MSL is 10 inches in all Type 1–4 streams, and provides protection for wild or recently-stocked juvenile steelhead (Rainbow Trout) in rivers. The daily possession limit is five fish with no more than three individual trout being longer than 15 inches; the latter criterion limits harvest of large adult trout and steelhead.

Nearly 100% of male Brook Trout in small Michigan trout streams are mature by the time they grow to a length of 7 inches (McFadden et al. 1967). Thus, harvest of male Brook Trout over 7 inches

is not likely to jeopardize reproduction because most males have a chance to spawn at least once. Approximately 80% of female Brook Trout in small streams are mature at 7 inches, so even if they are harvested under a 7-inch MSL, there is sufficient egg-laying capacity to sustain populations (McFadden et al. 1967; Alexander 1974). In a study conducted at the Hunt Creek Fisheries Research Station researchers found no difference in the abundance of young trout between a 17-year period when an experimental section of Hunt Creek was open to angling under a 7-inch MSL (1949-65) and a 27-year period (1966-92) when all fishing was prohibited (Nuhfer and Alexander 1993).

In contrast to Brook Trout, most Brown Trout are not sexually mature when they reach the MSL (8 inches) in Type 1 stream reaches. Taube (1975) evaluated Brown Trout maturity in the Platte River. At 7.0-7.9 inches, 35% of males and 8% of females were sexually mature. At 8.0-8.9 inches, 68% of males and 35% of females were mature. At 11 inches, approximately 80% of the female Brown Trout in the Platte River were sexually mature. Despite potential harvest of immature fish with an 8" MSL, many Type 1 stream reaches have had self-sustaining Brown Trout populations for several decades, in part because Brown Trout are less susceptible to angling than Brook Trout (Becker 1983).

Type 2 trout waters are generally larger than Type 1 streams, often have less stable flows, and somewhat faster-growing trout (Figure 13). Depending on the magnitude of groundwater inputs, some Type 2 stream reaches contain self-sustaining trout stocks, while others are supported by stocking. Because of their potential to support faster-growth and suitable overwinter survival of trout, Type 2 waters have higher MSLs (12 inches for Brown Trout and 10 inches for Brook Trout). Type 2 reaches are intended to support higher overall densities and catch rates of trout, and increased densities and angler catch rates of larger trout. Season, tackle, and possession restrictions are the same as Type 1 waters. Fourteen stream reaches (207 miles) have Type 2 regulations.

Type 3 stream reaches typically receive seasonal runs of migratory fish from the Great Lakes, and therefore are open to fishing and harvest all year (Figure 14). Resident Brown and Brook trout fisheries are usually minor or nonexistent in Type 3 streams, but if these species occur, they receive substantial protection from a 15-inch MSL. In stream reaches accessible to Great Lakes fishes, the 15-inch MSL protects stocked Brown Trout for Great Lakes fisheries from harvest prior to their out-migrating to the Great Lakes, and provides some protection for adfluvial Brook Trout. Type 3 regulations occur on 60 stream reaches (approximately 826 miles).

Michigan's 130 Type 4 reaches (about 1,960 miles) vary greatly in size, exhibit flows ranging from moderately stable to quite variable, and have summer water temperatures that may be above optimal levels for trout (Figure 15). Trout growth may be average to above average, but survival and natural recruitment generally are low. Trout fisheries in Type 4 waters may have only seasonal runs of Great Lakes salmonids or be supported by stocking. For these reasons, fishing is permitted year-round, but harvest of Brown and Brook trouts can only occur from the last Saturday in April to September 30. The 10-inch MSL for Brown Trout is higher than for Type 1 streams, and helps to protect stocked fish prior to their outmigration to the Great Lakes. The 7-inch MSL applies to Brook Trout in Type 4 waters, since they are expected to occur rarely or not at all.

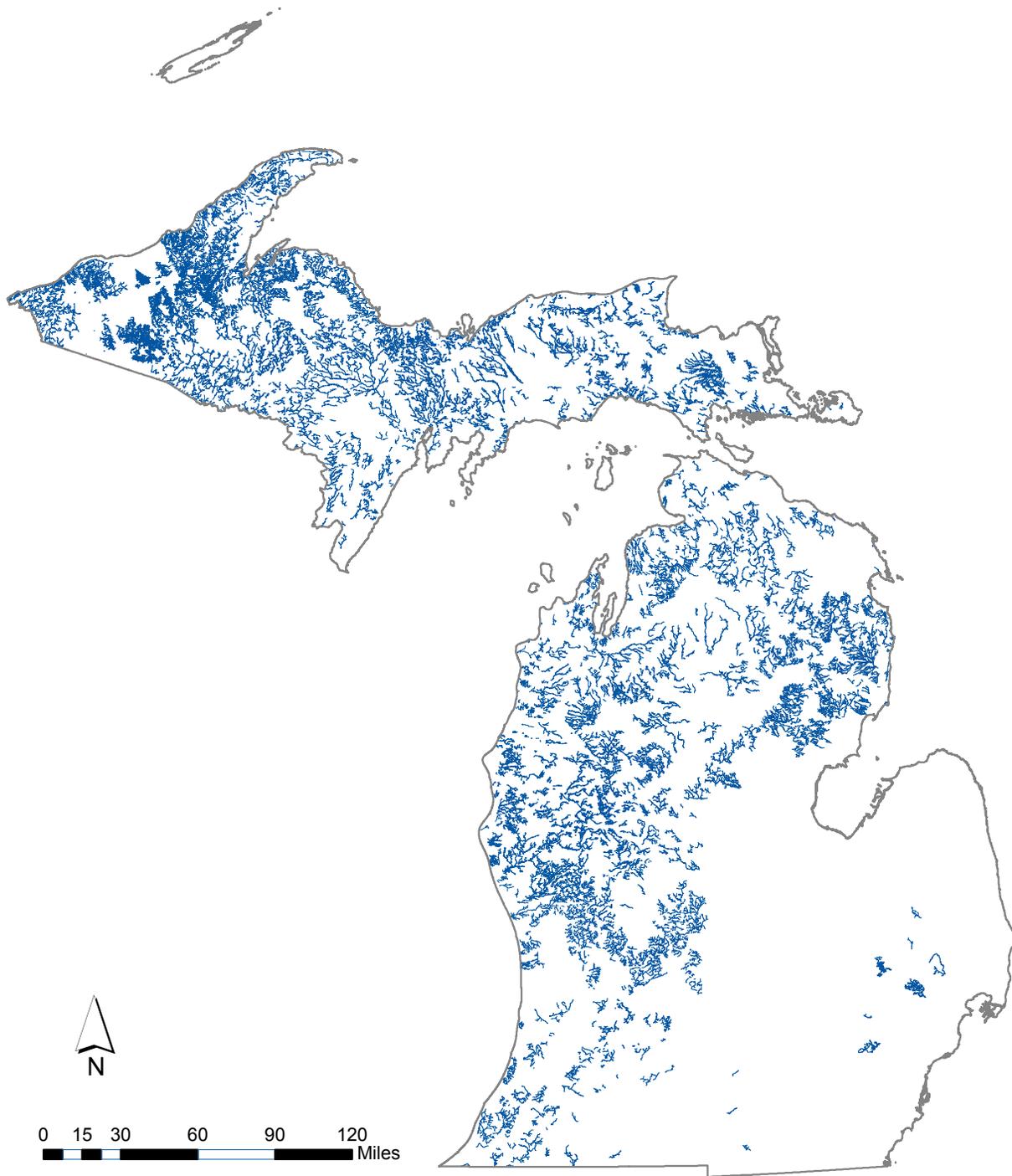


Figure 12.—Trout streams in Michigan with Type 1 fishing regulations.

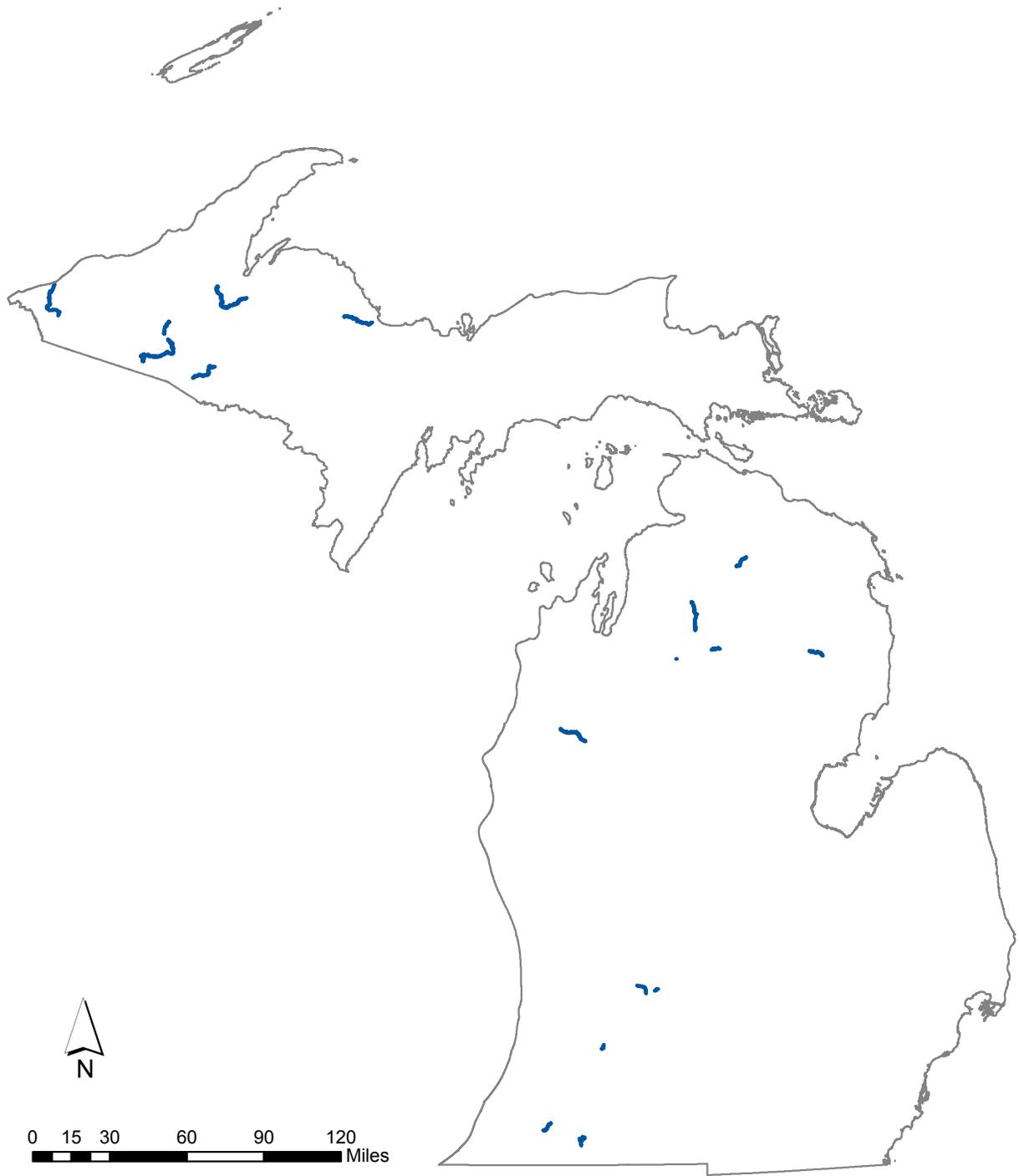


Figure 13.—Trout streams in Michigan with Type 2 fishing regulations.

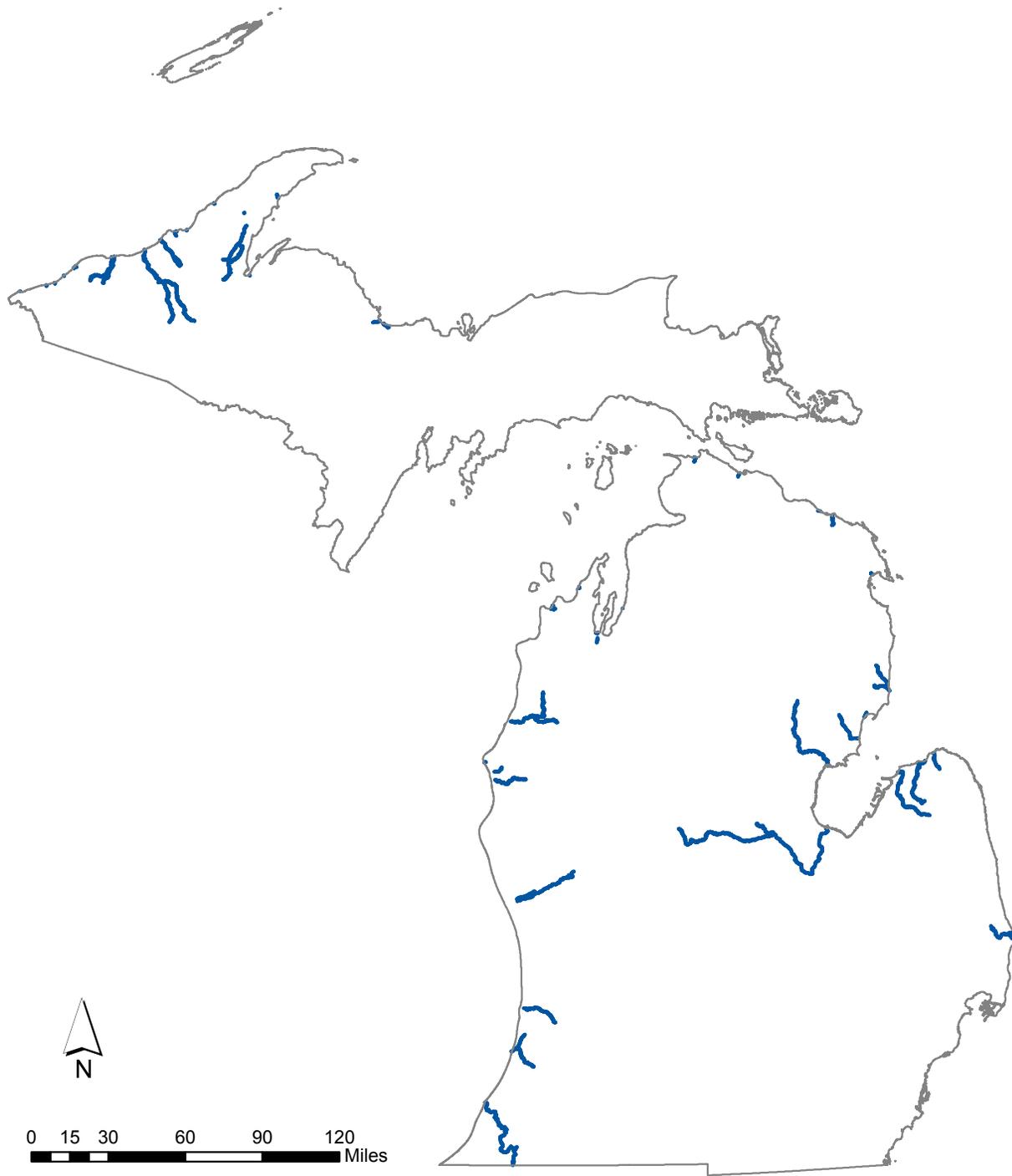


Figure 14.—Trout streams in Michigan with Type 3 fishing regulations.

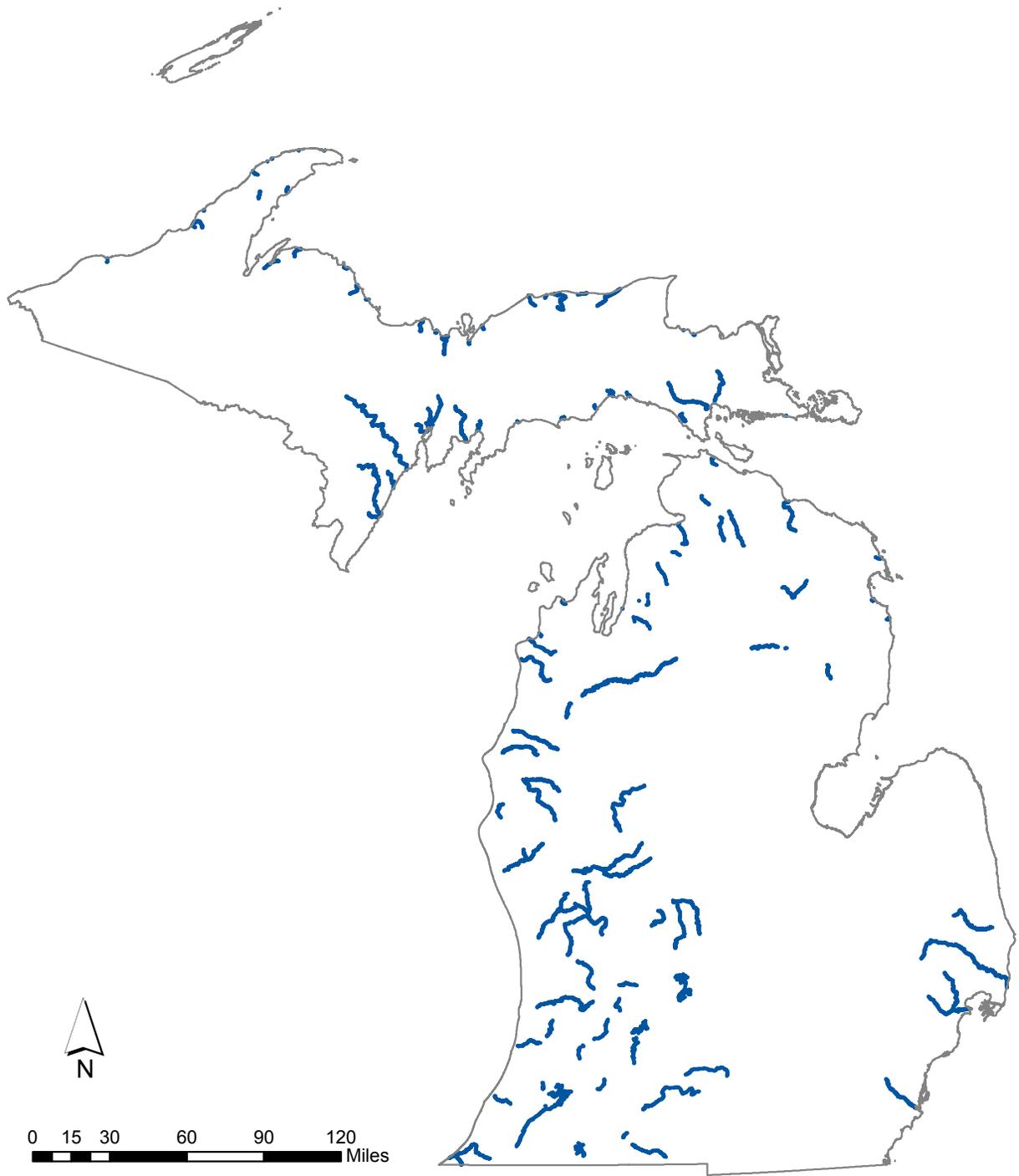


Figure 15.—Trout streams in Michigan with Type 4 fishing regulations.

Gear-restricted regulations occur on 20 stream reaches, and are employed for a variety of purposes (Figure 16). The Michigan Legislature has limited application of gear-restricted regulations to a maximum of 212 river miles, and 183 miles of streams currently have gear-restricted regulations. The last statewide review of gear-restricted stream reaches occurred during 2010–2011. As outlined in Fisheries Order 213.15 and consistent with scientific recommendations (e.g., Barnhart 1989), stream reaches assigned to this category should meet several criteria prior to receiving gear-restricted regulations:

1. The fishery is dominated by trout.
2. Growth of trout is average or above average.
3. The natural mortality rate is low.
4. The fishing mortality rate is high.
5. The stream reach is two miles or more in length.
6. Public access is assured.
7. The public is supportive of gear restrictions.

Most of these streams are fairly large, high-quality, stable-flow systems. On these reaches, Fisheries Division employs gear restrictions, flies-only or artificials [lures and flies] only, to limit mortality of hooked trout. These restrictions are coupled with high MSLs or no-kill regulations to maintain larger populations and higher catch rates of larger-sized trout. Barbless hook restrictions have not been applied to gear-restricted waters because they would further complicate fishing regulations, and studies indicated that use of barbless hooks resulted in minimal or no significant reduction in hooking mortality for fly or lure caught trout (Schill and Scarpella 1997; Arlinghaus et al. 2007). For gear-restricted waters, the slight biological benefit of a barbless hook regulation from the reduction in angler handling time during unhooking needs to be weighed against the tradeoff of further complicating regulations for law enforcement and anglers not using barbless hooks.

To encourage recruitment of new anglers, many gear-restricted waters allow year-round fishing and daily harvest of one 8- to 12-inch trout by children under 12. Two such waters, Paint Creek and Huron River, are located in the metropolitan Detroit area and have the potential for high angler use and recruitment of urban and suburban anglers to stream trout fishing. Therefore, these two streams also have gear, season, and trout-size restrictions that allow for high use, while maintaining relatively high catch rates and some harvest.

It is generally accepted that appropriate use of gear-restricted and catch-and-release regulations will contribute to higher catch rates of larger-sized trout in streams (Arlinghaus et al. 2007). Early evaluations of special regulations were pioneered on Michigan's Au Sable River (Shetter et al. 1954), and other Michigan evaluations followed (e.g., Shetter and Alexander 1962; 1966; Latta 1973). These short-term evaluations found a mix of fish population and fishery responses, depending on the stream, while noting reduced angler use of special regulations stretches. It is very difficult to demonstrate effects of regulations in short-term field studies due to the inherent variability of trout populations over such time scales (Wiley et al. 1997), and longer-term (decadal) changes in regional climate, water quality, and habitat quality in Michigan streams (Alexander et al. 1979; Zorn and Nuhfer 2007a; 2007b). A later and more rigorous evaluation of catch-and-release regulations in the South Branch Au Sable River by Clark and Alexander (1992) conclusively showed that flies-only, catch-and-release regulations produced a better population of larger Brown Trout than would have occurred with just flies-only regulations. There were no detectable effects on the Brook Trout population. They also noted an increasing trend in voluntary release of trout over time, with anglers in the mid-1970s releasing about 40% of trout caught, but 80-90% of fish by 1990. Like earlier studies, they noted a decrease in fishing pressure in the catch-and-release reach. Fishing pressure in gear-restricted reaches today may be different, as several reaches on the Au Sable, Manistee, and Pere Marquette rivers are thought to be quite heavily fished compared to nearby trout waters without such regulations.

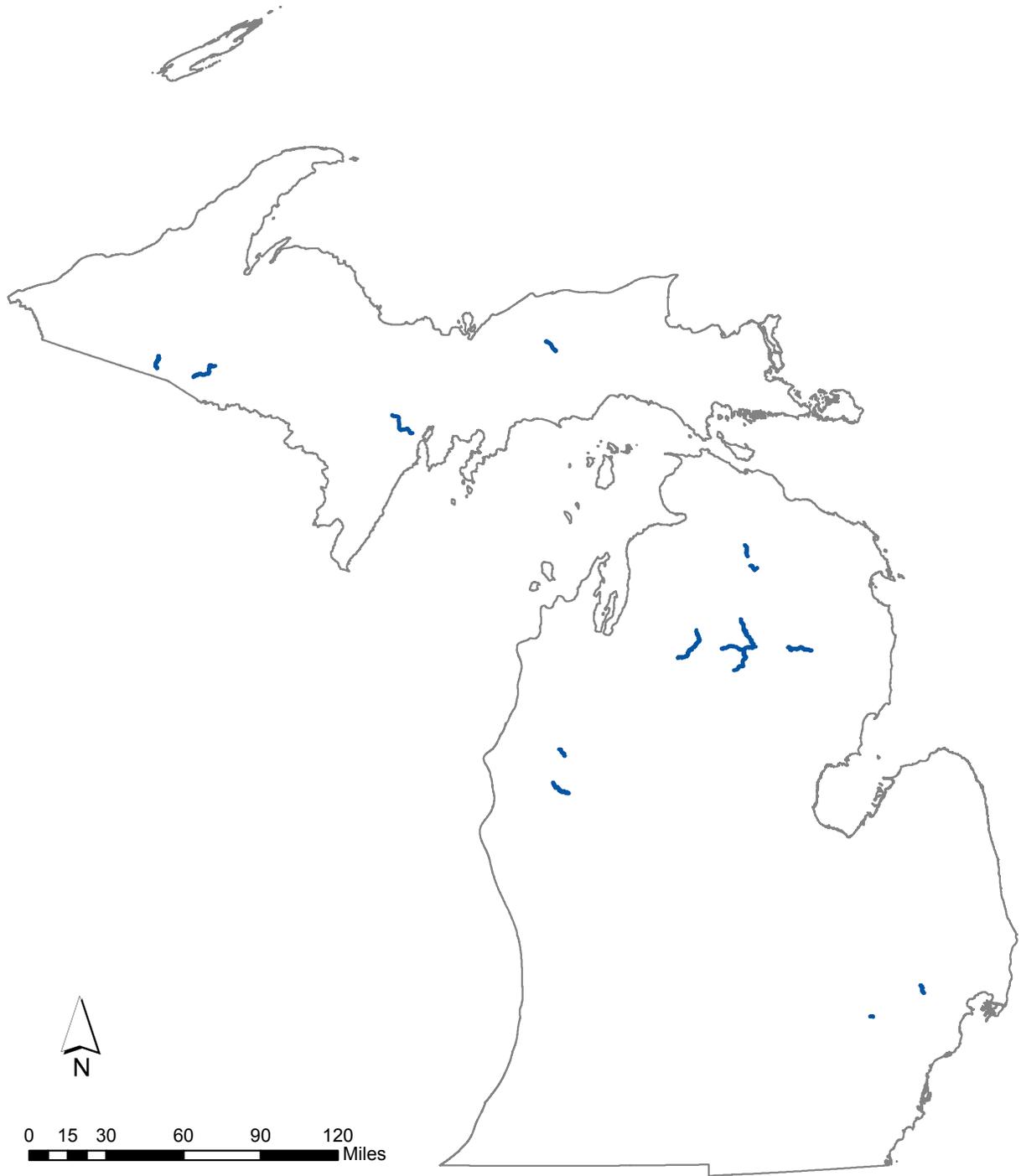


Figure 16.—Trout streams in Michigan with gear restricted fishing regulations.

There are distinct differences in values, behaviors, and preferences among trout anglers. For example, compared to bait anglers, fly anglers may focus more on the means by which a trout is caught, be less interested in taking fish home to eat, and desire more space in streams to accommodate fly-casting (Bachman 2001). Accompanying these differences, many fly anglers show a greater desire for management objectives that maximize catch rates and the numbers of fish in the stream, and often support regulations which minimize hooking mortality (e.g., bait restrictions), limit harvest (e.g., high MSLs or no-kill), and limit angling methods consistent with a desire for casting space (e.g., flies-only). These types of behaviors and preferences were apparent in recent Michigan surveys of trout anglers (e.g., Knoche and Lupi 2016; Carlson and Zorn 2018).

A recent study highlighted distinct differences between segments of Michigan trout anglers in regards to preferences for restrictive gear and trout harvest. Knoche's (2014) study of Michigan trout anglers indicated that "the average angler is substantially and negatively affected by the most highly restrictive regulations." He found that the average angler was willing to drive 130 miles to avoid mandatory catch-and-release regulations at trout fishing sites and 79 miles to avoid artificial flies-only fishing regulations. However, 26% of anglers preferred to fish on flies-only stream reaches, even if those regulations did not produce improvements to trout catch rates or the size structure of the trout population (Knoche and Lupi 2016). In acknowledgment of the sizeable percentage of trout anglers that prefer such regulations, providing an equitable distribution of gear-restricted waters in Michigan seems a worthwhile endeavor. A first step might involve determining the number of coldwater stream miles in Michigan that are suitable for fly-casting and the number that meet gear-restricted criteria, and comparing them with the mileage currently under gear-restricted regulations.

Michigan does and will continue to accommodate both ends of the trout-angling spectrum. The state has many miles of coldwater habitat, but a limited number are suitable for fly angling, and one may argue that some of the "best" fly-fishing reaches are already in gear-restricted regulations (e.g., parts of the Au Sable, Manistee, and Pere Marquette rivers). While bait anglers may not share all fly angler preferences, many would enjoy fishing these larger, more productive trout reaches, if they did not have to change gear. Conversely, fly anglers may see 1,000s of miles of headwater stream habitat as available to bait anglers, but not themselves because of their preferred fishing technique. As a result, MDNR fish biologists typically hear a portion of the angling population requesting more flies-only water in the state, while another segment wants less flies-only water. To ensure everyone is given full consideration, MDNR Fisheries Division uses thorough internal and public vetting processes for all regulation changes on trout streams.

In some situations, a compromise approach to gear restrictions may appeal to a broader array of anglers while still achieving objectives of high catch rates and increased density of larger trout. Average Michigan trout anglers were less averse to artificials-only regulations, which significantly reduce hooking mortality by excluding use of bait, than flies-only regulations according to Knoche and Lupi's (2016) study. Michigan Department of Natural Resources' recent trend towards increased use of artificials-only regulations for new gear-restricted stream reaches aligns with these observations and with studies showing fairly comparable levels of hooking mortality for trout caught using artificial lures or flies (Shetter and Allison 1955; 1958; Pavol and Klotz 1996).

Special regulations may be applied to certain stream reaches to facilitate specific fishery management goals, even though they may be speculative or not well-supported by scientific evidence. For example, the Brook Trout bag limit was raised from five to ten on a select number of UP streams with the intention of increasing angler use on these rivers. However, a recent Michigan study (Melstrom et al. 2015) suggested that anglers are more likely to fish waters where they think Brook Trout density is high. So, a higher bag limit may give the perception that Brook Trout in these waters have been more heavily exploited, making them less attractive to prospective anglers. Conversely, the regulation may give anglers the unintended impression that these rivers hold larger Brook Trout populations than other UP rivers and can safely withstand greater levels of harvest. Decision-support models with information

specific to UP streams on Brook Trout populations, angling pressure, and angler harvest practices (e.g., percentage of legal-sized fish released) are needed to better predict the effects of changing bag limits on fish populations and angler use or satisfaction.

Special regulations are also being used in an effort to rehabilitate populations of adfluvial (coaster) Brook Trout, whose life history involves increasing their body size by dwelling and foraging in Lake Superior and spawning in its tributaries. This project attempts to reduce fishing mortality on Brook Trout by placing a 20-inch MSL and a one-fish daily possession limit on the species in portions of eight Lake Superior tributaries (37 miles) for at least 10 years. A similar approach appears to be achieving some success in rehabilitating adfluvial Brook Trout in Minnesota and Ontario tributaries to Lake Superior. As rehabilitation of adfluvial Brook Trout is a long-standing goal of the public, tribal nations, and state and federal agencies in the Great Lakes (e.g., Newman et al. 2003), broader application of such a regulation should be considered if the experimental regulation is successful in rehabilitating adfluvial Brook Trout in this initial set of streams.

In the 1980s, certain streams were labeled as Blue Ribbon Trout Streams. To be designated as a Blue Ribbon Trout Stream, a stream had to meet the following criteria: (1) be one of Michigan's best trout streams, (2) support excellent stocks of wild, resident trout, (3) have the physical characteristics to permit fly casting but be shallow enough to wade, (4) produce diverse insect life and good fly hatches, (5) have earned a reputation for providing an excellent (quality) trout fishing experience, and (6) have excellent water quality. The blue ribbon designation had no bearing on a stream's fishing regulations or the quality or size structure of its trout population. Rather, it was a marketing tool that was developed to help anglers identify potential fishing locations that are relatively easy to fish, particularly by fly fishers. Today, MDNR Fisheries Division's web-based Trout Trails program serves this function.

Current Trout Lake Regulation Types

Michigan's trout lakes are divided into six types (Figure 17). A complete listing of trout lakes is detailed in MDNR's Michigan Fishing Guide (regulations booklet), and a recent count of lakes by type is as follows: Type A (78 lakes), Type B (76 lakes), Type C (31 lakes), Type D (25 lakes), Type E (14 lakes), and Type F (15 lakes). In some lakes, trout are the only game fish present. Other lakes provide fisheries for trout in addition to warmwater species such as Bluegill *Lepomis macrochirus* and Largemouth Bass *Micropterus salmoides*. Minimum size limits for trout generally are higher in lakes than in Type 1 streams due to the relatively rapid growth of trout in lakes and the greater potential for production of quality or trophy fish.

Type A lakes are small, cold lakes in the UP and the northern LP, and are frequently managed as trout-only systems. Other species are either naturally absent or removed by treatment with a piscicide. In most Type A lakes, trout are stocked annually to sustain the population. MDNR generally stocks these lakes at moderate rates to produce growth similar to that in Type 2 streams. Therefore, the MSLs of 10 inches for Brook Trout and 12 inches for Brown and Rainbow trouts are similar to Type 2 streams. These lakes are open to all types of bait use except minnows. The reason for this restriction is to prevent the introduction of undesirable fish species via minnow bucket releases, which could compete with or consume stocked trout. Because these lakes are small, seasonal closures from October 1 until the last Saturday in April occur due to concerns about potential overharvest during the ice-fishing season.

Type B lakes are often referred to as two-story systems. During the summer, the shallow waters (upper story) of these lakes are too warm for trout. However, trout can live in deeper waters (lower story), which remain cold throughout the summer, if these waters have sufficient oxygen. MDNR stocks trout in many of these lakes to provide fishing opportunities for trout in deeper water in addition to their fisheries for warmwater species in shallower water. Trout growth in these lakes is similar to that

in Type A lakes and MSLs are identical for both types. Restrictions on the use of bait would interfere with fishing for warmwater species, so all types of tackle are allowed on Type B lakes.

Lake Type	Fishing Season	Possession Season	Tackle	Daily Possession Limit	Brook Trout	Brown Trout, Rainbow Trout, & Splake	Lake Trout	Coho, Chinook, & Pink Salmon	Atlantic Salmon
					Minimum Size Limit (inches)				
A	Last Sat. in Apr. - Sep. 30	Last Sat. in Apr. - Sep. 30	All except minnows	5/3*	10"	12"	15"	10"	15"
B	Open All Year	Open All Year	All	5/3*	10"	12"	15"	10"	15"
C	Open All Year	Open All Year	All	5/3*	8"	8"	8"	10"	15"
D	Last Sat. in Apr. - Sep. 30	Last Sat. in Apr. - Sep. 30	Artificial lures only**	1	15"	15"	15"	10"	15"
E	Open All Year	Open All Year	All	3	15"	15"	15"	10"	15"
F	Open All Year	Lake Trout Jan. 1 - Oct. 31 Other Trout & Salmon open all year	All	5/3^	10"	10"	10"	10"	10"

Figure 17.—Overview table of sportfishing regulations for trout and salmon in Type A through Type F inland lakes from MDNR’s 2016-2017 Michigan Fishing Guide.

Most Type C lakes are located in the southern portion of the LP. Water temperatures and dissolved oxygen concentrations often are marginal for trout. Carryover of stocked fish to age 2 is limited in these systems and most trout are caught as yearlings. MSLs of 8 inches for Brook, Brown, Lake, and Rainbow trouts, along with splake are low in Type C lakes to facilitate harvest.

Type D lakes are managed to provide high catch rates and opportunities for capturing large fish. Trout are generally the only game fish in these lakes, and environmental conditions, including abundant well-oxygenated coldwater habitat in summer and few to no competing fish species, facilitate rapid growth and overwinter survival of stocked fish. Four mechanisms are used to reduce fishing mortality in Type D lakes: high MSLs, low daily possession limits, gear restrictions, and seasonal closures.

Certain large inland lakes are classified as Type E waters. In these lakes, trout growth is fast enough that higher MSLs are warranted. However, restrictions on seasons and gear are generally unnecessary because fishing rates are less intense than in smaller lakes, and there are usually several species other than trout available for anglers to pursue.

Type F waters are drowned river mouth lakes. The fish community composition in these systems changes seasonally with the migrations of species from the Great Lakes. These waters have seasonal closures to restrict harvest of Lake Trout, to protect Great Lakes populations of this species, whereas other trout species may be harvested throughout the year.

As with streams, inland trout lake regulations are intended to balance site-specific optimization with the objective of maintaining a suite of regulations that are readily understood by anglers. Recent input from MDNR biologists and anglers suggests that there are opportunities for simplifying inland trout lake regulations. For example, MDNR is considering the possibility of eliminating Type F lakes in 2018. Under this scenario, the existing Type F lakes could be moved into one of the other lake types or managed under the statewide regulations for lakes not classified by lake type. These unclassified waters are open all year, have a MSL of 8" for all trout species, and a daily possession limit of five fish with no more than three fish 15" or greater.

With costs for yearling trout often exceeding \$2.00 per fish, stocking inland lakes with trout is costly and the return on investment is not known at this time for most stocked lakes. Given this information gap, more creel census effort is needed to ensure an acceptable return on investment. Fishery managers work to ensure judicious use of hatchery fish. Some waters may be stocked at higher densities to overcome predation on stocked trout. Oftentimes, managers will discontinue stocking trout in lakes where returns of trout to anglers has declined substantially due to changes in lake habitat conditions, predation, or competition from other species within the lake.

Designated Trout Waters

Certain streams and lakes in Michigan are identified as designated trout waters based on the presence and abundance of trout, or the occurrence of self-sustaining populations. All Type 1, 2, and gear-restricted streams and all Type A and Type D lakes are designated trout waters. Some Type 3 and Type 4 streams and Type B lakes also are designated trout waters. Designated trout lakes are listed in Fisheries Order 200.15 and designated trout streams are listed in Fisheries Order 210.15. Unless otherwise specified, designated trout waters are closed to bow fishing and spearing. Exceptions to this rule are listed in Fisheries Order 219.13 and the Michigan Fishing Guide. Designated trout waters also have higher water quality standards to protect these species as specified in Article 2, Part 31 of Michigan Public Act 451 of 1994.

Recent Trends in Trout Fishing Regulations

Anglers are a key component in fishery management, and an understanding of angler behavior, preferences, and attitudes is needed in order for management to be effective. Although the basic tools available to regulate fisheries have not changed substantially since the late 1800s, the expectations of anglers have changed markedly in recent years. In the early days of fisheries management in Michigan, anglers primarily were interested in harvesting as many trout as possible. Thus, regulations were designed to maximize harvest while protecting trout populations from extinction (Clark et al. 1981). Today, some anglers are less concerned about harvesting fish and are more interested in catching large fish or catching and releasing large numbers of fish per outing, while other anglers continue to prioritize harvest of trout for table fare.

Several Michigan-based efforts have been undertaken or are ongoing to help MDNR better understand trout angler behavior and opinions. Knoche and Lupi (2016) used a choice experiment approach to examine the willingness of Michigan trout anglers to tradeoff increased driving distance to a fishing site for specific attributes of fishing at that site (e.g., trout species available, trout sizes, and catch rates of trout). They found that on average, trout anglers prefer higher catch rates, shorter travel distances to a fishing site, and are highly averse to restrictive fishing regulations such as catch-and-release and artificial flies only regulations. However, 18-26% of anglers showed a strong preference for restrictive regulations (Knoche and Lupi 2016). Melstrom et al. (2015) compared fish biomass

estimates with fishing trip information from a 2008-2010 survey of Michigan anglers, and found that Brook Trout abundance was an especially important determinant in fishing site selection.

In preparation for development of this plan, MDNR Fisheries Division collaborated with Michigan State University to conduct e-mail and on-line surveys of resident trout anglers (Carlson and Zorn 2018). Several findings from the survey merit mention in this document as they are directly related to regulations. When deciding where to fish for inland trout, aesthetic beauty was the most important attribute for stream anglers, and one of the most important attributes for lake anglers. The presence of quality trout was important, which in this summary includes the “important” and “very important” responses, to more than 75% of lake and stream anglers, whereas the presence of trophy trout was important to about half of the respondents. The majority of lake (73%) and stream (67%) anglers thought that regulations that allowed them to use their preferred fishing gear were important. Regulations that allowed harvest were important to 53% of stream anglers and 65% of lake anglers. For both lakes and streams, the potential to catch large numbers of trout was important to about half of the respondents, 55% for streams and 53% for lakes.

Anglers were generally satisfied with the existing numbers of Type 1, 2, 3, and 4 trout streams. The responses for gear-restricted streams showed a sharp divide between anglers that were members of organized trout fishing organizations, such as Trout Unlimited, and anglers who were not members of these organizations (Carlson and Zorn 2018). Organization members were more likely to support an increase in the number of gear-restricted stream reaches than a decrease in these waters. Conversely, nonorganization members were about twice as likely to support a decrease in the number of gear-restricted waters rather than an increase in these stream reaches. Controversy regarding gear restrictions is not unique to Michigan. Petchenik (2014) found that 34% of Wisconsin trout anglers supported artificials-only regulations, whereas 49% opposed such regulations. Forty-eight percent of Michigan trout survey respondents were very satisfied or satisfied with how streams were categorized for MSLs and bag limits, while 15% were dissatisfied or very dissatisfied. With respect to trout fishing seasons for streams, 64% of respondents were very satisfied or satisfied, while 9% were dissatisfied or very dissatisfied. Fifty-six percent of respondents were very satisfied or satisfied with trout-fishing regulations in general, while 16% were dissatisfied or very dissatisfied. Once again, Michigan results were similar to findings in Wisconsin, where 59% of anglers were very or fairly satisfied with fishing regulations on trout streams (Petchenik 2014).

Approximately 40% of the Michigan trout angler survey respondents fish for trout in inland lakes. Of those anglers who fish for trout in inland lakes, 49% were satisfied or very satisfied with fishing regulations for trout in lakes, and only 5% of survey respondents were very dissatisfied. Anglers most commonly indicated they were “satisfied with” how lakes were categorized for regulations, current trout seasons in inland lakes, the Michigan Fishing Guide, Michigan’s trout fishing regulations for inland lakes in general, and their personal fishing experiences for trout in inland lakes (Carlson and Zorn 2018). The majority of anglers (70-81%) thought that the number of lakes in each type should remain about the same. Few anglers indicated the number of lakes of a particular type should be much lower or much higher, with the exception of Type D. Ten percent of anglers thought the number of Type D lakes should be much lower, compared to only 2% that indicated the number of them should be much higher.

Fisheries Division also interacts with anglers through meetings of the Coldwater Resources Steering Committee (CRSC). This group includes representatives of several sportfishing organizations, as well as “anglers at large” that are not affiliated with any organization. The CRSC recently asked Fisheries Division to consider opening more waters to fishing during fall-early spring (i.e., the closed season on Type 1 and Type 2 streams). The Fisheries Division is open to this idea, provided that it can be accomplished without jeopardizing trout populations. Requests for discussion of suggestions such as this one are exactly why the Fisheries Division established this CRSC. Thorough vetting of ideas and management goals internally and with stakeholder representation provides the Fisheries Division the greatest opportunity for successful implementation of an idea with the greater public.

Status of Fisheries

Overview

Michigan is blessed with an abundance of coldwater streams, which host regionally or nationally renowned fisheries for Brook and Brown trouts. Some of the most notable fisheries occur within the Au Sable, Cheboygan, Boardman, Manistee, Pere Marquette, Muskegon, Menominee, Ontonagon, and Manistique watersheds. In addition, thriving, self-sustaining populations of inland trout abound in many other UP and LP streams. Brook Trout generally play a more prominent role in the UP, where they were originally native, while Brown Trout are the dominant inland trout species in LP waters that were historically the stronghold of the now-extirpated Arctic Grayling. Portions of the Manistee and Au Sable watersheds support self-sustaining populations of resident Rainbow Trout, and many rivers host migratory runs of steelhead (adfluvial Rainbow Trout). Populations of all three species are highly sought after by stream anglers.

Fisheries for inland trout historically and currently center around sportfishing, though Arctic Grayling were historically commercially exploited by hook and line anglers. Catches as high as 5,000 Arctic Grayling from a 5-mile section of the North Branch Au Sable River were reported by anglers who commercially fished there (Norris 1878). While the need for regulations to protect Michigan's stream trout from excessive angler harvest was identified early (Michigan Fish Commission 1873), there has never been a commercial fishery for Brown or Brook trout. However, there is a robust professional sportfishing guide industry in Michigan, which has existed since the mid-late 1800s when Arctic Grayling were the targeted species, later replaced by Brook and Brown trouts.

Approximately 380 individuals are currently permitted to guide on inland waters in Michigan. Of those, fewer than 15 were located in the UP. Many of the guides pursue salmon and steelhead in the spring and fall, although some guides fish year-round for inland trout. The exact number of guides targeting inland trout in various Michigan waters is unknown because there is presently no reporting system nor reporting requirement for inland trout guides. Those who guide on foot (i.e., wading, ice fishing, etc.) or who guide under a US Coast Guard Merchant Mariners license are not required to have an Inland Pilot license. Others guide illegally without a license. Most guides fish out of boats, such as drift boats or jon boats. Some of the most heavily guided waters include the Muskegon, Pere Marquette, Manistee (including the Upper Manistee), and the Au Sable rivers. The river guide industry is important to communities near some of the more heavily guided streams. On some of the more heavily guided rivers such as the Pere Marquette and Muskegon, there have been conflicts among anglers and guides over various issues. The Michigan legislature is currently considering legislation that would formalize the requirements for inland guiding, set penalties for violations by guides, and create a mandatory catch reporting system similar to existing requirements for Great Lakes charter boat operations.

Recreational Fishing Effort and Economic Value

Michigan's streams are a valuable, productive, and sustainable resource. For example, the 3,200 miles of Michigan's "top quality" coldwater streams alone, as defined in Anonymous (1967) as main-stem and feeder streams with good, self-sustaining populations of trout, were estimated to support wild populations of over 10.7 million Brook and Brown trouts (Gowing and Alexander 1980). The estimated 2.7 million naturally-reproduced age-1 Brook and Brown trouts in these streams is about 3.5 times greater than the number age-1 Brook and Brown trouts stocked into inland waters by MDNR Fisheries Division in 2016 (Wills et al. 2006). If we assume a rearing or direct replacement cost of \$2 per age-1 trout, these naturally-reproduced fish annually provide a \$5.6 million fish-production benefit to anglers, provided the rivers are properly cared for. Clearly, naturally-reproduced trout represent a major economic asset to Michigan. In addition, many of these streams serve as important spawning and rearing

grounds for other highly-prized adfluvial salmonids caught in the Great Lakes and tributary streams (e.g., steelhead [Rainbow Trout] and Chinook and Coho salmon). Abundant natural production of wild fishes also provides food for many species of wildlife (Alexander 1976) and humans. Most of the “top quality” coldwater streams in Michigan are located in the northern LP or the UP (Figure 2). Coldwater streams are rare in the southeastern LP, where old lakebeds with clay soils are the primary geological feature, but the southwestern LP does feature many small coldwater streams due to the occurrence of coarse-textured glacial deposits (Figure 1).

Recreational fishing is an important activity in Michigan, with the state ranking in the top four states in the United States in terms of total annual angler numbers (1.74 million), annual angling effort (over 28.2 million total fishing days), total annual angler expenditures (US\$2.46 billion in retail sales and \$4.2 billion overall effect), and angling-related jobs (37,989) (Southwick Associates 2012). In 2011, Michigan’s rivers and streams provided an estimated 8,159,000 days of angling for approximately 586,000 anglers, many of whom fished for trout and salmon (U.S. Fish and Wildlife Service 2013). Recreational fisheries are a critical economic engine for the state, and along with recreational boating, provide one of the largest and highest-value uses of Michigan’s aquatic resources.

Estimates of how much angling occurs for inland trout on streams and lakes is scattered, and few recent surveys exist. The following discussion highlights key points from the more complete surveys of angler use and provide benchmarks for future comparisons. Angling effort was monitored during 1951–1964 on three small trout streams associated with the Pigeon River Trout Research Station and Hunt Creek Trout Research Station (A. Nuhfer, MDNR Fisheries Division, unpublished summary of 21 Institute for Fisheries Research reports from 1957 to 1964). Average number of trips and angler hours per mile for this 14-year period were as follows: Pigeon River (300 trips per mile and 815 hours per mile); Hunt Creek (345 trips and 708 hours); and Fuller Creek, a small tributary to Hunt Creek, (76 trips and 158 hours). The data on angler recreation in these small trout streams clearly shows that small trout streams are very valuable resources. Tributaries that are too small for anglers to fish are also valuable because they produce trout that migrate to downstream areas. Average angler effort for three considerably larger branches of the Au Sable River are as follows: 1790 angler hours per mile during 1958-1990 for 13.5 miles of the North Branch Au Sable River, from Sheep Ranch to Kellogg’s Bridge; 3290 angler hours per mile during 1960-1983 for 14.3 miles of the Main stem Au Sable River from Grayling to Wakeley Bridge; and 2280 angler hours per mile during 1981-1990 for 9.4 miles of the South Branch Au Sable River from Chase Bridge to Smith Bridge (Zorn and Sendek 2001). No trend in effort over time was apparent at any of these sites. However, angling effort for inland trout on streams and inland lakes is generally thought to have declined during the last couple of decades as angling choices have increased, particularly with the changes in the Great Lakes and warmwater fisheries, but limited data are available to document this perceived change. Such a change would be consistent with declines in Michigan fishing licenses sold over the last two decades, and creel survey information from the Michigan waters of the Great Lakes which shows declining angler effort in most regions (MDNR Fisheries Division, unpublished data).

Small stream trout fishing in particular seems to have become somewhat of a lost art. The following is an excerpt from a 2014 report on Slagle Creek in Wexford County: “For example, MDNR file correspondence from 1951 indicates very heavy fishing pressure, despite the fact that the stream was only lightly stocked. The correspondence states that “38 cars were counted along the highway in the first mile west of the hatchery on opening day.” The report also states “While the opening day of trout season (the last Saturday in April) is still one of the busiest fishing days of the year, Slagle Creek currently does not see that level of pressure” (Tonello 2014). This level of fishing pressure may relate to stocking of legal-sized trout, which occurred during this period, and opening day frenzies of anglers on rivers with hatchery plants of legal-sized trout (Whelan 2004). Incidentally, opposition to MDNR’s put-and-take trout stocking policy during the 1950s to early 1960s was the impetus for formation of the coldwater conservation organization, Trout Unlimited, on the banks of the Au Sable River in 1959.

Within a few weeks after trout season opener (last Saturday in April), fishing pressure often declines notably on small inland trout streams. For example, in a season-long creel survey on Dowagiac Creek in southwest Michigan, 64% of angling effort occurred between the last Saturday in April and May 31, while the remaining 36% occurred during the rest of the season, between June 1 and September 30 (Smith 2006). On average, 44% of angler effort and 42% of angler catch for the fishing season occurred between the last Saturday in April and May 31 on four UP rivers during 1988-1992 (Wagner et al. 1994).

Data from creel surveys conducted on four UP streams during the 2013 and 2014 inland trout harvest seasons (April to September) show relatively low fishing pressure, despite the fact that some of them provide well-known Brook Trout fisheries. Average estimated angler trips and hours for the seasons and hours per mile on these streams were as follows: Bryan Creek (tributary to Escanaba River)—140 trips, 699 hours, 98 hours per mile; Two-Mile Creek (tributary to Ford River)—55 trips, 90 hours, 31 hours per mile; East Branch Tahquamenon River—92 trips, 250 hours, 24 hours per mile; and upper Tahquamenon River—305 trips, 827 hours, 118 hours per mile (T. Claramunt, MDNR Fisheries Division, unpublished data). In general, angling effort per mile in these reaches was several times lower than the Pigeon River and Hunt Creek surveys several decades ago, and ten or more times lower than more recent surveys in the Au Sable River system. Reasons for the seemingly low level of inland trout fishing in Michigan may be similar to a recent survey of lapsed anglers in Wisconsin (Petchenik 2012), where time constraints (e.g., work or household responsibilities) and other more enjoyable activities were the primary reasons former trout anglers cited for leaving the sport.

There are notable seasonal differences in angling pressure on streams that host adfluvial runs of Great Lakes salmon and steelhead. For example, in 2011 creel survey of 63.8 miles of the Pere Marquette River, of the 184,263 angler hours of effort (2,888 hours per mile) estimated for the period, 81% occurred in September (salmon anglers), 8% were spent in April (steelhead anglers), and the inland trout fishing months of May, June, July and August hosted the remaining 11% of angler effort (O'Neal and Kolb 2015). Angling effort was concentrated in the upper portion of the area surveyed, with 7,305 hours per mile occurring in the river between M37 and Gleason's Landing, 1,951 hours per mile between Gleason's Landing and Rainbow Rapids, and 3,694 hours per mile between Rainbow Rapids and Reek Road. Similarly, in an earlier creel survey on the Pere Marquette River, Kruger (1985) found that anglers typically pursued salmon or steelhead, with Brown Trout being sought by only 3.6% of the anglers interviewed. In 2010, a 47.4 mile-long Great Lakes accessible reach of the Betsie River, 1,521 angler hours per mile and 435 hours per mile were spent in September and October, while only 13 hours per mile occurred in May, the first full month after the inland trout opener (Tonello et al. 2017). A 22.3 mile-long reach of the Au Sable River between Mio Dam and Alcona Pond, which is inaccessible to Great Lakes fish, hosted an average of 1,372 hours of angling effort per mile in 1999 and 1,558 hours per mile in 2000 (Sendek and Nuhfer 2007). The lower 46.4 miles of the Boardman River, which is mostly an inland trout fishery but includes a 1.6 mile reach accessible to salmon and steelhead, hosted 507 angler hours per mile in 2015 (MDNR Fisheries Division, unpublished data). Such information further supports the notion that river reaches without migratory runs of Great Lakes salmonids receive less fishing pressure than those with such runs. O'Neal and Kolb (2015) provide additional summaries of angler effort on Great Lakes accessible and inaccessible reaches of coldwater streams in Michigan.

Nevertheless, stream trout fishing is still an important activity on many Michigan rivers. For example, 34% of campers in a 2011 survey at five state forest campgrounds on the upper Manistee River and Pigeon River (Cheboygan County) were trout anglers (Thomas and Burroughs 2012). While there may not be as many inland trout angling participants as in past years, many who fish for inland trout remain ardent and organized. Groups such as Trout Unlimited, the International Federation of Fly Fishers, and Anglers of the Au Sable staunchly support coldwater fishery management and conservation, often supporting more restrictive regulations on gear and harvest.

Data documenting angling effort for trout in Michigan's inland lakes are limited, though creel surveys have been conducted on several inland lakes stocked with trout over the last 15 years. A June 1 to August 31, 2007 creel census was conducted on Shavehead and Birch lakes, two Cass county lakes stocked with Rainbow Trout. In both lakes, anglers appeared to primarily target panfish, with 24 Rainbow Trout being harvested in Birch Lake (0.005 fish harvested per hour) and no Rainbow Trout caught in Shavehead Lake. Trout stocking was discontinued in Shavehead Lake after this survey. Boat anglers fishing Gull Lake, a large Kalamazoo and Barry county lake stocked with trout, were surveyed from April 27 to August 31 2002. Anglers spent an estimated 22,359 hours fishing the lake, but no trout or salmon were reported as harvested or released. A creel survey done on four water bodies in the lower Grand River watershed (Crockery Creek and Half-Moon, Lime, and Clear lakes) during May 1 to August 31, 2003 found that 322 Rainbow Trout and 19 Brown Trout were harvested, and 290 Rainbow Trout and 19 Brown Trout were released from an effort of 17,031 angler hours (Su et al. 2007). An April 28 to September 30, 2007 creel survey on Thumb Lake (Charlevoix County) estimated a harvest of 127 splake (0.010 fish harvested per hour), following Bluegill and Smallmouth Bass *Micropterus dolomieu* as the third most harvested "species". It is likely that much of the angling effort in each of these surveys was not directed towards stocked trout, since in each case other lake fishes were more frequently harvested than trout.

The MDNR Fisheries Division has been experimenting with using trail cameras as a low-cost approach to documenting angler use, and potentially trout harvest, for small trout lakes. Four surveys have been conducted during the late-April to September 30 trout harvest season on remote trout lakes in the eastern UP. A 2014 trail camera survey of Brockies Pond documented use by 46 anglers, a total of 21.8 angler hours of fishing, with no fish being observed on camera. A 2014 trail camera survey of Spring Creek Pond showed use by 34 anglers, a total of 26.6 angler hours of fishing, with no fish being observed on camera. Trail-cam surveys also occurred at King's and Millecoquin ponds in 2015, but data records were incomplete at these locations due to vandalism and other factors (C. Kovacs, MDNR Fisheries Division, personal communication).

Tribal Fishing

In addition to state-licensed recreational anglers, Michigan trout lakes and streams are open to fishing by several Native American tribes. Several treaties, which in total cover the entire state, exist between the United States government and tribes residing in Michigan (Figure 18) and are described by Smith et al. (2016). "Tribal governments' signatory to the treaties of 1836 and 1842 retained fishing rights for Tribal members, and the Tribes may view management of trout differently than the state. Tribal governments are sovereign nations and operate their fisheries pursuant to their own regulatory and management systems. As per the 2007 Inland Consent Decree (United States v. Michigan 2007), each tribe sets its own fishing regulations, and they are generally more liberal than those for sport anglers licensed through MDNR Fisheries Division."

The Treaty of Washington, signed in 1836, covers the eastern UP and the northern LP of Michigan. In 2007, the State of Michigan, the Little River Band of Ottawa Indians, the Grand Traverse Band of Ottawa and Chippewa Indians, the Little Traverse Bay Bands of Odawa Indians, the Sault Tribe of Chippewa Indians, the Bay Mills Indian Community and the United States government signed a Consent Decree, which defines the extent of the Tribes' inland treaty rights that include tribal trout fishing and harvest in the 1836 ceded territory. This agreement requires tribal reporting of effort and harvest in ceded territories. Thus far, tribal effort and harvest of trout in the 1836 Treaty-ceded territory has been low (Patrick Hanchin, MDNR Fisheries Division, personal communication).

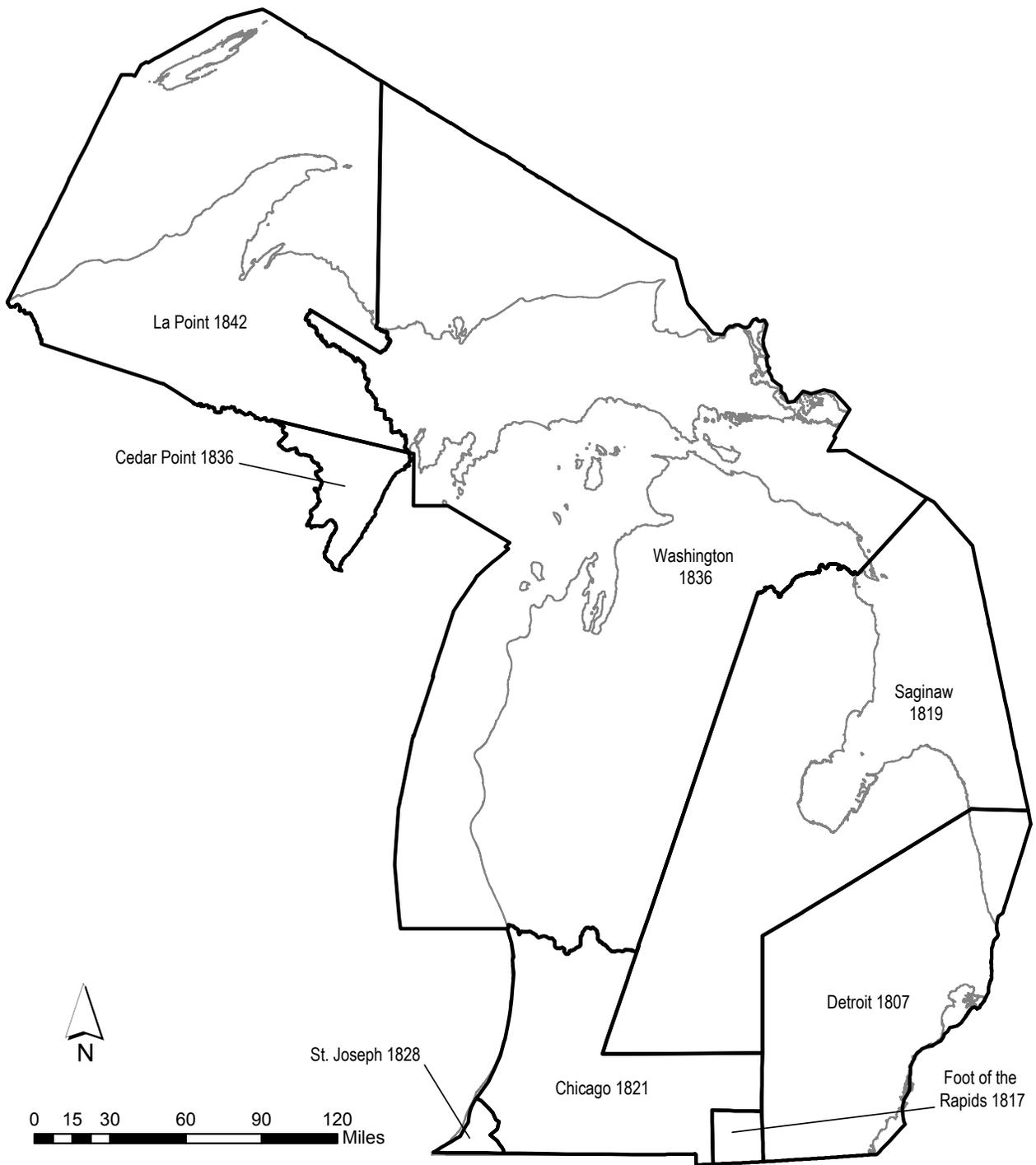


Figure 18.—Tribal treaty areas for Michigan.

The Treaty of La Pointe, signed in 1842, covers the western UP and a portion of northern Wisconsin. Currently there is no formal agreement in place between the Tribes and the State of Michigan to define the extent of the Tribes' reserved fishing rights there. However, the 1842 Treaty rights have been adjudicated in Wisconsin. The Tribes of the Voigt Intertribal Task Force conduct intertribal coordination and manage the Tribal fisheries within the portion of the 1842 ceded territory located within the State of Michigan pursuant to their own regulatory and management systems. It is believed that tribal effort and harvest of trout in the 1842 Treaty-ceded territory has also been low, but fish harvest information on trout has not been provided to MDNR.

The 1836 treaty tribes provide reports of harvested inland fish to MDNR Fisheries Division as per terms of the 2007 Inland Consent Decree (*United States v. Michigan* 2007). These reports include fish harvested via spearing, bow fishing, impoundment netting, seining, trotline fishing, dip netting, or fishing with hands. During 2008-2014, reports provided by the signatory tribes indicated that only one Brown Trout and no Brook Trout, Lake Trout, or splake were harvested via these methods. Reported annual Rainbow Trout harvests (which consist primarily of steelhead) varied from 9 fish to 85 fish. These reports do not include fish harvested via hook and line or fish harvested by 1842 treaty tribal fishers in the western UP. In general, the daily possession limits for tribal fishers are higher than for state-licensed recreational anglers.

Hatcheries and Stocking

The vast majority of Michigan trout streams have the temperatures and habitat necessary to support naturally-reproducing trout populations. Of more than 1,600 trout streams in Michigan, only 19 streams were stocked with Brook Trout in 2014, while just 78 were stocked with Brown Trout. On the other hand, most of Michigan's nearly 250 inland lake fisheries for trout are supported by stocked fish, though some lakes do support naturally-reproducing populations of Lake Trout (Table 1). These waters range from small Brook Trout ponds to very large water bodies like Higgins and Torch lakes.

Since the late 1800s, state fish hatcheries have stocked trout in many lakes and streams all over Michigan. For much of that time, the biological parameters and capabilities of the receiving waters were not even considered. The move towards self-sustaining populations is a significant shift in management philosophy from the 1950–1964 period, when legal-sized trout were stocked into streams during the weeks surrounding the opening day of trout harvest season to maximize the proportion of stocked fish creel by anglers (Westers and Stauffer 1974; Whelan 2004). In 1964, the Michigan Department of Conservation, the precursor to today's MDNR, initiated a stocking strategy shift in which "put and take" fisheries were greatly reduced in favor of stocking sub-legal trout into waters where the natural productivity of the lakes and streams would be used for growing trout (Michigan Department of Conservation 1964). This marked the first time that the biological potential of streams was taken into consideration when determining stocking regimes. At that time, hatchery space was also needed for rearing Pacific salmon for stocking in the Great Lakes (H. Tanner, personal communication). One important recommendation of the 1964 report was that streams capable of supporting an acceptable sport fishery through natural reproduction should no longer be stocked.

Today, trout are still stocked throughout Michigan, though the practice is not as widespread as it once was and is more strategic. The current MDNR Fisheries Division fish stocking guidelines (Dexter and O'Neal 2004) call for trout to be stocked into streams that provide trout a reasonable chance of surviving and growing to a larger size. Streams with robust natural reproduction are typically not stocked, while some water bodies with low levels of natural reproduction may be supplemented with stocked trout.

The number of inland waters stocked with trout has generally declined over time. Stockings of individual streams are discontinued when surveys identify a self-sustaining trout population at the site,

when fisheries data indicate survival of stocked trout is poor, or when habitat data suggest the stream is thermally unsuitable (Figure 19; Table 4). Declines in the numbers of lakes stocked with Brook or Rainbow trout are also apparent for the last couple decades (Figure 20; Table 5). Stocking is often discontinued in lakes for various reasons, all of which limit survival of trout. These include thermal conditions becoming unsuitable over time, long-term declines in dissolved oxygen concentrations in colder (deeper) habitats where trout would reside during warm weather, and increased occurrence or abundance of predator or competitor fishes (e.g., Northern Pike *Esox lucius*, Smallmouth Bass, or Yellow Perch).

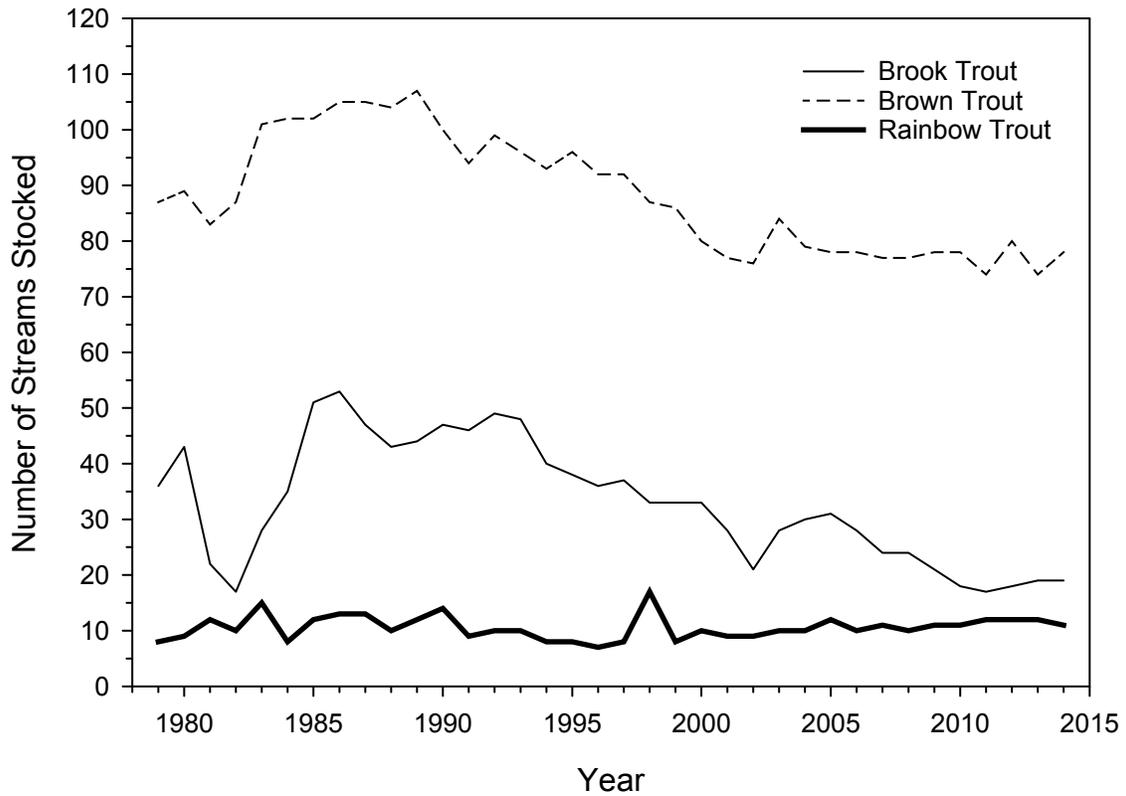


Figure 19.—Numbers of streams stocked with Brook, Brown, and Rainbow trouts for inland fisheries management purposes during 1979–2014. Data from MDNR Fisheries Division’s, Fish Stocking Information System.

Table 4.—Number of streams stocked, number of fish stocked in streams, and average length of fish stocked for Brook Trout (BKT), Brown Trout (BNT), and Rainbow Trout (RBT) for inland trout management from 1979 to 2014. Data from MDNR Fisheries Division’s Fish Stocking Information System.

Year	Number of streams stocked			Number of fish stocked			Average length of fish (cm)		
	BKT	BNT	RBT	BKT	BNT	RBT	BKT	BNT	RBT
1979	36	87	8	123,127	457,393	167,521	12.4	15.7	14.3
1980	43	89	9	120,333	489,781	141,051	8.9	14.0	18.0
1981	22	83	12	58,994	398,099	124,191	8.8	12.6	15.7
1982	17	87	10	82,762	421,825	80,492	9.9	13.7	16.7
1983	28	101	15	98,626	868,481	142,082	9.5	15.0	16.4
1984	35	102	8	109,491	784,082	76,707	11.9	14.7	11.9
1985	51	102	12	132,935	505,526	195,875	13.4	16.8	13.3
1986	53	105	13	144,073	679,256	140,147	14.5	15.9	17.8
1987	47	105	13	215,804	658,830	129,504	12.6	14.7	15.8
1988	43	104	10	152,980	910,607	162,481	15.6	13.8	15.0
1989	44	107	12	171,144	945,769	171,119	13.1	14.9	14.0
1990	47	100	14	186,600	781,870	228,116	16.2	14.3	16.5
1991	46	94	9	174,210	753,496	108,987	14.2	15.2	18.4
1992	49	99	10	210,804	817,061	206,011	14.3	14.7	12.4
1993	48	96	10	242,335	770,017	204,483	17.3	17.3	17.1
1994	40	93	8	174,605	744,606	167,041	17.8	17.3	16.6
1995	38	96	8	142,376	694,371	159,853	19.1	16.4	16.4
1996	36	92	7	128,126	684,111	133,741	16.6	16.4	16.8
1997	37	92	8	100,725	744,955	227,788	17.1	15.8	14.5
1998	33	87	17	124,720	781,656	562,404	11.5	15.2	15.3
1999	33	86	8	137,101	765,976	229,449	14.1	15.1	17.4
2000	33	80	10	164,074	813,195	490,796	13.0	14.1	12.0
2001	28	77	9	130,488	865,539	287,741	12.5	14.0	15.6
2002	21	76	9	69,895	745,409	276,180	12.9	14.9	16.3
2003	28	84	10	96,020	795,232	253,118	14.0	16.1	16.2
2004	30	79	10	144,975	691,502	273,376	10.6	15.5	16.9
2005	31	78	12	121,866	750,567	299,126	13.3	16.5	16.9
2006	28	78	10	91,451	748,296	269,619	12.6	16.5	16.2
2007	24	77	11	88,032	558,273	269,292	14.9	16.6	15.7
2008	24	77	10	104,904	675,002	244,983	12.3	15.6	17.8
2009	21	78	11	90,901	818,727	336,530	14.6	15.1	15.0
2010	18	78	11	58,580	723,139	238,570	16.3	15.6	16.9
2011	17	74	12	61,272	805,938	313,258	17.6	14.3	14.9
2012	18	80	12	48,766	1,152,699	284,178	18.7	13.2	17.3
2013	19	74	12	62,780	663,641	273,287	18.6	15.5	16.6
2014	19	78	11	42,130	681,851	331,607	21.6	16.4	

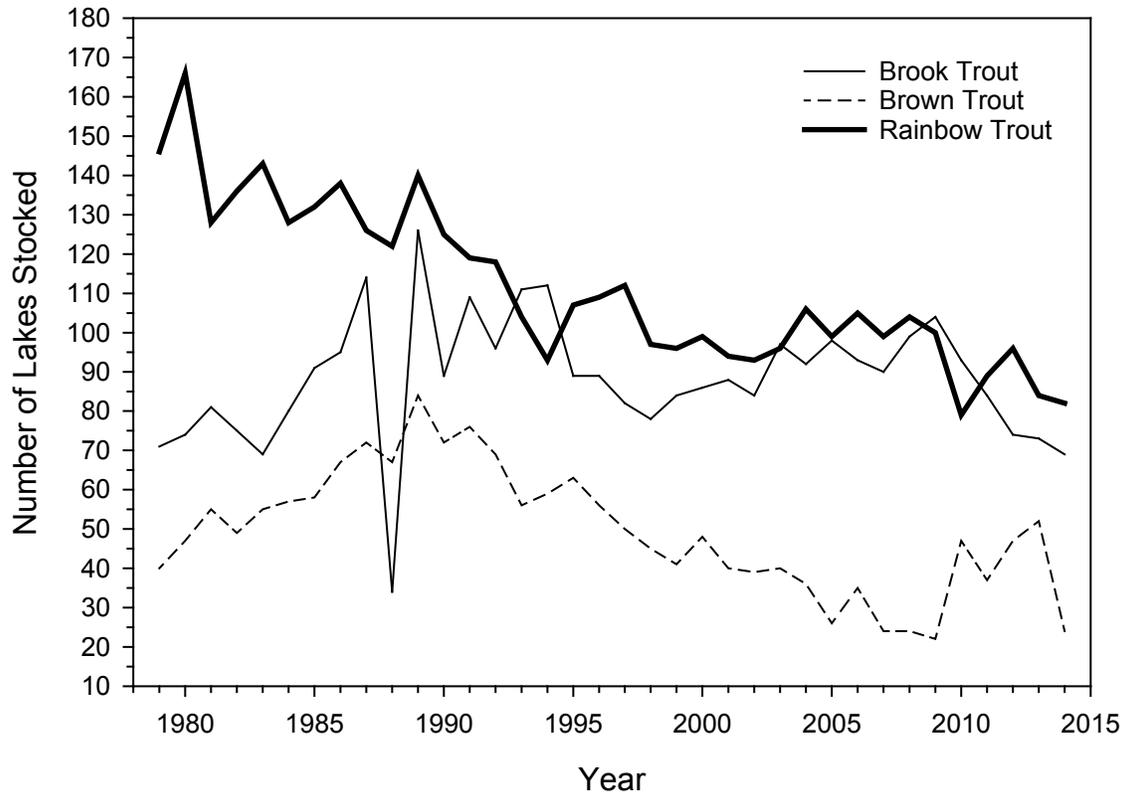


Figure 20.—Numbers of inland lakes stocked with Brook, Brown, and Rainbow trouts during 1979–2014. Data from MDNR Fisheries Division’s, Fish Stocking Information System.

Table 5.—Number of inland lakes stocked and number of fish stocked in inland lakes for Brook Trout (BKT), Brown Trout (BNT), Lake Trout (LKT), Rainbow Trout (RBT), and splake (SPL) for inland trout management from 1979 to 2014. Data from MDNR's Fish Stocking Information System.

Year	Number of lakes stocked					Number of fish stocked				
	BKT	BNT	LKT	RBT	SPL	BKT	BNT	LKT	RBT	SPL
1979	71	40	25	146		96,388	160,079	460,365	585,653	
1980	74	47	19	166		84,271	163,710	460,325	641,881	
1981	81	55	25	128	36	146,786	171,464	399,490	547,120	197,965
1982	75	49	24	136	37	96,997	170,715	461,929	505,874	226,004
1983	69	55	26	143	27	84,400	358,355	485,595	731,835	128,846
1984	80	57	10	128	29	145,498	329,774	229,013	534,005	210,620
1985	91	58	30	132	56	134,441	286,049	154,446	665,464	484,185
1986	95	67	14	138	46	147,520	381,111	271,703	636,740	288,785
1987	114	72	37	126	48	193,202	464,801	642,215	837,119	458,026
1988	34	67	11	122	46	60,097	638,613	431,368	634,436	367,951
1989	126	84	17	140	2	174,658	614,067	684,782	798,563	12,000
1990	89	72	13	125	43	96,430	514,863	320,352	596,456	376,095
1991	109	76	13	119	35	111,287	603,015	180,864	501,198	229,020
1992	96	69	12	118	41	102,064	374,657	324,830	829,081	276,339
1993	111	56	24	104	43	116,843	316,410	346,200	473,252	248,572
1994	112	59	22	93	38	93,563	323,456	274,768	510,090	302,152
1995	89	63	4	107	34	86,497	393,074	79,890	526,433	262,645
1996	89	56	43	109	34	86,852	407,506	364,212	545,394	177,020
1997	82	50	35	112	34	64,375	316,159	312,270	617,332	162,900
1998	78	45	23	97	31	74,815	242,336	303,228	388,749	157,155
1999	84	41	28	96	37	68,984	199,837	375,830	403,835	190,825
2000	86	48	21	99	34	123,011	287,844	348,893	420,471	164,880
2001	88	40	19	94	30	80,660	179,935	395,480	397,876	156,290
2002	84	39	19	93	27	88,630	167,368	338,216	503,186	187,031
2003	97	40	21	96	35	107,722	146,665	378,073	449,123	157,097
2004	92	36	29	106	36	127,330	149,564	556,906	447,664	147,777
2005	98	26	26	99	31	106,164	96,971	355,344	472,824	200,910
2006	93	35	35	105	26	94,073	129,475	277,479	400,018	124,610
2007	90	24	16	99	23	75,618	77,152	242,553	454,719	99,494
2008	99	24	29	104	20	127,931	82,545	257,921	411,483	123,150
2009	104	22	18	100	17	92,645	98,219	201,620	529,007	107,603
2010	93	47	12	79	18	74,938	110,029	164,992	313,001	99,650
2011	84	37	17	89	18	68,946	96,470	213,493	406,589	96,697
2012	74	47	16	96	18	50,463	71,091	173,958	532,325	94,838
2013	73	52	18	84	19	53,134	65,609	215,066	490,828	91,669
2014	69	24	13	82	18	55,869	64,468	140,914	416,259	86,478

MDNR hatchery operations

Today's MDNR fish production system consists of six state fish hatcheries: Wolf Lake (near Kalamazoo), Harrietta (near Cadillac), Platte River, Oden (near Petoskey), Thompson (near Manistique in the UP), and Marquette state fish hatcheries. Brown Trout are reared at Harrietta and Oden state fish hatcheries, while Rainbow Trout are reared at Harrietta and Oden state fish hatcheries. Brook Trout, Lake Trout, and splake are only reared at Marquette State Fish Hatchery. Wolf Lake and Platte River state fish hatcheries raise primarily Pacific salmon, steelhead, and Atlantic Salmon, as well as some coolwater species. Lake Trout are stocked into Great Lakes waters by the three U.S. Fish and Wildlife Service (USFWS) hatcheries in Michigan along with another USFWS hatchery in Wisconsin. A few surplus broodstock Lake Trout are stocked in selected Michigan inland lakes by the USFWS hatcheries.

The MDNR Fisheries Division hatchery program uses state-of-the art technology to efficiently produce high-quality, relatively disease-free trout with high genetic integrity. Protected water supplies along with rigorous biosecurity and disinfection procedures at hatcheries minimize the incidence and spread of disease. For example, whirling disease plagues the western United States but Michigan sees little expression of it as a result of (1) good hatchery practices; (2) the high resistance of Brown Trout to infection by *Myxobolus cerebralis* (the parasite causing whirling disease), likely a result of them co-evolving with the disease; and (3) a lack of the least resistant clade/lineage of *Tubifex tubifex*, the intermediate hosts for this pathogen, in our waters (G. Whelan, MDNR Fisheries Division, personal communication). MDNR hatcheries also employ wastewater treatment prior to discharge. For example, through use cutting-edge wastewater treatment technologies, Platte River State Fish Hatchery releases some of the lowest discharges of phosphorus in the world for a facility of its size and type.

Many different genetic strains of Brown, Rainbow, and Brook trouts have been stocked into Michigan waters over the last 100+ years. Most were domesticated strains that performed well by showing good growth and survival in a hatchery environment, with less consideration given to performance after stocking. Some domesticated strains still remain in Michigan's hatchery system, but today, performance of hatchery trout after stocking is more closely scrutinized and given more consideration (e.g., Wagner et al. 1994; Nuhfer 1996; Wills 2005). This has resulted in replacement of domestic strains with strains sourced from wild trout populations in Michigan waters. While domestic strains still tend to perform well in the hatchery environment (and in lake environments), wild trout strains appear to be more wary and likely to survive after stocking, particularly in rivers and streams.

Brown Trout are currently reared at two state fish hatcheries (Oden and Harrietta), though some Brown Trout were raised at Thompson State Fish Hatchery up until 2015. Three strains of Brown Trout are currently raised: (1) Gilchrist Creek strain fish are from captive-reared brood stock originally obtained in the 1990s from a wild, stream-resident population of Brown Trout in Gilchrist Creek, in the northern LP; (2) Sturgeon River strain Brown Trout are also from captive brood stock originally sourced in 2007 from the Sturgeon River, which has a mix of wild, stream-resident fish and adfluvial Brown Trout that migrate from Burt and/or Mullet lakes in the northern LP; and (3) Wild Rose strain Brown Trout are a long-domesticated strain originally obtained from the Wild Rose State Fish Hatchery in Wisconsin.

From experience and strain evaluation studies (e.g., Nuhfer 1996; Wills 2005), MDNR fisheries managers have identified commonly-occurring situations in Michigan where each strain generally performs best. Sturgeon River strain Brown Trout are stocked at locations where there is potential for a lake or stream fishery, and adfluvial spawning runs. The Gilchrist Creek strain is primarily used to provide river-resident Brown Trout fisheries in streams where water quality is good for multi-year survival of stocked fish, but natural reproduction is lacking (most often due to lack of spawning habitat). Wild Rose strain fish are preferred in situations where survival beyond one summer is questionable and a put-grow-and-take fishery is desired. Wild Rose browns also seem to be a good fit for stocking in lakes where piscivorous fish are present, because their larger size at stocking enhances post-stocking survival.

There are currently two strains of Rainbow Trout in Michigan's hatchery system, Eagle Lake and Little Manistee. The Eagle Lake strain was originally developed from northeastern California. Michigan Department of Natural Resources fish originated from USFWS broodstock system and is a domesticated strain with the MDNR broodstock being held at Oden State Fish Hatchery. The Little Manistee strain (also known as the Michigan or Michigan Winter-Run strain) fish are reared from eggs collected from wild Lake Michigan "steelhead" that annually migrate into Michigan's Little Manistee River to spawn. This strain was brought into Michigan in the late-1870s from the McCloud River, a tributary to the Sacramento River in California (Westerman 1974). The Little Manistee strain is primarily stocked into Great Lakes tributaries throughout Michigan (and several other states) to create migratory steelhead runs. The Eagle Lake strain is typically stocked into inland lakes and selected rivers to create a fishery for resident Rainbow Trout. The Eagle Lake strain has been particularly effective in creating fisheries in tailwater reaches of the Manistee and Muskegon rivers.

Both Little Manistee and Eagle Lake strain Rainbow Trout were stocked into inland lakes between 2004 and 2008 to compare post-stocking performance of the strains (Caroffino and Nuhfer 2014). In most instances, the Little Manistee strain outperformed the Eagle Lake strain, though each performed well enough to create popular fisheries in a number of inland lakes. At this time, Michigan's hatchery system is not capable of producing enough yearling Little Manistee-strain Rainbow Trout to meet demands for river stocking requests and inland lake requests resulting in many inland lakes being stocked with the available Eagle Lake strain Rainbow Trout.

The only strain of Brook Trout currently reared at Marquette State Fish Hatchery is the Assinica strain, a domesticated strain that originated from lake systems in Quebec. Three other strains (Temiscamie, Iron River, and Nipigon strains) were also raised at Marquette State Fish Hatchery during the last 20 years, but all were discontinued for various reasons including poor performance in the field (Nuhfer and Wills 2012), hatchery fish health and genetic concerns, and unsuitable characteristics of receiving waters.

Two Lake Trout strains are reared at the Marquette State Fish Hatchery, the Lake Superior Inshore Lean and the Seneca Lake strains. The Seneca Lake strain are reared from USFWS eggs and originated from wild broodstock from Seneca Lake in the Finger Lakes region of New York. Their behavior (e.g., temperature or depth preference) seems to make them less vulnerable to Sea Lamprey *Petromyzon marinus* predation in Great Lakes waters. The Lake Superior Inshore Lean strain broodstock was created from wild Lake Trout captured in Lake Superior waters near Marquette, Michigan and Ashland, Wisconsin during 2001-2004. Seneca Lake strain Lake Trout are typically stocked into Great Lakes waters, while the Lake Superior strain is stocked into inland waters. All splake are created in the hatchery by crossing age-3 male Assinica strain Brook Trout with age-7 female Lake Superior strain Lake Trout and are stocked in selected Great Lakes and inland lakes.

Fish and Habitat Assessments

When Michigan's Discretionary Powers Act was amended in 1945, the Conservation Commission received authority to designate experimental fishing regulations on up to 10 streams. This led to a number of studies on several LP rivers to evaluate the effects of various fishing methods, MSLs, and daily harvest limit restrictions (Shetter and Alexander 1966; Clark et al. 1981). Establishment of long-term trout population monitoring reaches (index stations), collection of angler harvest data, development of stream electrofishing gear for sampling, and standardization of field sampling and fish aging protocols for these studies were essential for developing an empirical understanding of trout population attributes and dynamics over these longer time periods (McFadden et al. 1967; Gowing and Alexander 1980; Clark et al. 1980; Clark 1981). This led to development of long-term trout population data sets on several rivers including the Pere Marquette, Pigeon, and Rifle rivers, the North, South,

and Main branches of the Au Sable River, and Hunt and Gamble creeks. Some of these study reaches continue to be sampled today, and represent some of the longest trout population data sets in the world.

During this time, trout populations were being sampled with electrofishing gear in other Michigan streams by local fisheries managers. However, no state- or region-wide plan existed for this sampling, and streams were typically selected for surveys by individual management units without coordination among units. Gear and survey methods often varied among management units and survey locations. In addition, habitat evaluation data were rarely collected. The contrast between the insights gained from the index stations and the uncoordinated approach used elsewhere made it apparent that a statewide, coordinated sampling scheme was needed to answer local-, regional-, and statewide-scale questions about Michigan trout and streams.

In 2002, MDNR Fisheries Division initiated the Stream Status and Trends Program (SSTP). This statewide program has several features that make it a significant advance over MDNR's previous stream survey efforts (Wills et al. 2006). It employed a two-pronged approach to sampling. First, a network of fixed sites (population index stations) was established throughout the state as a high-resolution system for describing temporal trends in important coldwater resources (trout populations and habitats), and for testing hypotheses related to changes in populations. Many current fixed sites are actually old "index stations", which allow for historical comparisons as well. Second, a stratified random sampling design is used for conducting an inventory of all streams in Michigan and providing information for quantitatively describing and comparing different types of systems. Michigan's statewide river valley segment classification (Seelbach et al. 1997) provided the strata for SSTP sample-site selection and data summarization. These data allow fishery managers to describe typical fish community and habitat conditions for each type of stream in Michigan, as defined by valley segment attributes such as river size, summer water temperature, channel gradient, and other key habitat features.

All SSTP surveys incorporate the following important features: (1) a state-level (centralized) approach to sample-site selection, (2) standardized and detailed field sampling protocols and forms for fish and habitat data collection, (3) specification of data to collect on fishes and habitat at each survey, (4) detailed written instructions for data entry, (5) a centralized database for data entry and summarization, (6) standardized data summaries and analyses for evaluating stream reaches, and (7) biologists charged with statewide oversight of this program. Fish population trend data from fixed sites are freely available online at MDNR's Stream Fish Population Trend Viewer website (<http://www.mcgi.state.mi.us/fishpop/>; MDNR 2015; Zorn et al. 2017). Written summaries from the random sampling component of the SSTP are also available (Wills et al. 2015), and efforts are underway to develop an online decision-support tool using these data. Data for both online tools will be refreshed annually, so biologists and the public continuously have the latest and best data available for understanding and managing Michigan streams and trout populations. The SSTP is scheduled to use 40% of each management unit's stream surveying effort, with the remaining 60% available for addressing other issues at each unit's discretion.

Management units also conduct discretionary surveys in trout streams, meaning that each survey's purpose, location, and field methods are chosen by the local biologist. Still, managers often follow SSTP protocols so their data are comparable with standardized SSTP data collected elsewhere. The purposes of discretionary surveys are varied and include assessment of: game fish abundance and growth; survival of stocked fish; potential of waters for trout stocking; effects of habitat improvement efforts; previously unsampled locations; and the effects of development projects or land use changes on fish populations. Overall, fewer trout stream surveys are conducted today than in past decades, primarily due to the fact that the MDNR Fisheries Division workforce is much smaller than in the past. Also, a typical survey today is more time consuming than in the past because more information is now collected on habitat and nongame species.

Sampling of inland lakes for trout is not as standardized as it is for streams, possibly due to the relative rarity of trout lakes in Michigan. Inland trout lakes are surveyed using different methods, including netting, electrofishing, hook and line, and creel surveys. These surveys are typically conducted

at the discretion of individual management units. While a status and trends sampling program does exist for inland lakes (Wehrly et al., in press), its field methods do not specifically target trout populations.

Creel surveys are also important tools for assessing inland trout fisheries. Typically, the primary emphasis for creel surveys is the collection of catch data, biological data from the fish caught, and angler effort. Creel surveys can also provide important data on angler preferences, behavior, and demographics for a particular fishery.

Habitat Concerns, Restoration, and Partnerships

Habitat Concerns

World class trout fishing opportunities occur in Michigan's many coldwater streams and lakes. There are, however, a number of threats that have the potential to negatively affect the quality of those fisheries. Threats include dams, poor road crossings, water withdrawals, water quality degradation, physical habitat degradation, and a range of effects from a changing climate. Each of these threats is discussed below, followed by a discussion of the processes and procedures that are in place to protect the resource from those threats.

Water withdrawals

A stream's hydrology, the amount and pattern of streamflow, is one of the key habitat-forming processes in our watersheds. Michigan's wealth of trout streams and coldwater lakes is due to the state's glacial geology and abundant groundwater resources associated with it. Groundwater is critical to the health of trout streams, as it provides cold, clean water to the stream and suitable water temperatures for trout. Furthermore, large amounts of groundwater provide stable flows, minimizing the fluctuations in streamflow associated with storm events in more "flashy" systems. Michigan is home to a broad range of stream types, including everything from warm, flashy, run-off driven streams to cold, stable, groundwater-fed streams (Zorn et al. 2002). As previously noted, coldwater temperatures and stable flows combine to make a stream more suitable for trout populations.

While Michigan's groundwater resources are abundant, they are not limitless (Zorn et al. 2008; Nuhfer et al. 2015). Michigan has enacted a law, Part 327 of the Natural Resources and Environmental Protection Act (NREPA, Michigan Public Act 451 of 1994) to protect water-dependent natural resources from future large-quantity withdrawals. Part 327 is tied to the Great Lakes Compact, and implements that agreement for Michigan. Under this act, the MDEQ is responsible for the following actions: registering large-quantity withdrawals, collecting annual water use data, evaluating the potential effects of proposed withdrawals, and issuing water withdrawal permits. Their Water Withdrawal Assessment Tool (WWAT) is available for users (and regulators) to evaluate the potential effects of a large-quantity withdrawal on a stream and its fish community (Hamilton and Seelbach 2011).

Some water withdrawals also take place from surface water. Similar to groundwater, new or increased large-quantity withdrawals from an inland lake or stream require a permit. Large-quantity surface water withdrawals are subject to permitting, regulation, and oversight by MDEQ under NREPA Part 327 as well.

Hydraulic fracturing, or "fracking", has recently gained more attention in Michigan as a potential threat to water quality and quantity. Fracking refers to the injection of water, sand, and a chemical mixture into a subsurface formation, under pressure, to fracture the rock and allow hydrocarbon resources to be removed. While fracking has long been used in the northern LP of Michigan for resource extraction from the Antrim formations, there has been recent interest in extractions from the deeper Utica-Collingwood and other shale formations. Since these wells require large quantity water withdrawals (20 million

gallons or more per horizontal well), they are screened using Michigan's WWAT, and are subject to permitting, regulation, and oversight by MDEQ. A better understanding is needed of the effects of short-term, high-volume water withdrawals on coldwater stream ecosystems. Also needed is an understanding of the effects of large quantity water withdrawals that take place outside of summer months.

State-owned and private mineral rights are leased to companies for oil and gas exploration and extraction. When state owned parcels are nominated by companies for potential leasing, they are reviewed for lease classification by all of the resource divisions of the MDNR. From a MDNR Fisheries Division perspective, they are reviewed based on their proximity to water and the potential for surface development to affect aquatic resources. Lease classification generally determines the amount of surface development allowed on a parcel. A classification of "nondevelopment" for instance would allow for resource extraction but would not allow for any surface development, such as roads and well pads, on the surface. A general provision of leases is that there can be no surface development within 1,320 ft (one-quarter mile) of a water body without a specific exemption.

Dams

Dams alter a river's hydrological, geomorphic (channel shaping), and biological characteristics. Dams alter hydraulic characteristics such as width, depth, and velocity; affect temperature and dissolved oxygen; alter sediment and nutrient transport dynamics; and result in habitat alteration and fragmentation (Cushman 1985, Lessard and Hayes 2003; Burroughs 2007).

Some dams have a major influence on water temperatures. The downstream effect can be either warming or cooling, and depends on several factors including the impoundment's storage volume and turnover ratio of inflow to storage, the degree of stratification in the impoundment, and the location of the outflow mechanism. If the reservoir is deep enough, it will stratify like a natural lake, resulting in a warmer epilimnion (top layer) and a colder hypolimnion (bottom layer). Top-draw dams will generally result in warmer downstream water temperatures during summer months, while bottom-draw dams will generally result in cooler downstream water temperatures during summer months if the impoundment stratifies (Petts 1984; Cushman 1985; Woldt 1998). Lessard and Hayes (2003) report that even small top-draw dams can increase downstream temperatures significantly at some locations. In addition, these elevated temperatures show little variation over the course of a 24-hour day, because the larger volume of impounded water gains and loses heat more slowly than a free-flowing stream would. In free-flowing rivers, water temperatures typically fall at night as the ambient temperature decreases. Below top-draw impoundments, however, there is little cooling at night, so no thermal relief is provided to downstream biota (Woldt 1998), which physiologically stresses trout. Consistent, suitably coldwater temperatures with a normal daily temperature fluctuation are critical for trout and trout streams.

Aquatic biological communities are affected by dams in a variety of ways. Because community composition is primarily dependent upon water temperature, dams that alter thermal regimes change riverine communities. Warmer temperatures below dams/impoundments often result in fewer trout and a shift in the macroinvertebrate community composition (Lessard and Hayes 2003).

Rivers can shape landscapes through erosion, transport, and deposition of sediment (Cushman 1985). Water depth, current velocity, and substrate are important components of physical habitat that influence fish and invertebrate species distributions and abundance within streams, and all are parameters that can be altered by dams (Cushman 1985; Bain et al. 1988). Dams are usually placed in high-gradient areas to capture the potential energy of the elevation change. These high-gradient reaches are often rare in Michigan's relatively flat landscape. Upstream of the dam, the water is obviously slowed and turns a previously lotic, or flowing, system into a lentic, or standing, water system. When water velocity is slowed by a dam, the river loses its energy to transport sediment and drops all or most of it in the upstream impoundment. In this manner, the impoundment acts like a giant sediment trap, capturing the silts and sands that are deposited. Downstream of the dam, the changes to substrate can

vary (depending upon the flow regime), as the river's velocity and ability to transport sediment return with distance downstream of the dam. By trapping sediments in the impoundments, dams often move sediment transport processes away from normal, equilibrium conditions and cause rivers to increase erosion rates, becoming sediment "hungry" rivers. The artificial fluctuation of flows by dam operators creates highly unstable habitat (Bain et al. 1988).

Dams that operate in a peaking mode are typically hydropower dams, and operate by holding water back (ponding) when energy demand is lower, and discharging high volumes of water (peaking) when energy demand is higher. Changes to water depth and velocity, associated with flow alterations, change the overall aquatic habitat available to fish (Bain et al. 1988). Increased flows can flush finer substrate along with incubating fish eggs and fry downstream, while flow reductions can dewater (dry up) productive riffle areas within a stream. Typically, river reaches downstream of peaking dams (i.e., tailwaters) have aquatic insect communities that show few large individuals and are dominated by small midges and "multivoltine" species which cycle through two or more generations per year (G. Whelan, MDNR Fisheries Division, personal communication).

Dams affect the flow of nutrients downstream, since they impound not just water, but hold back woody debris and other organic matter as well. Many stream ecosystems are dependent upon leaves and other coarse particulate matter for the base of the food chain. Dams may prevent downstream transport of debris, resulting in food web changes. Nutrient availability generally decreases downstream of an impoundment because production within the impoundment uses available nitrogen and phosphorous (Petts 1984). Dams also block upstream movement of nutrients that occur via migrations of fish for spawning (Childress et al. 2014).

Impoundments created by many dams in Michigan cannot provide productive fisheries like natural lakes because of high flushing rates of water through the impoundment. As a result, their ponds provide an environment somewhere between lotic and lentic. For example, Mio, Alcona, Loud, and Five Channels impoundments on the lower main stem of Au Sable River all have flushing times less than seven days and function more like rivers than lakes in regard to nutrient, plankton, and productivity cycles, in addition to thermally degrading the river for coldwater species (Zorn and Sendek 2001).

Dams present a barrier to fish movement and fragment available habitat. When barriers are present, resident stream fish may not have access to important seasonal habitats such as overwinter refugia. Dams and other barriers can also block access to habitats important for various life stages, such as spawning and nursery habitats. Additionally, dams block upstream transport of energy and nutrients from fish migrating from large downstream systems into less productive upstream reaches. This makes upstream reaches just exporters of energy and nutrients, with no chance of recharge from larger systems. By blocking access to key spawning, growth, or refuge habitats needed throughout a fish's life cycle, dams limit the river's overall ability to support abundant populations of stream fishes.

Most human-made dams are regulated at either the state or federal level. State regulation is administered by MDEQ under NREPA Part 315 (Dam Safety) if the dam is over 6 feet in height and impounds over 5 acres of water. Part 307 (Inland Lake Levels) of NREPA is part of dam regulation, but administration is designated by the circuit courts when levels are set. NREPA Part 483 pertains to fish passage at dams. MDEQ also administers sections 401 (water quality under NREPA Part 31) and 404 (wetlands) of the federal Clean Water Act. MDNR Fisheries Division staff review proposed dam construction or removal activities with consideration to operation, water temperature, flow regimes, size, fish migration, habitat, and other resource values using relevant statutes (e.g., NREPA Part 301, Part 483, etc.).

Federal regulation of hydropower dams is administered by the Federal Energy Regulatory Commission (FERC) under the Federal Power Act. In Michigan, FERC licenses generally require run-of-river (ROR) flow regimes, which provide more stable flows downstream. A FERC license is required if the project (1) is located on a navigable water of the United States; (2) occupies lands of the United States; (3) uses surplus water or waterpower from a government dam; or (4) is located on a body

of water over which Congress has Commerce Clause jurisdiction, project construction has occurred on or after August 26, 1935, and the project affects the interests of interstate or foreign commerce. Michigan Department of Natural Resources Fisheries Division, Habitat Management Unit is heavily involved in the relicensing of FERC projects, the oversight of environmental damage settlements, and the monitoring of license requirements. These responsibilities include the administration of a number of settlement agreements that have resulted in mitigation packages, such as the one with Consumers Energy that resulted in the Habitat Improvement Account (HIA), which was established to mitigate resource effects from hydropower dam operations on the Au Sable, Manistee, and Muskegon rivers.

Not all dams are human-made; waterfalls, beaver dams, and some logjams can also function as dams, preventing fish passage and material movement through the system. Poorly designed road-stream crossings, including “perched” or elevated culverts (where there is an artificial waterfall at the outlet), also function similar to dams. MDNR recognizes that beaver populations and excessive beaver damming, which can raise downstream temperatures beyond the tolerance limits of trout, may not be compatible with trout management, particularly in low gradient river reaches. Beaver dams interrupt the natural sediment transport function of rivers, which can also degrade trout habitat. MDNR has a beaver management policy, which directs MDNR Fisheries Division to maintain a list of high priority trout streams where aggressive beaver control should occur if necessary.

As mentioned above, dams function as barriers to aquatic organism passage. While barriers prevent the upstream movement of species like trout, they also prevent the spread of unwanted aquatic invasive species like Sea Lamprey. Following removal of the lowermost dam on a Great Lakes tributary, lampricides are used to prevent undesired production of Sea Lampreys in streams where production is detected. Lampricide treatments can have negative effects on aquatic macroinvertebrates and some fish species/life stages, but such effects are typically minor in comparison to the many benefits of dam removal. If established treatment protocols are followed, Sea Lamprey control generally has little effect on inland trout stream management. Additionally, Sea Lamprey are a Great Lakes issue as life stages of Sea Lampreys in streams do not parasitize stream fish.

Water quality degradation

Water quality can be affected by point- and non-point-source inflows and atmospheric deposition. Point-source pollutants from sources such as factories and wastewater treatment plants reach water bodies at designated outfalls or discharge points. Point-source discharges in Michigan are regulated by National Pollution Discharge Elimination System (NPDES) permits by MDEQ under NREPA Part 31.

Non-point-source pollutants – including nutrients, sediments, and pesticides -- reach water bodies through erosion and runoff. Poorly designed road-stream crossings and eroding stream banks can be primary inputs of these pollutants to Michigan streams. Excessive sediment, particularly sand, can cover productive substrates like gravel and decrease available spawning and nursery habitat for Michigan trout (Alexander and Hansen 1988). This is of particular concern, since gravel areas are relatively rare in Michigan’s predominately sand-bed streams. Runoff from agricultural fields is a major problem in southern Michigan. Non-point-source pollution from storm-water discharges and construction activities are regulated by NPDES permits and administered by the MDEQ. State laws governing non-point-source pollution include NREPA Part 91 (Soil Erosion and Sedimentation Control) and Part 31 (Water Resources Protection), administered by MDEQ.

Land-use and development

Land use and development also have the potential to influence inland trout habitat in either a positive or a negative way. MDNR fisheries biologists work with staff from other MDNR divisions and

from MDEQ to review various proposals and permits to ensure that the state's aquatic resources are protected.

Specific state forest parcels are inventoried and management actions are developed by MDNR's Forest Resources Division (FRD) on a 10-year rotational basis during forest compartment reviews. MDNR Fisheries Division reviews the proposed management actions for their potential to affect aquatic resources and provides recommendations to protect and maintain riparian habitat, basing recommendations on best management practices (BMPs; MDNR and MDEQ 2009), and Fisheries Division Policy and Procedure 02.02.011 on riparian vegetation protection. Recommendations may include things like different sized buffer strips along streams depending on the size and type of stream. We may also request that land management be done that discourages beaver populations if beaver dams are an issue in the watershed, such as managing away from soft wood trees. If forest management is occurring near a water body where access is currently limited, we may request that a landing and logging road be left to allow for parking and a carry-in access to the water body. Michigan Department of Natural Resources fisheries biologists also review forest treatment proposals, or actions like cutting or planting that take place outside of the MDNR FRD compartment review cycle.

Certain public uses of state land, such as large-group camping, equestrian, or motorcycle events, require use permits from MDNR FRD. Michigan Department of Natural Resources fisheries biologists review such proposals and comment on the potential effects on aquatic resources. This process provides a level of ongoing oversight at the state and local level.

MDEQ requires a permit when construction occurs at the land/water interface, pursuant to NREPA Part 301 (Inland Lakes and Streams). Examples of Part 301 permit applications include dredging, docks, seawalls, and instream structures. MDEQ is the permitting authority for this program, and MDNR Fisheries Division reviews these permit applications and provides comments and recommendations for protecting fish populations.

Some of Michigan's premier trout streams are also designated as state Natural Rivers, including the Au Sable, Upper Manistee, Jordan, and Pigeon rivers. State Natural Rivers designation includes zoning restrictions allowing riparian property owners the right for reasonable development while still protecting critical riparian zones along with other important values and uses such as fish, wildlife, boating, and aesthetic. Almost 2,100 miles of rivers and streams are designated as state Natural Rivers. MDNR Fisheries Division and local governments (townships) have regulatory authority for Natural Rivers, under NREPA Part 305 (Natural Rivers). Recent angler surveys (Carlson and Zorn 2018) indicate that the natural beauty and aesthetics of a fishing location are a priority. This makes the Natural Rivers program an important tool for not only protecting streams, but also ensuring angler satisfaction. Over 650 miles of rivers in Michigan are federally designated as Wild and Scenic rivers, which provide additional protection for these systems and their associated riparian zones.

Trees in and along streams are a natural part of the river landscape, and provide valuable instream fisheries habitat. On smaller- and medium-sized rivers, kayakers and canoeists should expect to have to deal with trees in the river and choose the appropriate watercraft for those conditions rather than modifying the river to accommodate a certain type of watercraft. Portaging around objects or hazards may be necessary. It is generally held that in navigable waters, an individual can remove a portion of a fallen tree if it is blocking navigation downstream. The "portion" removed should be minimized to just allow for navigation of watercraft that are appropriate and common for that stream and no more, with the maximum opening not exceeding 8 feet. This same standard applies to any wood that is not attached to any particular property.

Drains

In Michigan, designated drains are regulated by county drain commissioners under the authority of the Michigan Drain Code (Act 40 of the Public Acts of 1956, as amended). Some drains are also

designated trout streams, particularly in the southern LP. Michigan county drain commissioners have the authority to designate, extend, and maintain all designated drains. Activities for drain maintenance include straightening, widening, dredging/deepening, tiling, and relocating, and do not require MDEQ approval on drains designated before 1972 (Michigan Drain Code; Wesley and Duffy 1999).

Most drain maintenance activities increase sedimentation and nutrient loading to rivers and contribute to wetland degradation or loss. “Cleaning” of designated drains often includes removal of instream logs/large woody material, as well as the removal of riparian vegetation, and the channelizing or straightening streams. These activities negatively affect fish populations, as instream habitat and riparian vegetation play important roles in trout population dynamics. An example of this habitat destruction is what happened on the Coldwater River in Southwest Michigan in 2014-2015. Approximately 12 miles of this stream were “maintained” under a contract by the drain commissioner, and involved removing riparian trees and the removal of large wood debris jams (Burroughs 2015).

Efforts are underway to promote the use of alternative drainage techniques that are effective yet still maintain the function and benefits of naturally occurring streams and rivers. A group called the Drain and Water Resources Workgroup (DWRW) is working on these issues, and includes representatives from MDEQ, MDNR, USFWS, along with drain and water resources commissioners. The goal of this workgroup is to develop ways to maintain drainage per legal requirements, while at the same time maintaining functioning aquatic ecosystems. MDNR Fisheries Division is participating in the DWRW (P. Ertel, MDNR Fisheries Division, personal communication).

Toxins/contamination

Some species and sizes of fish may be unsafe to eat because of chemicals in their flesh, which they accumulated from their environment. Species like Common Carp *Cyprinus carpio*, Largemouth Bass, and Northern Pike may have higher levels of contaminants because of their size, age, and diet. The Michigan Department of Community Health (MDCH) provides fish consumption guidelines in their Eat Safe Fish publications. Although some species of trout have fish consumption advisories, they typically only apply to Great Lakes fish or to specific reaches of a few streams. Consumption advisories generally do not occur for inland trout species due to their fairly short life cycles and the generally good water quality of the coldwater ecosystems in which they are found. There are, however, some rivers where Brown, Brook, or Rainbow trout have consumption advisories. Specific fish consumption guidelines can be found at MDCH’s website, www.michigan.gov/eatsafefish.

Private aquaculture

Improperly designed and/or operated fish hatcheries have the potential to harm coldwater streams and their aquatic communities in a number of ways. Discharges of from hatcheries can introduce or influence diseases in downstream trout waters. Diseased fish may be brought in to a facility, and the disease may then spread through water discharged from the hatchery or by fish that escape the hatchery. Disease prevalence in the stream may also be increased by improving conditions for disease hosts. For example, the host for whirling disease, which is caused by the myxozoan parasite *Myxobolus cerebralis*, is *Tubifex tubifex*, a worm that lives in organic stream sediments. The genetic clade of *Tubifex tubifex* that is specifically necessary to complete the *Myxobolus cerebralis* life cycle thrives in areas rich in organic sediments. If hatchery discharges are not treated properly and fish wastes are not removed, then organic sediments may accumulate downstream of the facility, resulting in more habitat for disease hosts. Whirling disease was first detected in Michigan in 1968 as the result of fish imported into our state from an infected private hatchery in Ohio then widely distributed with the private fish hatchery network. This parasite is currently present in approximately 11% of our trout streams, but clinical signs

are rarely seen due to the lack of the appropriate susceptible *Tubifex tubifex* clade (G. Whelan, MDNR Fisheries Division, personal communication).

Stocking activities can potentially cause problems as well. Hatcheries can adversely affect the genetics of wild trout populations through outbreeding depression if escaped hatchery trout interbreed with resident wild trout in waters the hatchery drains into. Stocking of hatchery fish can also serve as a vector for aquatic invasive species such as the New Zealand mud snail *Potamopyrgus antipodarum*, unless appropriate measures are taken to prevent their spread. Water bodies that receive hatchery discharge waters may suffer from unintentional introductions of undesirable species (fish, parasites, etc.).

In addition, fish waste and excess feed may be discharged from the hatchery, resulting in elevated nutrients, in particular phosphorus, downstream. The elevated nutrients can lead to increased aquatic plant growth, nuisance algal blooms, and water quality degradation. The increased nutrients may also improve growth rates of fish and overall productivity of the stream (Merron 1982; Zorn and Nuhfer 2007a). However, mechanisms linking increased nutrients from hatchery discharge and increased growth rates are poorly understood. It is likely that there is a “fine line” between the amount of increased nutrients that result in increased growth and the amount that causes undesirable effects in the receiving waters.

Many of the hatchery threats identified above may be exacerbated in poorly designed flow-through systems. Many of the risks are eliminated or greatly reduced through best management practices or the use of different hatchery systems, such as recirculating aquaculture systems (RAS), with small environmental footprints.

Aquaculture activities in Michigan are regulated by several state agencies. The Michigan Department of Agriculture and Rural Development (MDARD) oversees the licensure, interstate movement and approved species list for aquaculture facilities. The Michigan Aquaculture Development Act (1996 Public Act 199, MCL 286.871-286.884) also allows for research facility permits, which are issued for facilities studying fish species not on the approved species list for aquaculture. This enables an aquaculture producer and/or State of Michigan to develop a scientific basis for including a species onto the approved species list. MDNR Fisheries Division regulates some aspects of the aquaculture industry, primarily through the oversight of stocking and fish health in public waters, importation of fish and eggs, and other permits. The list of permits and licenses administered by the MDNR Fisheries Division that may be required for aquaculture includes permit for private stocking of public waters, salmonid importation, and a Natural Rivers permit if on a designated natural river. MDEQ is responsible for regulating the industry with regard to potential environmental effects. The following MDEQ permits may be required for aquaculture: water withdrawal, groundwater discharge, wetlands/inland lakes and streams, noncommunity water supply, NPDES, NPDES storm water, soil erosion and sedimentation control, water use program registration, and Great Lakes Bottomlands. Note that a NPDES permit is required if annual production at a facility is 20,000 or more pounds for cold-water species (trout and salmon) or 100,000 or more pounds for warmwater fishes.

Changing climate

Any change in climate has the potential to change Michigan trout streams. Trout of course, need cold water, and an increase in the temperature regime of a stream or changes in its flow characteristics will change the fish community composition (Carlson et al. 2017; Zorn et al. 2008). While altering climate is beyond the scope of MDNR Fisheries Division, steps to monitor conditions and adaptively manage the waters of the state are conducted including monitoring the temperature of a number of streams every year with data loggers that record hourly water temperatures; and surveying fish communities in streams to look examine species composition, growth rates, and other key parameters. These activities help us monitor stream temperature regimes and fish communities to look for changes. Furthermore, our SSTP allows MDNR Fisheries Division to look at fish communities on a regional basis. As thermal conditions change, MDNR Fisheries Division will update its management of trout waters to reflect their

current condition. Actions to mitigate for the effects of climate change on resident trout in Michigan include: elimination of barriers that limit or prevent seasonal movements of trout to reaches which provide thermal refuge (suitably cold) habitat (Zorn et al. 2009); removal or modification of dams to eliminate excessive warming of downstream reaches in summer; and appropriate management of riparian corridors along streams.

Habitat Restoration

Trout populations are partly managed through habitat protection, restoration, and rehabilitation efforts, with the other management components being regulations to control angling mortality and fish stocking. Habitat work may be at a watershed-level or site-specific scale. Some of the tools that managers use have changed over the decades, with many agencies focusing on watershed-level efforts to improve overall ecosystem health and how local-scale habitat manipulations affect the geomorphic (channel-shaping) processes of individual streams. For example, costly maintenance of sand trap excavation may not be prudent when the specific point and non-point-sources of the sand bedload are not identified and corrected, or when the trap is placed in a system with extensive, naturally-occurring sand deposits.

Today, MDNR and comanaging agencies often look at the watershed's overall health and prioritize key habitat improvements based not only on project costs and availability of funding, but also on an examination of watershed processes. Restoration and rehabilitation tools such as sand trap maintenance, bank stabilization, and in-stream habitat enhancement are site-specific habitat tools, targeted towards improving local conditions. Other improvements, such as dam removals and road-stream crossing improvements, can benefit trout populations in larger portions of the stream network. All these management tools have a place in the fisheries manager's "tool box", although some tools, such as habitat protection, should always be used to maintain the integrity of trout waters. Many Michigan rivers are in relatively good condition with appropriate temperatures and intact riparian zones, so protection of the existing high quality habitat in such streams is more important and provides a much higher return on investment than restoration of degraded stream reaches.

Sand traps

Sand traps, or sediment basins, are widened and deepened reaches of streams that reduce current velocities and facilitate deposition of sand, and to a lesser extent, silt and clay particles. Sand trapped in these artificial pools is periodically removed with an excavator and deposited in upland areas. In-channel sedimentation basins were initially proposed as a trout habitat management tool by Hansen (1973). This notion was amplified by Alexander and Hansen (1988), who promoted sediment traps as a tool for shortening the "clean-out time" for abnormally high sand bedload, particularly in larger river systems, which due to their length and slow rates of bedload transport (roughly 1 mile/year) were still suffering from "excessive erosion created by mans' land developments and logging operations, particularly log drives in the late 1800s".

Following the work done by Alexander and Hansen (1988), sand traps routinely were built by state and federal agencies, and even private entities throughout Michigan. These sediment traps were viewed as possible immediate remedies to ailing but popular trout streams. Sand was viewed as deleterious and fisheries managers could potentially use this tool to remove excess sand bedload from local trout streams (despite the large and very deep deposits of glacial sand occurring naturally across Michigan). By 1993, at least 166 sediment traps had been built in Michigan streams (Zorn and Wills 2012). Maintenance of the traps was costly and with limited personnel and funding available to excavate them, many traps were not maintained on a routine basis, reducing their effectiveness. In addition, many sediment traps were improperly designed, which also contributed to their ineffectiveness (T. Wills, MDNR Fisheries

Division, unpublished data). Zorn and Wills (2012) re-evaluated Michigan's sediment trap program by studying local-scale effects at 65 traps that had been characterized by managers as "successful." They found sand traps had not achieved desired objectives of increasing channel depth and the availability of gravel and coarser substrates. Their findings are corroborated by data collected over a 10-year period at five sediment traps in Michigan (Wills 2013). Since 2012, many traps have been decommissioned. However, some traps are still maintained by various resource agencies or angling groups, and are considered valuable as a local management tool, particularly when dealing with site-specific issues such as dam removals or construction at road-stream crossings.

Instream habitat

Healthy riparian corridors yield many benefits to aquatic ecosystems. Well-vegetated corridors (e.g., trees, shrubs, or unmowed grass) help stabilize stream banks, limit erosion by keeping sediment from entering rivers, and consume excess nutrients that might otherwise flow into rivers. Riparian zone trees provide overhead cover for fish and shade for thermal cooling. Live and dead trees that recruit, or fall, into rivers and creeks serve as cover, velocity barriers, spawning refuges for fish, and facilitate substrate scouring and invertebrate production. The value of large and small woody debris in coldwater streams is well documented in the literature (e.g., Roni et al. 2015) and cannot be overstated, particularly in Michigan's sand-based systems where it functions as the key channel-controlling feature.

Many Michigan trout streams were considered to be lacking in large woody debris (LWD) dating back to when the state was originally cutover and its rivers used for log drives in the mid-late 1800s. During that period, Michigan's old growth forests were cut, all wood removed from streams to allow for log conveyance, and dams constructed to enable log transport on our rivers and systems. After the logging era, early research and management efforts focused on ways to increase trout survival and abundance in streams that had been scarred. Methods for rehabilitating the diversity of stream channel habitats through installation of structures were developed and tested on several Michigan rivers (Hubbs et al. 1932; Tarzwell 1935). Habitat improvement structures were built throughout Michigan and were supported by low-cost, federally funded labor programs such as the Civilian Conservation Corps (Hubbs et al. 1933). Many of early structures, such as wing dams, did not consider river dynamics, geomorphology, or physics and were improperly installed, or included hard-engineered approaches, such as rock gabions.

Since then, much of the riparian forest habitat in the state has remained relatively young in regrowth or has been actively managed, and senescent trees that would naturally fall into rivers are less abundant or absent. As a result, inputs of LWD to trout streams have been limited, and efforts to add LWD to Michigan's rivers to restore some of this lost habitat have occurred since at least the 1920s (Hubbs et al. 1932), and have increased in recent decades. Today's efforts to restore lost habitat complexity in Michigan streams range from construction of an individual log complex or logjam as a group service project to construction of dozens of habitat structures on a stream reach to placement of hundreds of whole trees from outside of the riparian zone into rivers using helicopters. Since permits are required for these activities, fairly complete records are available from MDEQ dating back to 1991. These data show LWD-related activities including bank stabilization or fish structure installation occurring at an average of 21.5 streams per year (MDEQ, unpublished data). Numbers of permits for LWD activities have varied from year to year with no obvious trend over time (Figure 21). Aside from federally funded projects on U.S. Forest Service lands, which totaled 36% of projects since 1991, most LWD-related activities are conducted by NGOs with their actions guided by MDNR Fisheries Division and funded by various grants (MDEQ, unpublished data). A review of North American studies of fish responses to LWD (e.g., Roni et al. 2015) and work in Michigan (e.g., Zorn and Nuhfer 2007a; Wills and Dexter 2011) have shown with few exceptions (e.g., Klungle 2006) that when other aspects of habitat are suitable, stream salmonids such as Brown Trout respond positively to improved woody habitat in streams. Future agency work should examine relationships between in-stream habitat variables including LWD, water depth,

riffle-pool ratios, and substrate size with trout population variables. Understanding the relationships among these variables will help agencies and groups to better identify when restoration or maintenance of habitat is needed.

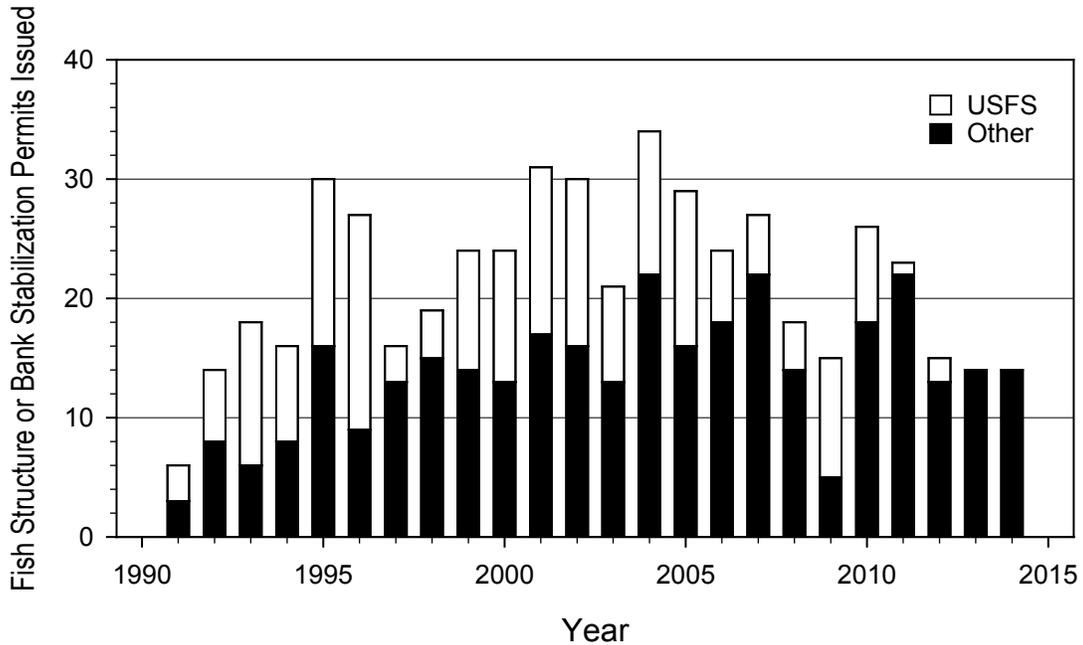


Figure 21.—Numbers of streams for which Michigan Department of Environmental Quality (MDEQ) permits issued were issued for projects involving fish shelters or bank stabilization (R. Merrick, MDEQ, unpublished data).

Goals of LWD placement should be site-specific and may include (1) creating diverse in-stream habitat, (2) increasing surface area for macroinvertebrates and periphyton (e.g., attached algae), (3) modifying channel substrates (e.g., scour sand, accumulate silt, or uncover cobble and rock), (4) creating additional holding cover for juvenile trout, (5) creating additional holding cover for adult trout, and (6) stabilizing unstable banks that are eroding at excessive rates for the surficial geology. The addition of LWD often improves channel dimensions by narrowing channels that are overly wide, increasing channel depth diversity. In recent years, there has been increased emphasis on understanding the natural geomorphology of the stream prior to project design. Accurate information on channel slope, velocity, catchment area, and cross sections is critical to agencies to better understand where to place needed LWD, ensure long-term channel stability, and achieve site-specific goals without generating adverse channel effects. Since such information is often scattered, river geomorphic data should be collected using a standardized protocol and archived statewide, either through centralized state or federal databases that are publicly accessible and capable of storing a diverse array of information.

Road-stream crossings

Over 67,000 public road-water crossings occur in Michigan, with nearly 90% of them being culverts and the remainder bridges (C. Fizzel, MDEQ, personal communication). Like any other infrastructure, crossings fail over time in a variety of ways. Bridges are more stream-friendly than culverts. Regulatory

authority over construction of crossings falls under the regulatory authority of MDEQ and MDNR Fisheries Division comments on such construction activities.

Inadequate road-stream crossings in Michigan degrade stream habitat in a variety of ways. These include undersized crossings that cannot accommodate high flow events, and pond water and accumulate materials upstream, while providing excessively high water velocities within the crossing; undersized culverts that become “perched” above the streambed with waterfalls at their outlets; those with insufficient flow capacity and excessive substrate, which limit sediment transport and organism passage; very long culverts without any light; and crossings with unnatural and relatively smooth streambed materials, such as concrete box or corrugated metal culverts. Each type of adverse crossing degrades habitat for fish, invertebrates, reptiles, amphibians, and mammals.

The main goal of any construction activity, in particular bridges, culverts, and pipelines, over or under a stream should be to maintain natural stream flow and appropriate channel dimensions, which allow for unhindered sediment and woody debris transport. Poorly designed crossings can generate sedimentation and unfiltered runoff from poorly designed approaches; act as a barrier to fish or other aquatic organisms; act as a sediment barrier; or scour the streambed downstream creating a ‘plunge pool’, which affects stream hydrology, connectivity, and geomorphology (channel shape and bottom type). In Fish Division Policy and Procedure 02.01.007, MDNR Fisheries Division recommends free-flowing streams be maintained at road-stream crossings with natural channel dimensions and bottom substrate. Most importantly, crossing dimensions and sizes should match appropriate bankfull widths. Following these procedures and best management practices will ensure better ecosystem health along with less frequent infrastructure replacement or maintenance costs. Impaired crossings and their habitat degradation will contribute to limited or no fish, reptile, or amphibian passage; increased mortality of individual organisms and reduced populations; and loss of fish habitat through excessive sedimentation.

The following considerations should be given to road-stream crossings across the Michigan landscape:

- 1) Whenever possible, existing crossings should be used instead of creating new crossings;
- 2) Unnecessary or abandoned crossings should be removed;
- 3) Best management practices should be followed to reduce surface runoff, sediment, and chemical pollutants;
- 4) The slope at the sides of the road should be gradual and designed to reduce erosion;
- 5) Crossings should be a clear span across the natural stream channel at bankfull capacity;
- 6) Culverts should be buried or be bottomless to allow for proper sediment and woody debris transport downstream; and
- 7) Culverts should be aligned with the natural stream channel sinuosity and slope.

The traditional method of culvert replacement considered only hydrology and used the smallest possible culvert. Hydrologic models were developed that predicted high flows, and infrastructure was constructed to pass this maximum flow. Today, agencies consider a broader array of factors when evaluating permit applications for stream crossings. Designers must be more aware of river functions such as sediment transport, debris transport, aquatic organism passage, and stream channel dimensions and adjustments. The lower reaches of a watershed are reliant on materials from the upstream reaches including sediment, nutrients, and wood. Constriction points or barriers that interrupt their delivery move streams from equilibrium, negatively affect channel stability, and limit the productivity of the entire watershed.

Road-stream crossings properly designed for humans and the environment may initially cost more, but if done right, they will last much longer than those designed in prior decades, all the while benefiting fish and other stream biota. Over time, these initial costs will be offset by reduced maintenance and replacement costs. A proper crossing is one that is essentially invisible to organisms that use it. An

actively-maintained, centralized archive on road-stream crossings needs to be maintained among agencies, while field inventories using standardized protocols should be maintained among all agencies and resource groups (Januchowski-Hartley et al. 2016).

Bank stabilization

Michigan streams traverse a variety of landscapes from low to high gradient. Many of these streams have high-quality riparian zones, though some have been altered significantly. Stream banks can degrade as a result of natural processes or human activities. Stream banks erode naturally, as a stream channel transports sediment and changes its position and pattern over time. Humans degrade riparian zones, and often accelerate bank erosion, by widening or narrowing channels, building and operating dams, and through improper road-stream crossings. Maintaining high-quality streambank vegetation and natural sinuosity are important strategies for reducing bank erosion.

The first step for any bank stabilization project is to identify the source and type of erosion. Natural erosion should not be addressed except in unusual circumstances and is a much lower priority than human-made erosion. Human-made erosion of a stream or river environment should be viewed as the consequence of controllable factors. Watershed characteristics such as discharge patterns and riparian vegetation types should be considered prior to actively correcting bank erosion. Older stream bank erosion procedures often included the use of hard structures such as rock rip-rap, sheet or log pilings, and gabions. Although some of these structures worked at some locations, they usually lead to stream energy being diverted to downstream bank locations, and consequently shift erosion problems downstream. In addition, these types of structures often reduce the natural stream character and are expensive. Today, engineers and biologists need to work together on natural designs for streambank erosion remediation. Best management practices should include “soft” designs, which use large woody debris, correct streambank slopes, and of course, proper rooted vegetation and healthy riparian zones. Soft-engineered approaches are less expensive and more aesthetic, although at times have shorter lifespans than some hard-armoring structures.

Dam removal

The adverse effects of dams on lotic environments are well documented in the literature and earlier in this document. Dam removal has gained great momentum in recent decades and outpaces dam construction. This is evident in the number of grants available for dam removal and fish passage installation. Properly removing a dam involves consideration of river processes and physics, including hydrology, geomorphology, slope, flow, discharge, and sediment. Social and economic values must also be considered. Most dam removals involve collaboration between multiple partners, including MDNR, MDEQ, federal and local units of government, NGOs, and private landowners. All these groups need to be part of the dam removal process and help promote the benefits of this high priority management tool.

Partnerships

Successful management of our trout communities requires collaboration of multiple entities. With reduced MDNR Fisheries Division staffing, it is essential that habitat protection, rehabilitation, and restoration be pursued by more than just one group or agency. This has been a major shift in focus for MDNR Fisheries Division, which for decades conducted stream habitat improvement projects alone. This philosophy is reflected today in the habitat management grants, which are administered by MDNR Fisheries Division and awarded to collaborators, often under the review and oversight of MDNR Fisheries Division biologists. For example, one grant known as the Habitat Improvement Account (HIA) was established as part of a settlement to mitigate adverse resource effects from hydropower

dam operations on the Manistee, Muskegon, and Au Sable river watersheds. Funds are awarded for habitat improvement projects in these watersheds. Local watershed and angling groups often are key conduits for identifying site-specific habitat issues. Funded projects are implemented by a variety of entities such as NGOs and fisheries interest groups. Other large-scale habitat projects are identified by MDNR Fisheries Division through formal river assessment documents. Michigan Department of Natural Resources Fisheries Division will continue to be the leader in quantifying and assessing fish communities statewide, with local fisheries management units taking the lead for their respective areas. This was true decades ago and will remain so into the future. Local fisheries managers will also protect habitat by reviewing other land management practices (forestry management, oil and gas development). With a declining staff base and a broad list of duties, other agencies and citizen scientists will need to fill the gaps when additional data, such as temperature data, are needed. Local management units and local resource groups need to strengthen their relationships and work together to determine what those gaps are for specific systems. Localized MDNR management will likely have a lesser role with instream habitat enhancement, including sand traps construction and maintenance as well as bank erosion mitigation, except in the shared identification and planning phases. The true power of habitat restoration is when a variety of agencies and resource groups work together to not only identify but to maintain and restore coldwater trout habitat in Michigan.

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Appendix A.—An abbreviated listing of key issues and recommended actions by plan goal. A more detailed discussion of each occurs under “Goals, Key Issues, and Actions” in the main body of the text.

Goal 1. Ensure adequate technical information is available for managing trout fisheries.

1. Expand creel data collection and periodically survey trout anglers opinions.
2. Seek partners and funding to increase annual numbers of status and trends surveys.
3. Update modeling of effects of various fishing regulation scenarios on trout populations.
4. Partner to develop a system to document activities of fishing guides on inland waters.
5. Develop standardized protocols for assessing trout in inland lakes.
6. Partner to obtain pre- and post-trout population data for stream reaches with extended fishing seasons.
7. Partner to better understand sediment dynamics in various types of Michigan streams.
8. Partner to better identify key instream habitat parameters for trout in Michigan.
9. Partner to establish flow gages on stable, nonimpounded trout streams.
10. Partner to monitor water temperatures on additional trout streams.
11. Partner to incorporate drift thickness in updated groundwater velocity models.
12. Partner towards statewide optimization of dam and road-stream crossing habitat improvement projects.
13. Develop a statewide decision-support tool to support local-level trout management.
14. Allocate appropriate MDNR Research Section staff time to inland trout issues.

Goal 2. Stewardship of coldwater habitat.

1. Institute a “Trout Stream Habitat Improvement 101” course for partners.
2. Identify and maintain properly functioning sediment traps.
3. Foster efforts to provide adequate woody cover in trout streams.
4. Direct dam removal efforts to where the benefit to cost ratio is highest.
5. Partner to address fish passage barriers in trout streams and tributaries to coldwater lakes.
6. Partner to direct road-stream crossing remediation to where the benefit to cost ratio is highest.
7. Protect riparian corridors on trout waters with existing state rules and zoning processes.
8. Partner to protect coldwater streams that are designated drains.
9. Partner to maximize benefits of streambank stabilization efforts.
10. Highlight the importance of healthy aquatic environments to trout and everyone.

Goal 3. Stewardship of coldwater fisheries and aquatic communities.

1. Maintain seasonal harvest closures on trout streams as needed.
2. Minimize effects of human development activities on trout populations.
3. Partner to prevent the spread of aquatic invasive species.
4. Use status and trends surveys to inform trout management in a changing climate.
5. Partner to better understand instream habitat needs of trout and manage trout habitats.
6. Experimentally assess feasibility and success of Arctic Grayling reintroduction efforts.

Appendix A.–Continued.

Goal 4. Provide diverse fishing opportunities for inland trout.

1. Help anglers to better understand trout regulations and MDNR Fishing Digest.
2. Discuss the use of special regulations for individual trout waters where appropriate.
3. Consider expanded catch-and-release trout fishing opportunities where appropriate.
4. Maintain bait restrictions on trout waters where appropriate.
5. Enable broader use of experimental regulations if they prove effective in rehabilitating coaster Brook Trout.
6. Conduct a comprehensive review of trout fishing regulations.

Goal 5. Communicate and promote value of Michigan’s coldwater fisheries.

1. Continue meetings with angler groups and periodically survey inland trout anglers.
2. Develop smartphone applications to provide location-specific trout fishing regulations.
3. Promote stewardship of trout waters and trout fishing.
4. Improve decision-making through information-sharing, stakeholder meetings, and partnerships