North Manistique (Round) Lake
T45N R12W Section 13
Manistique River Watershed, Last Surveyed 2014

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Environment

North Manistique (Round) Lake is a 1,709 acre (Breck 2004) natural lake in the Manistique River Watershed located in southwestern Luce County (Township 44 N Range 12W Section 13) in Michigan's Upper Peninsula. In Luce County, Helmer (Lakefield Township) resides southeast and McMillan resides to the northeast of North Manistique Lake. North Manistique Lake is located within the Manistique bedrock geological formation which is comprised of a thin east to west dolomite and limestone strip spanning from Delta to Mackinac counties. North Manistique Lake is fed by several springs on the northern and eastern shores and a small inlet on the west shore. The only outlet, Helmer Creek, flows south into Big Manistique Lake. Riparian areas of North Manistique Lake are extensively developed with private and commercial residences, though some public land exists.

The bathymetry of North Manistique Lake is mainly bowl-shaped, with both shallow flats and a deep central area in the lake. The maximum depth is approximately 50 feet. Approximately 48 percent of the lake area is less than 15 feet deep, and 81 percent of the lake volume is contained in waters greater than or equal to 15 feet. Substrate in the shallow areas is sand and marl, with substrate in deeper areas consisting of pulpy peat. There is a shallow rock reef on the western shoreline. Aquatic vegetation is mostly sparse, consisting of rushes, Chara, and Potomogeton.

Additional chemical and biological parameters provide a picture of a lakes level of productivity. The more productive a lake is, the more aquatic organisms (e.g., fish, insects) the lake can `grow' and support. Chemical and biological parameters often used to gauge a lake's level of productivity include temperature, chlorophyll-a, water transparency, phosphorus, nitrogen, total alkalinity, pH, and dissolved oxygen. These parameters can often be pooled together to evaluate an `index' (i.e., Trophic index) which then allows managers to compare lakes with different levels of productivity.

In 2003 and 2014, North Manistique Lake was sampled for a temperature profile and was observed to be thermally stratified into three distinct layers sufficient to support life. In 2003 and 2014 the lake thermocline was located at approximately 39 and 40 feet deep, respectively. Thermal stratification in lakes impacts temperature and oxygen dynamics, and also influences nutrient availability and the distribution and size of zooplankton. Thermal stratification in lakes typically occurs in deep lakes during the summer months of the year where three water column `layers' form, which are called the epilimnion, metalimnion, and hypolimnion. The epilimnion consists of the upper layer of the water column which has adequate levels to support photosynthesis and primary production. The hypolimnion is the bottom-most layer of the water column, typically characterized by colder water and light levels which are too dark to support photosynthesis. The metalimnion is the layer between the epilimnion and hypolimnion characterized by a quick transition in temperature change. The point at which temperature change is greatest within the metalimnion is referred to as the `thermocline'.

As described earlier, the limnological or trophic index of the lake refers to the total weight of living biological material (biomass) and is a measure of overall lake productivity. The concept is based on the fact that changes in nutrient levels (measured by total phosphorus) affect changes in algal biomass (measured by chlorophyll-a), which in turn affect changes in lake clarity (measured by water transparency). A Secchi disk is commonly used to measure the depth to which it can easily be observed through the water, (i.e., transparency). Secchi disk transparency, chlorophyll-a (an indirect measure of phytoplankton), and total phosphorus (a limiting nutrient) are often used to define the degree of productivity, or trophic status of a lake. Oligotrophic, mesotrophic, and eutrophic lakes are those which exhibit low, medium and high levels of productivity, respectively.

Water transparency, which is measured using a Secchi Disk, provides an index of phytoplankton production and overall lake productivity. For example, lakes with greater transparency are often classified as Oligotrophic, meaning there are low levels of lake productivity. In 2003 and 2014, North Manistique Lake Secchi depth readings were 13.5 and 17.0 feet, respectively which were higher (deeper) compared to most large Michigan lakes. This suggests that North Manistique Lake is relatively unproductive compared to other large lakes in the state. Secchi depth transparency increased from 2003 to 2014 by 26%.

Chlorophyll-a is a pigment used by plants for photosynthesis and when measured during the summer months provides a way to measure levels of primary production by phytoplankton. As mentioned earlier, levels of Chlorophyll-a, when accompanied by additional chemical parameters (i.e., Total Phosphorus, Total Nitrogen, Secchi Disk depth) allow managers to gauge a lake's trophic state. Chlorophyll-a concentrations vary widely across Michigan's inland lakes having low (<1.9 ug/L), medium (1.9 to 4.8 ug/L) and high (>4.8 ug/L) concentrations. Chlorophyll-a samples were collected and analyzed in 2003 and 2014 and were reported to be 1.7 and 1.4 micrograms per liter (ug/L), respectively (low in both years).

Total Phosphorus occurs in relatively low concentrations in the aquatic environment and as a result tends to be the limiting nutrient for primary producers (phytoplankton, periphyton, and aquatic vegetation) in an aquatic ecosystem. Phosphorus values typically vary quite widely across Michigan's inland lakes having low (<9.0 ug/L), medium (9.0 to 20.0 ug/L), and high (>20.0 ug/L) concentrations. In 2003 and 2014, Total Phosphorus values in North Manistique Lake were 6.0 and 8.1 ug/L, respectively (low). In contrast to Total Phosphorus, Total Nitrogen occurs in relatively high concentrations in aquatic environments and as a result, rarely limits primary production in lakes. Nitrogen values typically vary quite widely across Michigan's inland lakes having low (<0.403 mg/L), medium (0.403 to 0.750 mg/L), and high (>0.750 mg/L) concentrations. In 2003 and 2014, Total Nitrogen values in North Manistique Lake were 0.405 and 0.364 mg/L, respectively (low).

Based on the ratio of Total Nitrogen to Total Phosphorus (N:P), managers can classify lakes that may be limited by one nutrient versus the other. For example, plants typically require a specific ration of N:P which tends to be approximately 18:1 where Total Phosphorus is the limiting nutrient. In 2003 and 2014, the N:P values for North Manistique Lake were 68:1 and 45:1, respectively, which suggests that Total Phosphorus has been the nutrient which limits primary production.

Total Alkalinity is a measure of buffering capacity and plays an important role in determining the pH and consequently, overall lake productivity. Alkalinity values in Michigan inland lakes can be

classified into low (< 49.5 mg/L as CaCO3), medium (49.5 to 141.5) and high (> 141.5) categories. In 2003 and 2014, Alkalinity values in North Manistique Lake were 85.0 and 90.0 mg/L, respectively (medium). Additionally, pH at the surface of North Manistique Lake in 2003 and 2014 was 8.2 and 8.6. Alkalinity and pH values have changed very little over time and help to explain the unproductive nature of North Manistique Lake. Because of the Alkalinity, calcium carbonate forms a precipitate known as `marl' found in shallow areas of North Manistique Lake. Marl material then binds to available phosphorus reducing nutrients needed for the production of phytoplankton (primary production).

Dissolved Oxygen (DO) is a critical component to available habitat in aquatic ecosystems. Dissolved oxygen in lakes derives from the atmosphere as well as from aquatic plants during photosynthesis. Concentration of DO in lakes can limit the distribution and growth of fish in lakes as well as the size composition and biomass of zooplankton. Concentrations of DO begin to limit fish populations at approximately 4.0 mg/L and are often lethal below 0.5 mg/L. On 8 August 2003, DO measurements from the surface to the lake bottom ranged from 9.4 to 0.1 mg/L, becoming hypoxic (below a preferred concentration) at approximately 39 feet (total depth 46 feet). On 3 September 2014, a similar DO profile existed where measurements from the surface to the lake bottom ranged from 9.9 to 0.1 mg/L becoming hypoxic at approximately 40 feet (total depth 46 feet). Critical depth is defined as the depth at which DO concentrations are below 0.5 mg/L which may be lethal to fish populations. The critical depth in North Manistique Lake was recorded in 2003 and 2014 to be at 42 feet in both years.

Trophic status refers to an index which allows managers to characterize Michigan's inland lakes into categories that define the level of primary production in a lake. The Carlson's Trophic State Index (TSI) utilizes measurements of phosphorus (ug/L), Secchi depth feet (ft), and chlorophyll-a (ug/L) and rescales these values to a 0 to 100 index (Fuller and Jodoin 2016). Threshold values for TSI are broken down into three categories where TSI values <38 are Oligotrophic, from 38 to 48 are Mesotrophic, from 49 to 61 are eutrophic, and >61 are hypereutrophic. In 2003, the Total Phosphorus, Secchi depth, Chlorophyll-a values were reported to be 6.0 ug/L, 13.5 ft, and 1.7 ug/L, respectively (average TSI = 35.1, Oligotrophic). In 2014, the Total Phosphorus, Secchi depth, and Chlorophyll-a values were reported to be 8.1 ug/L, 17.0 ft, and 1.4 ug/L, respectively (average TSI = 34.8, Oligotrophic).

Based upon the physical and biological parameters measured, North Manistique Lake is characterized as an Oligotrophic lake. Oligotrophic lakes are typically deep, cool lakes which have low levels of productivity, low species richness, lower fish abundance, and slow growth rates. However, Oligotrophic lakes are known to produce small numbers of large fish (e.g., Northern Pike, Muskellunge, Walleye) with intermittent strong year-classes of panfish (e.g., Yellow Perch).

North Manistique Lake is recreational destination which offers diverse fishing and boating opportunities. A large proportion of North Manistique Lake's shoreline is developed with private and commercial residences, though some public land exists in the form of a county park and boat launch (GPS location: 46.278144 -85.724650). Residential development provides an index of the potential influence human activities have in areas adjacent to shoreline resources. Building structures (dwellings) in riparian areas, removing vegetation or woody debris, armoring shorelines, and building docks all have the potential to impact lake ecosystems and negatively affect fish populations and water quality.

Dwelling density values along Michigan inland lake shorelines can be classified as low (<4.8 dwellings per mile), medium (4.8 to 30.4 dwellings per mile) and high (>30.4 dwellings per mile). The number of dwellings per mile along the shoreline of North Manistique Lake was not measured in 2003, however in 2014 was recorded to have 25.0 dwellings per mile (medium).

The density of boat docks, measured as the number of docks per mile of shoreline, provides an index of the nearshore disturbance level as well as the potential boat activity level. Construction of docks often is accompanied by the removal of large woody debris and aquatic vegetation which disrupts nearshore sediment and reduces available refuge habitat for aquatic organisms. Dock density values along Michigan inland lake shorelines can be classified as low (<1.9 docks/mile), medium (1.9 to 21.9 docks/mile), and high (>21.9 docks/mile). The number of docks in North Manistique Lake was not measured in 2003, however in 2014 was recorded to have 17.7 docks per mile (medium).

The degree to which lake shorelines have been armored, to reduce the impacts of wave action, provides an index of the extent to which shorelines may have been modified from their natural state. Shoreline armoring, is measured as the percent of shoreline armored across all transects. The amount of shoreline armored in Michigan's inland lakes varies considerably across the state with lakes having low (<0.6 percent), medium (0.6 to 30.1 percent) and high (>30.1 percent) armoring. The extent to which North Manistique Lake shoreline was armored was not measured in 2003, however in 2014 was estimated to be 20.1 percent (medium).

Large woody debris is an important habitat component providing structure (i.e., cover) for aquatic organisms (e.g., fish, aquatic insects) during various life periods and providing stability of the lake bottom (e.g., sediments, vegetation). Trees growing adjacent to shoreline fall into the water and become a primary source for large woody debris habitat. Additionally, large woody debris lying along the shoreline helps to dissipate wave action and minimize erosion along the shoreline. However humans have greatly impacted the degree to which large woody debris exists in many lakes. Humans often remove woody debris from shoreline areas reducing critical lake habitat. Furthermore, humans reduce recruitment of new large woody debris by removing trees from shoreland areas during landscaping. The amount of large woody debris in Michigan's inland lakes can be broken down into three categories; low (<1.1 trees per mile), medium (1.1 to 22.7 trees per mile), and high (>22.7 trees per mile). The amount of large woody debris in North Manistique Lake was not quantified in 2003, however in 2014 was recorded to be 10.4 trees per mile (medium).

North Manistique Lake's level of development could be characterized as `moderately' developed compared to other inland lakes in Michigan. This level of development may help to explain the observed results from fish community surveys and support findings that suggest that increased habitat is needed to support primary production and provide `cover' for various fish species at multiple life periods.

History

In the 1920s and 1930s, the first survey was conducted in North Manistique Lake in July of 1926 by J.N. Lowe using a seine to characterize the fish community. Northern Pike, Lake Herring (Cisco), Mimic Shiner, Golden Shiner, Logperch, Johnny Darter, and Brook Silversides were all captured. Following this survey, fisheries management began in the 1930s when general interest in Walleye and

Yellow Perch production resulted in annual stocking of Walleye and intermittent stocking of Yellow Perch. Walleye were stocked at an average rate of 107 spring fry per acre, while yellow perch were stocked at an average rate of 2 fall fingerlings per acre. Additional surveys were conducted in 1936 to collect information pertaining to fish abundance, aquatic plant identification, benthic macroinvertebrates, and lake chemistry profiles.

In the 1940s and 1950s, North Manistique Lake was stocked and managed for Rainbow Trout after a limnological survey had been conducted to evaluate the likelihood that a fishery would develop. Following the limnological survey, Rainbow Trout were stocked (average 1.7 nine-inch fish per acre) in addition to Northern Pike and Walleye in attempt to improve unproductive pan and gamefish fisheries. Approximately 1,180,000 spring fry Walleye were stocked at an average rate of 345 spring fry Walleye per acre. During this same time, an interest toward Northern Pike management also began by stocking 130 adult Northern Pike. Creel surveys were scheduled annually from 1950 to 1959, and a general survey was conducted in 1957 to provide a demonstrative survey for resort operators and anglers after reports of poor fishing.

Surveys during the 1950s and 1960s were limited to manual removals and creel census. Results from stocking Rainbow Trout reported minimal returns, so Rainbow Trout was discontinued in 1961. Walleye stocking continued at an average annual rate of 335 spring fry per acre, while Northern Pike were also being stocked at an average annual rate of 1 adult per 20 acres. During this period biologists and area property owners began focusing management efforts towards fish habitat improvement.

In 1952 and 1953, biologists placed 300 brush bundles near the 8 to 15 foot contour break. Additionally, riparian owners placed log-rock filled cribs (1961) near the southern portion of the lake. These habitat structures were noted to produce large catches of Rock Bass and Yellow Perch (and a few Smallmouth Bass), but had begun to deteriorate by 1973. A summary of fish growth from 1957 indicated that Yellow Perch and Rock Bass were growing below state average, while Walleye were at state average, and Smallmouth Bass were above. Additional habitat projects included the installation of a 100 by 50 foot rock `Walleye Reef' in 1961 as part of the collaborative project involving lake property owners, the Luce County Road Commission and the Michigan Department of Natural Resources (MI DNR). Several annual plants of Walleye eggs and fry were made to initiate an increase in natural reproduction of Walleye. However, in 1974 district fisheries biologists noted that no Walleye had been observed utilizing the reef for spawning. Placement of habitat structures offered some degree of success as catches of panfish were reported in areas adjacent to structures.

After continual complaints by anglers of poor panfish size (presumably in the late 50s) biologists initiated manual removal programs for adult suckers. At this time, biologists hypothesized that various sucker species (e.g., Redhorse Sucker, and Common White Sucker) competed for forage resources with other more preferable species, namely Yellow Perch and Rock Bass. As a result, a sucker or `rough fish' removal plan began in 1961. In 1957, prior to the onset of the sucker removal program, biologists had conducted a survey and noted that Smallmouth Bass fishing was `good' and `nice perch' were being caught. In 1968, growth was normal for all fish species captured in North Manistique. However, by 1969 Yellow Perch and Rock Bass had dropped below state average while Walleye growth remained unchanged. During the period that suckers were manually removed, discarded suckers were utilized in various ways; by area residents for fertilizer, as food for Northern Pike and

Muskellunge at the MI DNR Thompson Hatchery, and as food for residents at the state hospital in Newberry, Michigan.

Aside from habitat enhancement projects and attempts to improve size and abundance of panfish by removing suckers, attempts were also made to improve the Northern Pike population to aid in controlling the prey population as well as to offer an additional top-predator gamefish. Throughout the 1960s and into the 1970s several spawning marshes were operated to enhance Northern Pike natural reproduction. Initially a water control structure was placed near the Shoreline Resort adjacent to North Manistique Lake. Twenty-seven adult Northern Pike were stocked in 1962 to initiate a spawning stock. However, the structure was abandoned after 1962 due to difficulties associated with operating the structure. In 1961 an additional water control structure was installed on a culvert adjacent to County Road 413 (McCauley's Marsh). Adult Northern Pike were transferred from the Seney Wildlife Refuge and McCauley's Marsh was met with some success as a natural run of Northern Pike had become established by 1970, however the overall marsh production was noted as `fair' in 1971, and by 1973 was noted as `poor'. In 1964, a third marsh was created collaboratively by the Tahquamenon Junior Sportsman's Club and a local resident. However, operation of this marsh proved to be difficult due to excess flow and repeated loss of Northern Pike fry. In total, 875 adult Northern Pike were stocked at marsh locations in attempt to improve natural reproduction. Initially, results from various marsh operations were promising and `very good catches' were reported in the late 60s particularly during the winter fishery. However, by 1969 catches had begun to taper off reaching pre-1962 levels. From 1967 to 1970, the presence of `red sore' or Lymphosarcoma was documented to have infected Northern Pike in North Manistique Lake.

In the 1970s surveys in North Manistique Lake consisted of two limnological profiles, several general surveys, a species evaluation, and additional manual removals. During this period approximately 2,950,000 spring fry Walleye were stocked at an average rate of 431 spring fry per acre. A total 13,903 fall fingerling Walleye were stocked at an average rate of 2.71 fall fingerlings per acre. As stocking continued, biologists and area residents had also been conducting annual sucker removals for more than a decade. From 1961 to 1974, more than 31,000 suckers (about 53,000 pounds) were removed from North Manistique Lake in attempt to reduce competition among suckers and various panfish species without desired results. By 1972, in a summary prepared by the district biologist it was noted that although numbers of suckers had declined, there was little evidence of improved growth by other species. Therefore, MI DNR biologists recommended in 1972 that no further manual removals take place.

In 1973 property owners and MI DNR personnel met to discuss future management of North Manistique Lake. Resort and property owners were concerned about poor Walleye and Northern Pike production as well as the small size of Yellow Perch and Rock Bass. Additionally, residents were concerned that the McCauley Marsh, installed to improve Northern Pike reproduction, was a possible source for pollution (e.g., septic seepage). Several fisheries management recommendations were made at that time to address concerns with gamefish populations, continued sucker removals, and the potential for future habitat work.

Despite recommendations submitted by agency staff, sucker removals were discussed and planned to continue for the 1974 spawning season with local support. In the winter of 1975, an additional 100 rock crib-brush structures were added to North Manistique Lake near the 10 to 15 foot contour to

improve angling opportunities for panfish species. In June of 1974, water samples were collected at various locations in North Manistique Lake to evaluate water quality. Runoff from flooded marsh areas adjacent to agriculture areas was noted to have increased the amount of suspended solids in entering North Manistique Lake. Eventually operations of the marshes were discontinued due to concerns of excess nutrients entering the lake believed to have originated from nearby pastures (e.g., cattle waste products).

In 1977 additional Walleye rock-reefs were constructed to improve numbers and promote natural reproduction of Walleye by providing spawning habitat that was otherwise unavailable in North Manistique Lake. In 1977 an electrofishing survey was conducted to evaluate the use of the installed reef by adult Walleye. No Walleye were captured during the 1979 survey.

By the late 1970s, management of North Manistique Lake also shifted towards a `two-story' fishery offering Walleye as well as various trout species (i.e., Rainbow Trout, Lake Trout, Splake, and Brown Trout). Walleye were planted directly on the constructed reef to promote early life imprinting and catches of Walleye were expected to increase in the early 1980s. Rainbow Trout, Splake, Lake Trout, and Brown Trout were expected to fill the deepwater niche unoccupied by the current fish community while providing additional and diverse angling opportunities. In addition, managers assumed that trout species and the increased number of Walleyes would feed heavily on undersized Yellow Perch with an expectation of improved growth by that species.

In the 1980s, fisheries surveys consisted of limnological profiles, general surveys, manual removals, and species evaluations. Fisheries management of North Manistique Lake was initially focused towards creating a two story fishery which included Walleye and various trout species. In 1981 a species specific survey was conducted, using gill nets, to evaluate the survival of stocked Brown Trout. A total of 14 Brown Trout were captured with an average size of 13.5 inches (range 10 to 17 inches). During this period, a total of 74,044 Brown Trout, 420 legal sized Rainbow Trout, 10,679 Lake Trout, and 36,000 Splake were stocked into North Manistique Lake. By 1985, anglers expressed little interest in Rainbow Trout or Brown Trout so stocking of those species ceased.

During this period, a total of 149,094 fingerling Walleye were stocked at an average rate of 10.9 fingerlings per acre. Additionally, 950,000 spring fry Walleye were stocked at an average rate of 185 spring fry per acre. Effort focused more intently on Walleye stocking as Walleye were of greater interest to anglers and it was believed that Walleye, being Yellow Perch predators, would help reduce the number of undersized Yellow Perch. In 1983, an electrofishing survey was conducted to quantify the abundance of young of year Walleye and evaluate the current stocking program. No young of year Walleye were captured during this assessment.

In 1989 a general fish survey was conducted in North Manistique Lake to provide managers with catch summaries, species growth, and length-frequency information. Sucker numbers were reported as high and anglers had reported good success for Yellow Perch and Smallmouth Bass. Recent captures of Walleye were assumed to coincide with stocking in previous years. Recommendations were made to continue Northern Pike stocking with the goal of subsequently reducing the Common White Sucker population. Renewed interest in Northern Pike stocking resulted in the release of 41,500 fingerlings at a rate of 8 fingerlings per acre. Additionally, renewed interest in a sucker removal program prompted removal of suckers in 1985 and 1986 in hopes of improving size of panfish. In 1985 and 1986 a total

of 11,331 pounds of Common White Sucker, 2,207 pounds of Yellow Perch, and 2,348 pounds Rock Bass were removed from North Manistique Lake. These were the last reported manual removal surveys conducted on North Manistique Lake. Discussion for the introduction of Muskellunge began in the mid-1980s however; district biologists wanted to hold off and see how Walleye and Northern Pike performed post most recent stockings.

In the 1990s fisheries surveys consisted of one general survey and several species evaluations targeted towards monitoring recruitment of Walleye. Stocking of Northern Pike, Smallmouth Bass, Walleye, and Lake Trout in North Manistique Lake continued through this period.

In 1995, a general survey was conducted to evaluate the fish community. Managers noted that sucker biomass comprised 33 percent of the total biomass captured and that Rock Bass biomass comprised of 30 percent of the total biomass captured. Also, the total standing crop of North Manistique Lake was calculated to be approximately 25.9 pounds of fish per acre. After the 1995 survey, managers took note of the stocking rate for lakes in the area including North Manistique Lake. During this period, a total of 8,948 Northern Pike were stocked in the early 1990s at an average rate of approximately 2.6 Northern Pike per acre. Also, a total of 4,171,400 spring fry Walleye were stocked at an average rate of 814 spring fry per acre. A total of 420,529 spring fingerling Walleye were also stocked, at an average rate of 25 spring fingerlings per acre. In a 1995 report, South Manistique Lake was referenced as an example of a lake that had been ecologically damaged due to the high stocking levels received in recent times. Growth rates of Walleye were nearly four inches below state average in South Manistique Lake. Therefore, it was noted to closely monitor Walleye recruitment to ensure stocking levels in North Manistique Lake did not exceed capacity causing a collapse of the available forage base.

Additional surveys (Serns Indices) were conducted in 1996, 1997, and 1998 to evaluate young of year Walleye recruitment after years of stocking. In 1997, a total 132 young of year Walleye were captured (35 per mile) indicating a good year class was produced. A total of zero and three Walleye were captured during the 1996 and 1998 sampling years, respectively. While anglers remained enthusiastic about Walleye fishing, historical and current stocking rates were a concern with respects to the potential negative impacts of overstocking on the forage fish population. As a result, Walleye stocking was halted in 1997 and did not continue again until 2003.

Throughout the 1990s Lake Trout were being stocked at an average rate of 0.78 adults per acre (range 0 to 17 inches) sourced from `used' adult broodstock Lake Trout. Smallmouth Bass were also stocked at an average rate of 1.65 fish per acre (range 1 to 5). In the mid-1990s reports of habitat projects are sparse; however, a permit was issued by the Department of Environmental Quality to the MI DNR to install 40 to 50 cedar log cribs for additional fish habitat. It is unknown if this project was completed.

In the 2000s fisheries surveys consisted of one general survey, a population estimate targeting Walleye and Northern Pike, a creel census, and the lake's first Status and Trends assessment. In 2000, a general survey was conducted to evaluate the fish community in North Manistique Lake. Numbers of Walleye, Northern Pike, Common White Sucker, Yellow Perch, Rock Bass, and Lake Herring were all reduced compared to 1995 survey results. Additionally, sizes of many of these species had increased suggesting that numbers were reduced and forage becoming more abundant. Managers noted a reduction in the total number of species captured compared to the 1995 survey and as a result,

recommended discontinuing stocking of predators (namely Lake Trout, and Northern Pike). Adult Lake Trout were being planted experimentally in the 1990s and were not expected to `holdover' long before anglers would have harvested a large proportion of those fish. However, the 2000 survey results suggested that these large Lake Trout survived into the 2000s, which in part may explain the reduction in numbers of several species from the 1995 to 2000 surveys. Results from the 2000 general survey also showed that the standing crop of North Manistique Lake was calculated to be approximately 27.2 pounds per acre (Schneider 2000).

Following results from the 2000 survey, Northern Pike (96, 22-inch fish) were stocked for the last time in 2000. Surveys conducted in the early 2000s and an evaluation of the historical management involving Northern Pike allowed managers to determine that Northern Pike would no longer be stocked, and that Muskellunge should be considered for future plants. Since 1941, Northern Pike had been stocked as adults (transfers), juveniles, and fry in an attempt to reduce the abundance of undersize panfish, while providing additional angling opportunities which included a top predator gamefish. However, access to marsh spawning habitat in North Manistique Lake is virtually non-existent and as a result, natural reproduction of Northern Pike has been low at best. Transfer of undersized adult Northern Pike from other waterbodies (e.g., McDonald Lake) had produced some positive results in previous years. However, fish transfers became exceedingly expensive, labor intensive, and risky given the potential for introduction of disease (Lymphosarcoma) outbreaks in North Manistique Lake which occurred in the 1960s and early 1970s. Given the logistical difficulties and biological concerns associated with producing Northern Pike, Muskellunge were considered for introduction. Soft substrate and the presence of Chara, vegetation preferred by Muskellunge for spawning, were expected to provide the habitat necessary to initiate natural reproduction of this species. Additionally, Muskellunge were expected to utilize large Common White Suckers and Lake Herring as forage while providing additional and unique angling opportunities. In 2004 and 2008, a total of 611 and 1,700 fall fingerling Muskellunge (Northern strain) were stocked at an average rate of 0.68 fall fingerling Muskellunge per acre.

From 2003 to 2004, winter and summer creel surveys were conducted on North Manistique Lake in addition to a Large Lake survey aimed to quantify abundance of legal-size Walleye and Northern Pike. Creel survey results showed that approximately 5,017 trips were taken to North Manistique Lake totaling 10,614 angler hours. The population of legal size Walleye found in North Manistique Lake was calculated to be approximately 1,538 individuals (or 0.9 adults per acre). No estimate for Northern Pike could be calculated due to the low number of captures (n=15). Additional information gathered from the 2003 Walleye population estimate suggested that natural recruitment of Walleye in North Manistique Lake in highly variable and in some years, non-existent.

In 2003, North Manistique Lake was also surveyed using Status and Trends monitoring protocols. This is was the first year that a Status and Trends assessment was conducted in North Manistique Lake. The purpose of Status and Trends assessment is to provide a lake-wide inventory of various lake characteristics including fish community composition, water chemistry, and habitat status. Since the goal of the Status and Trends program is to provide an unbiased representative sample of lake condition (i.e., fish, habitat, limnology) nets are set at randomly selected locations to ensure that a range of conditions are sampled in each lake. After multiple Status and Trends surveys have been conducted, managers are provided with long-term trend information (Michigan Status and Trends

Inland Lake Habitat Viewer 2018, MiFish 2018) which provides insight about ecosystem health within and among Michigan's many inland waterbodies.

In 2003, a total of 2,928 fish were captured which included 13 fish species. Results from the 2003 Status and Trends survey also showed that the standing crop of North Manistique Lake was approximately 39 pounds per acre. Piscivore or gamefish species such as Walleye, Northern Pike, Smallmouth Bass, Largemouth Bass, Rock Bass, and Yellow Perch comprised 93 percent of catch by number and 60 percent of the total biomass. Benthic species, such as bottom dwelling Cisco, Common White Sucker, Mottled Sculpin, Johnny Darter, and Logperch comprised 5 percent of catch by number and 39 percent of the biomass. Lastly, pelagic species (Planktivores-insectivores) such as shiners, minnows, dace, and panfish comprised 2 percent of catch by number and nearly zero percent of the total biomass.

Additional data gathered from this survey suggested that Walleye were being produced in non-stocking years (e.g., 1998, 1999, and 2000) which supported findings from earlier surveys which showed that natural recruitment is highly variable. Furthermore, Walleye growth remained unchanged among the 1997, 2000, and 2003 sampling years. Large number of Yellow Perch were captured which likely explained the recent reduction in growth rate for that species (less forage available with more Yellow Perch). Lake Herring, or Cisco, numbers had appeared to rebound from the 2000 survey with growth above state average. Northern Pike numbers were low in 2003; however 75 percent of fish captured were above 30 inches.

Survey data gathered in the early 2000s allowed managers to initiate recommendations for continued stocking of Walleye, however on a biennial basis (every other year) given the evidence of some level of natural recruitment. Stocking Walleye would provide a predator to balance an overabundant Yellow Perch population as well as a safety net for years when natural reproduction of Walleye fails. Additionally, the proportion of benthic species had increased compared to previous surveys which provided an opportunity to begin Muskellunge stocking in North Manistique Lake. At this time, there were few angling opportunities available for Muskellunge in the Eastern Upper Peninsula. By stocking Muskellunge, managers expected a low abundance of large fish to be produced which would prey upon Common White Sucker and Lake Herring while providing unique angling opportunities.

Muskellunge stocking occurred for the first time in North Manistique Lake in 2004 and 2008 at the low rate of 1 fall fingerling Muskellunge (Northern strain) per 1 acre. Stocking rates of Muskellunge were conservative given the impact that stocking large Lake Trout had on the forage base within North Manistique Lake. During this period, North Manistique Lake was designated as closed to spearing to protect the Muskellunge population from overharvest.

Near the end of the 2000s, fisheries management in North Manistique Lake shifted from production of Walleye, Northern Pike, and Lake Trout to the continued production of Walleye and an introduction of Muskellunge. During this period, Walleye stocking resumed in 2003, and a total of 64,049 spring fingerling Walleye were stocked at an average rate of 7.5 spring fingerlings per acre. Additionally, a total of 1,300 fall fingerling Walleye were stocked at a rate of approximately 1.3 fall fingerlings per acre. Managers proposed to evaluate the stocking success of Walleye and Muskellunge through periodic surveys.

In the 2010s North Manistique Lake continued to be managed as a mixed bag fishery offering angling opportunities for Walleye, Yellow Perch, Smallmouth Bass, Rock Bass, and an occasional Northern Pike. Since 2010, a total of 153,256 spring fingerling Walleye (Bay De Noc strain) have been stocked into North Manistique Lake at an average rate of 15 per acre (range 7.6 to 27). Additional stocking of 680 fall fingerling Walleye was permitted in 2010. North Manistique Lake is also in the early period of a Muskellunge introduction program which is anticipated to provide additional angling opportunities.

Current Status

Three surveys were used to determine the current status of the North Manistique Lake fishery. Status and Trends surveys completed by MI DNR in 2003 and 2014 were conducted to gather general fish community, water chemistry and habitat information. During these surveys the following gear types were used: electrofishing, fyke nets, experimental gill nets, trap nets, and a minnow seine. In 2003 and 2014, total effort for these surveys totaled 51 and 53 efforts, respectively. In addition, a night electrofishing survey was conducted in 2016 to evaluate natural recruitment of Muskellunge stocked in 2004 and 2008. Information from general surveys, conducted in 1995, 2003 and 2000 were also referenced in the Analysis and Discussion section to evaluate long term trend capture information. A complete stocking history of North Manistique Lake can be found in Table 1.

A total of 6,330 fish were captured during the 2014 Status and Trends survey which included 14 species. Piscivore or gamefish species such as Walleye, Northern Pike, Smallmouth Bass, Rock Bass, and Yellow Perch comprised 47 percent of catch by number and 60 percent of the total biomass. Benthic species, such as bottom dwelling Cisco, Common White Sucker, Mottled Sculpin, Johnny Darter, and Logperch comprised 5 percent of catch by number and 38 percent of the total biomass. Lastly, pelagic species (Planktivores-insectivores) such as shiners, minnows, dace, and panfish comprised 48 percent of catch by number and 3 percent of the total biomass. Results showed that the standing crop of North Manistique Lake was approximately 40 pounds per acre.

The fish community in North Manistique Lake includes species typical of inland lakes in Michigan, Minnesota, and Wisconsin. A complete list of species captured in 2003 and 2014 during Status and Trends surveys can be found in Table 2. Overall, fish species composition in North Manistique Lake has changed very little over time (e.g., 50+ years) showing an abundance of Rock Bass, Yellow Perch, and Common White Sucker. Northern Pike, Smallmouth Bass, and Walleye are also common however in lower numbers.

A total of 41 Walleye averaging 17.3 inches comprised 0.6 percent of the catch by number and 12.7 percent of the catch by biomass. Walleye size ranged from 7 to 24 inches with 80 percent of the fish meeting or exceeding the legal size of 15 inches. Age distribution indicated sufficient recruitment with 9 age classes represented. A total of 17 four year old Walleye were captured which provided a sufficient number to assess the growth. Four year old Walleye in North Manistique Lake were growing approximately 1.4 inches above state average. Additionally, two fish captured exceeded ten years of age which may suggest that mortality in this population is low which is expected for Walleye (Schneider 2000). Age analysis indicated that year classes were produced in years when fish were not stocked (2000, 2006, and 2012) which is similar to previous surveys, which showed that some natural recruitment is occurring. Catch per unit effort (CPUE) for Walleye more than doubled in 2014 (CPUE = 0.77) compared to that reported in 2003 (CPUE = 0.31).

A total of 31 Smallmouth Bass averaging 8.3 inches comprised 0.49 percent of the catch by number and 2.4 percent of the catch by biomass. Smallmouth Bass ranged from 3 to 17 inches with 13 percent of the fish meeting or exceeding the legal size of 14 inches. Age distribution indicated sufficient recruitment with 6 age classes represented. A total of 13 two year old Smallmouth Bass were captured which provided a sufficient number to assess growth. Two year old Smallmouth Bass in North Manistique Lake were growing slightly below average (0.5 inches). Catch per unit effort for Smallmouth Bass decreased in 2014 (CPUE = 0.58) compared to that reported in 2003 (CPUE = 0.73).

A total of 3 Northern Pike averaging 28.5 inches comprised 0.05 percent of the catch by number and 2.72 percent of the catch by biomass. Northern Pike size ranged from 24 to 35 inches with 100 percent of the fish meeting or exceeding the legal size of 24 inches. Age distribution indicated variable recruitment as only two year classes were represented (Age 2 and 5). Although sample size was small (n=2), age and growth data suggest that Northern Pike may reach legal size in North Manistique Lake at two years of age. Catch per unit effort for Northern Pike decreased in 2014 (CPUE = 0.06) compared to that reported in 2003 (CPUE = 0.08).

A total of 2,366 Rock Bass averaging 4.8 inches comprised 37.4 percent of the catch by number and 30.8 percent of the catch by biomass. Rock Bass size ranged from 2 to 11 inches with 8 percent of the fish meeting or exceeding the acceptable size of 6 inches. Age distribution indicated sufficient recruitment with 9 age classes represented. Three and four year old fish were represented with the strongest year classes, however were growing slightly below state average. Catch per unit effort for Rock Bass increased nearly 6-fold in 2014 (CPUE = 44.6) compared to that reported in 2003 (CPUE = 8.1).

A total of 32 Pumpkinseed Fish averaging 4.7 inches comprised 0.5 percent of the catch by number and 0.5 percent of the catch by biomass. Pumpkinseed Fish size ranged from 3 to 8 inches with 16 percent of the fish meeting or exceeding the acceptable size of 6 inches. Age distribution indicated sufficient recruitment with 6 year classes represented. Although sample size was small for each age group captured, age and growth data suggest that Pumpkinseed Fish were growing at or slightly above state average. Catch per unit effort for Pumpkinseed Fish increased in 2014 (CPUE = 0.60) compared to that reported in 2003 (CPUE = 0.08).

At total of 526 Yellow Perch averaging 6.2 inches comprised 7.5 percent of the catch by number and 9.4 percent of the catch by biomass. Yellow Perch size ranged from 2 to 12 inches with 26 percent of the fish meeting or exceeding the acceptable size of 6 inches. Age distribution indicated sufficient recruitment with 10 year classes represented. Two, six, seven, and eight year old fish were represented with the strongest year classes, however, were growing below state average (similar to that reported in 2003). Catch per unit effort for Yellow Perch decreased in 2014 (CPUE = 9.92) compared to that reported in 2003 (CPUE = 43.96).

A total of 145 Common White Sucker averaging 15.9 inches comprised 3 percent of the catch by number and 36 percent of the catch by biomass. Common White Sucker size ranged from 6 to 21 inches. A large proportion of the Common White Sucker captured were between the 13 to 19 inch size rage. Catch per unit effort for Common White Sucker increased in 2014 (CPUE = 2.74), compared to that reported in 2003 (CPUE = 1.73).

A total of 48 Cisco (Lake Herring) averaging 8.4 inches comprised 0.7 percent of the catch by number and 1.1 percent of the catch by biomass. Cisco size ranged from 6 to 10 inches. Age distribution indicated sufficient recruitment with four year classes represented. One and two year old Cisco were represented with the strongest year classes and were growing at state average. Catch per unit effort of Cisco increased in 2014 (CPUE = 0.91) compared to that reported in 2003 (CPUE = 0.71).

In 2016, MI DNR conducted a night electrofishing survey to evaluate natural recruitment of Muskellunge that were stocked in 2004 and 2008. No Muskellunge were captured during this survey. Yellow Perch, Rock Bass, Walleye, and Common White Sucker were observed.

Analysis and Discussion

North Manistique Lake is characteristic of a large, deep-bodied unproductive (Oligotrophic) lake with a non-complex shoreline altered by moderate to high levels of riparian development. Physical attributes of this lake coupled with the level of development allow managers to focus on supplementing a stocked, mixed bag fishery where there are low to moderate densities of large gamefish.

Over several decades, standing crop biomass (a measure of lake productivity) was measured after each of four surveys (1995, 2000, 2003, and 2014) conducted in North Manistique Lake. Standing crop biomass averaged 41 pounds per acre (range 27 to 51) from 1995 to 2014. A notable difference was observed in 2000 when the standing crop biomass of fish in North Manistique Lake decreased to approximately 27.2 pounds per acre, which was likely due to the temporary stocking of adult Lake Trout which preyed heavily upon several fish species during this time. However, once stocking of Lake Trout ceased, the standing crop biomass rose to nearly 51 pounds per acre in 2003. Most recently in 2014, the total standing crop biomass for North Manistique Lake was reported to be 49 pounds per acre.

Overall, fish community composition has changed little over the past two decades. For example, the average percent by biomass of benthivores was 34 percent (range 25 to 39). Additionally, the percent biomass of piscivores averaged 65 percent (range 60 to 75). When Rock Bass are removed from the calculation average biomass of piscivores is 45 percent (range 29 to 66), which may be more indicative of a population of predators near or above a preferred balance limit (less than 50 percent representation). Percent by biomass of pelagic planktivores-insectivores increased (3 percent) in 2014 compared to previous years, when this community represented less than 1 percent of the total biomass. This increase is likely due to the large number of Sand Shiners captured during the 2014 assessment, compared to previous years when no Sand Shiners were captured.

Adult Walleye density estimates are low, however, are consistent with unproductive lakes similar to North Manistique Lake. While, Status and Trends assessments are not designed to provide species-specific population estimates for inland lakes. Status and Trends assessments conducted in the same year as a species specific population estimate, may provide managers with the opportunity to make general statements about the abundance of that species provided future Status and Trends data are available. For example, in 2003 a Large Lakes survey (Hanchin and Kramer 2008) was completed to provide species-specific indices of abundance for Walleye. Additionally, several months later, a Status and Trends assessment was conducted in the same year using identical protocols to those used for the

2014 Status and Trends assessment. Results from the population estimate survey conducted in 2003 showed that a population density of 0.90 legal sized Walleye per acre coincided with a 2003 Status and Trends survey catch per unit effort of 0.10 Walleye per net night. Therefore, the 2014 Status and Trends catch per unit effort of 0.13 Walleye per net night may correspond to a density of approximately 1.2 adult Walleye per acre.

Walleye stocking rate as well as the periodicity in stocking should continue to be monitored with respect to the lakes predator and prey population to ensure that overstocking does not occur. The shoreline of North Manistique Lake is quite homogenous and developed to the extent that the forage base is likely negatively affected by the lack of suitable habitat. In 2017, Zeigler et al. stated that stocking of Walleye in a lake which has a density of development beyond 29 dwellings per mile may not be cost effective in terms of the number of Walleye produced and the revenue generated from the waterbody being stocked. Currently, the level of shoreline development in North Manistique Lake is estimated to be 25 dwellings per mile (Figure 1) which suggests that a habitat component be considered as a future management strategy prior to any increase in stocking rate.

The low nutrient levels of North Manistique Lake, coupled with historical high stocking levels of Walleye and other predators may greatly explain the fluctuation in panfish size and abundance over several decades. The number of Walleye captured during the 2014 Status and Trends assessment is encouraging given that 80 percent were of legal size and the average size for four year old Walleye was slightly above the state average. Additional improvements could be gained by having more recent species-specific population data to gauge the health and abundance of the Walleye population in North Manistique Lake. Moreover, the Walleye population in North Manistique Lake supports catches of legal-size fish and growth rates are above the state average for four year-old fish in a lake with low productivity.

Captures of Northern Pike and Smallmouth Bass in survey gear were rare, similar to that encountered during historical surveys conducted in North Manistique Lake. Low capture numbers of Northern Pike are the result of limited habitat for natural reproduction as has been determined in previous years. Captures of Northern Pike are too few to adequately gauge age and growth information; however fish captured are often of preferred size (26 to 32 inches) (Gabelhouse 1984). To date, no Muskellunge have been captured in North Manistique Lake during any survey. Therefore, it is likely that fish planted in 2004 and 2008 either did not survive, or have not recruited to the gear used during surveys. Additional Muskellunge (Great Lakes strain) stocking occurred in 2012, 2014, and 2016 and additional stockings are scheduled to occur in 2018 and 2019. Additional recruitment surveys are needed to confirm whether or not a population has become established. To date, no angler reports of Muskellunge being captured exist for North Manistique Lake. If no Muskellunge are captured during future survey efforts, no further attempts to introduce Muskellunge shall be made.

Diversity and proportional density of panfish in North Manistique is low consisting of Yellow Perch, Rock Bass, and the occasional Pumpkinseed Fish. Over time, size and abundance of Yellow Perch and Rock Bass fluctuated from large numbers of relatively small fish, to fewer numbers of relatively larger (more preferable) fish. Fluctuations in panfish are normal in response to variable recruitment success of predators (namely, Walleye and Smallmouth Bass) which prey on panfish. For example, percent of Yellow Perch captured in 2003 which met the preferred length of 6 inches was only 2 percent. However in 2014, percent of Yellow Perch captured above 6 inches was greater than 26 percent.

These fluctuations could also be indicative of an overabundance or balancing number of predators (namely Walleye) which reduce the number of Yellow Perch providing additional forage to fewer individuals, therefore explaining the increase in the proportion of Yellow Perch that are of a preferred size in 2014.

Common White Sucker have a history of being considered a `rough' fish where lake biomass would become `trapped' and unavailable to other more desirable species that may compete against Common White Suckers for forage. In the past (1960s and 1970s), large efforts were undertaken to remove a large proportion of the population to reduce the level of competition among these competing species. More recent research highlights the importance of `benthic' species such as the Common White Sucker. For example, Childress et al. (2014) reported that the removal of sucker species from lake ecosystems can reduce the amount of nutrients that are transferred to their breeding locations (e.g., rock reefs, streams) and that nearly 18 percent of nutrients utilized by particular macroinvertebrates are sucker-derived. Taylor et al. (2006) highlight the importance of benthic species as they provide a wave of nutrients in response to spawning and caution against removing these species due to the potential for ecological catastrophe. Survey notes recorded during manual removals have documented the consumption of sucker eggs by Yellow Perch. Therefore, the abundance of Common White Suckers directly benefits Yellow Perch during a period when Yellow Perch are consuming forage to prepare for final egg maturation. This information pertaining to the benefit of benthic species such as suckers is relatively new compared to the time frame when these removals were taking place. Therefore, given new information and a review of historical lake specific data suggesting that removals did not benefit competing more desirable species (i.e., Yellow Perch), manual removals should not occur in North Manistique Lake in the future. Common White Sucker capture numbers have been consistent from 1995 to 2014. However, the average size of individuals captured from 2003 to 2014 suggests that the population is getting older with fewer young individuals recruiting to the population. This could be due to an increase in the number of predators that require a soft-rayed prey item which ranges in size from 2 to 12 inches. In 2014, a large proportion of Common White Suckers were found to be 13 inches or greater (approximately 88 percent).

Cisco (Lake Herring) numbers appear to be improving since their decline reported in the 2000 general survey report. In fact, catch per unit effort for Cisco is the highest it has been in the past two decades. The initial decline in 2000 was likely due to the abundance of adult Lake Trout. However, Lake Trout are no longer stocked in North Manistique Lake and numbers have subsequently recovered. Cisco are currently listed in the State of Michigan's Wildlife Action Plan (Eagle et al. 2005) as a Species of Greatest Conservation Need. There are only a few populations statewide and most have exhibited declines in abundance over the period of the past 50 years. Given that numbers appear to be recovering, continued monitoring would benefit this population should a small Muskellunge population develop and start preying on them.

Management Direction

Given the physical attributes of this waterbody (i.e., Oligotrophic) that make this a beautiful yet unproductive lake, managers are encouraged to make minor adjustments (e.g., stocking rate) providing sufficient time for evaluation of previous management strategies prior to submitting additional prescriptions. Physical attributes of this lake, coupled with the level of development, allow managers to focus on supplementing a stocked, mixed bag fishery where there are low to moderate densities of large gamefish. The management goals of this lake are to 1) engage with riparian owners and

association members to serve as a broker of information pertaining to shoreland protection and enhancement, 2) maintain a healthy balance of predators and prey, 3) supplement Walleye to balance Yellow Perch while providing angling opportunities for Walleye, and 4) continue to introduce Muskellunge to provide additional angling opportunities.

The current fish community consists of 60 percent piscivores (29 percent without Rock Bass), 38 percent benthivores, and 3 percent pelagic planktivores-insectivores. Assuming a 30 percent balance, where 30 percent of the biomass is represented by benthivores and 30 percent by piscivores, North Manistique Lake may be near balance. As stocking continues, the balance of each community should be monitored closely. Currently there are two ongoing prescriptions which request stocking of Walleye and Muskellunge.

Walleye (Bays De Noc strain) spring fingerlings will be stocked at the rate of 25 per acre to maintain a balance in the Yellow Perch fishery whereby 30 to 50 percent of the Yellow Perch are greater than the preferred size (6 inches). Stocking will supplement a highly variable but existent naturally reproducing population while continuing to provide angling opportunities for Walleye. If Walleye growth declines 1.0 inches below state average in conjunction with a significant decrease in Yellow Perch abundance, stocking periodicity will be reduced to once every three years.

Muskellunge will be stocked in an effort to provide additional angling opportunities while utilizing a forage base of large benthivores (i.e., Common White Sucker, Cisco). If no Muskellunge are captured during future survey efforts by 2025, no further attempts to introduce Muskellunge shall be made.

The following recommendations can be made to accomplish these goals:
1. Provide education information pertaining to shoreland protection. For example "Natural Shoreline Landscapes on Michigan's Inland Lakes: Guidebook for property owners". Provide information from Michigan State University Extension agents about upcoming shoreland protection workshops.
2. Conduct a full assessment of North Manistique Lake, which includes a Spring Walleye population estimate and a Status and Trends survey by 2025.
3. Conduct periodic (every two to three years) fall electrofishing assessments to evaluate the recruitment success and survival of Walleye and Muskellunge.

References

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

Childress, E. S., J. D. Allan, and P. B. McIntyre. 2014. Nutrient subsidies from iteroparous fish migrations can enhance stream productivity. Ecosystems 17: 522-534.

Eagle, A. C., E. M. Hay-Chmielewski, K. T. Cleveland, A. L. Derosier, M. E. Herbert, and R. A. Rustem. 2005. Michigan's wildlife action plan. Michigan Department of Natural Resources, Lansing, Michigan.

Fuller, L. M, and R. S. Jodoin. 2016. Estimation of Trophic State Index for selected inland lakes in Michgan, 1999-2003: U.S. Geological Survey Scientific Investigations Report 2016-5023, 16p.

Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4: 273-285.

Hanchin, P. A., and D. R. Kramer. 2008. The fish community and fishery of North Manistique Lake, Luce County, Michigan in 2003-2004 with emphasis on walleyes. Michigan Department of Natural Resources, Fisheries Special Report 49, Ann Arbor.

Schneider, J. C. (ed.) 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Taylor, B. W., A. S. Flecker, and R. O. Hall Jr. 2006. Loss of a harvested fish species disrupts carbon flow in a diverse tropical river. Science 313: 833-836.

Ziegler, J. P., E. J. Golebie, S. E. Jones, B. C. Weidel, and C. T. Solomon. 2017. Social-ecological outcomes in recreational fisheries: the interaction of lakeshore development and stocking. Ecological Applications 27(1): 56-65.

https://umich.maps.arcgis.com/apps/MapSeries/index.html?appid=968632529e9747cd9af11dd6b2fff30d. Michigan Status and Trends Inland Lake Habitat Viewer. Michigan Department of Natural Resources, accessed February 2018.

http://ifr.snre.umich.edu/MiFISH/. MiFish. Michigan Department of Natural Resources, accessed February 2018.

Figure 1. Number of dwellings per mile for inland lakes in Michigan's upper peninsula where Walleye populations exist (natural or stocked) and data are available. Dotted line indicates point at which stocking may no longer be cost-effective (29 dwellings per mile: Zeigler et al. 2017) due to levels of riparian development and a lack of course woody habitat refuge.

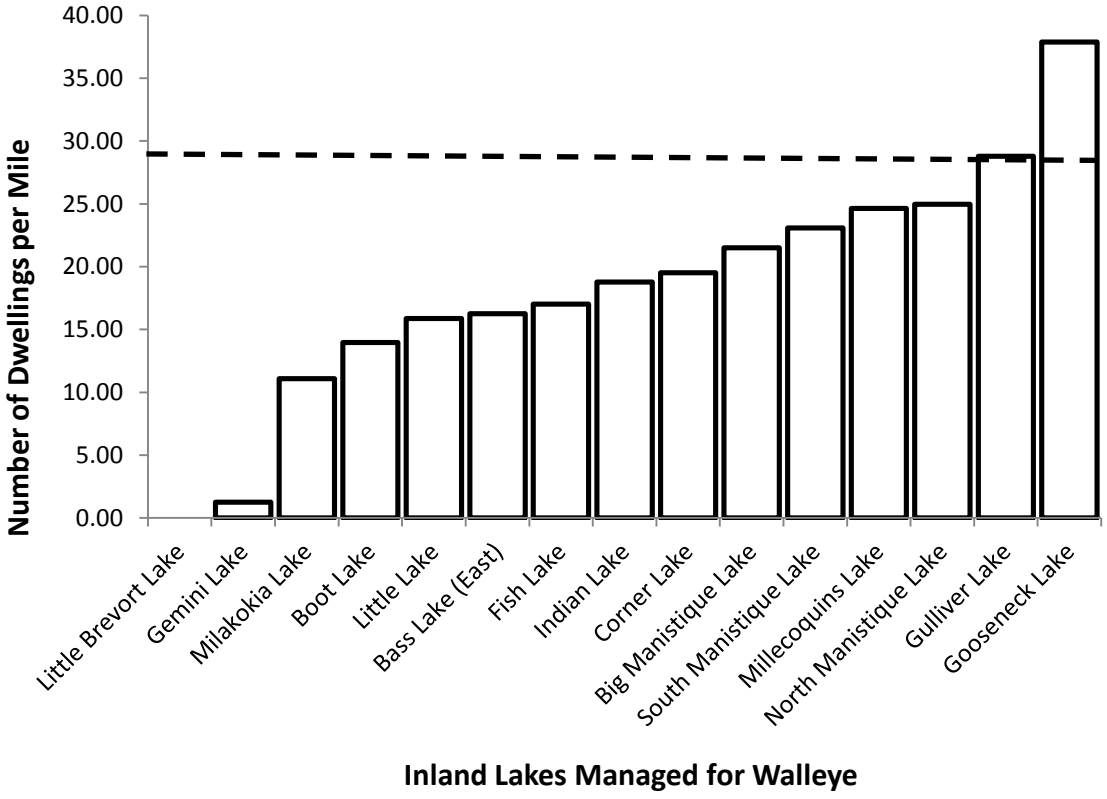

Table 1. Species, strain, year, and the number stocked (N stocked) into North Manistique Lake from 1933 to 2017.

Species	Strain	Year	N Stocked
YELLOW PERCH		1933	2,000
WALLEYE		1934	60,000
WALLEYE		1935	210,000
WALLEYE		1936	150,000
YELLOW PERCH		1936	4,000
WALLEYE		1937	180,000
YELLOW PERCH		1937	5,500
WALLEYE		1938	200,000
WALLEYE		1939	300,000
YELLOW PERCH		1939	3,000
NORTHERN PIKE		1941	130
WALLEYE		1941	180,000
RAINBOW TROUT		1948	2,000
RAINBOW TROUT		1949	2,000
RAINBOW TROUT		1950	2,000
RAINBOW TROUT		1951	500
RAINBOW TROUT		1951	2,000
RAINBOW TROUT		1952	2,000
RAINBOW TROUT		1953	2,000
RAINBOW TROUT		1956	3,000
RAINBOW TROUT		1957	3,000
RAINBOW TROUT		1958	2,000
RAINBOW TROUT		1959	2,000
WALLEYE		1959	1,000,000
RAINBOW TROUT		1960	2,000
RAINBOW TROUT		1961	500
RAINBOW TROUT		1961	500
WALLEYE		1962	150,000
NORTHERN PIKE		1962	40
NORTHERN PIKE		1963	139
WALLEYE		1963	150,000
WALLEYE		1964	1,000,000
WALLEYE		1964	135,000
NORTHERN PIKE		1964	120
NORTHERN PIKE		1964	23
WALLEYE		1965	1,000,000
NORTHERN PIKE		1965	88
NORTHERN PIKE		1965	19
NORTHERN PIKE		1966	122
NORTHERN PIKE		1967	120
NORTHERN PIKE		1968	99

NORTHERN PIKE		1969	105
WALLEYE		1970	75,000
NORTHERN PIKE		1970	200
NORTHERN PIKE		1971	20,000
WALLEYE		1971	1,600
NORTHERN PIKE		1972	356
WALLEYE		1972	1,589
NORTHERN PIKE		1973	25,000
NORTHERN PIKE		1973	1,000
NORTHERN PIKE		1974	10,000
LAKE TROUT		1975	225
LAKE TROUT		1975	335
NORTHERN PIKE		1975	400,000
NORTHERN PIKE		1975	1,921
NORTHERN PIKE		1976	1,075,000
LAKE TROUT		1976	325
NORTHERN PIKE		1976	488
RAINBOW TROUT		1976	10,062
NORTHERN PIKE		1977	601
RAINBOW TROUT		1977	10,000
WALLEYE		1977	375,000
WALLEYE		1978	10,714
WALLEYE		1978	1,000,000
Walleye		1979	1,500,000
Walleye		1979	4,736
Brown trout		1980	6,000
Brown trout		1980	11,000
Walleye		1980	760
Walleye		1980	6,570
Brown trout		1981	12,000
Brown trout	Harrietta	1981	5,714
Walleye		1981	40,000
Walleye		1981	1,289
Brown trout	Harrietta	1982	80
Brown trout	Harrietta	1982	8,500
Lake trout	Marquette	1982	604
Rainbow trout	Harrietta	1982	420
Walleye		1982	17,406
Brown trout	Harrietta	1983	20,000
Walleye		1983	17,099
Brown trout		1984	10,750
Lake trout		1985	870
Lake trout		1985	250
Lake trout	Marquette	1985	225

Lake trout	Marquette	1985	191
Northern pike		1985	15,000
Walleye	Manistique	1985	150,000
Walleye		1986	40,523
Walleye		1986	25,447
Walleye	Manistique	1986	300,000
Lake trout		1987	200
Lake trout	Marquette	1987	8,339
Splake	Hybrid	1987	12,000
Splake	Hybrid	1987	12,000
Splake	Hybrid	1987	12,000
Walleye		1987	17,918
Northern pike		1988	15,000
Northern pike		1989	11,500
Walleye	Manistique	1989	500,000
Walleye	Bay De Noc	1990	34,247
Northern pike		1991	8,876
Walleye	Manistique	1991	974,000
Walleye	Bay De Noc	1992	1,097,400
Walleye	Bay De Noc	1992	40,430
Walleye	Bay De Noc	1992	24,062
Lake trout	Marquette	1993	90
Northern pike		1993	72
Walleye		1993	2,100,000
Walleye	Bay De Noc	1993	20,014
Walleye	Bay De Noc	1994	70,923
Walleye	Bay De Noc	1994	30,303
Walleye	Bay De Noc	1995	4,988
Walleye	Bay De Noc	1995	65,370
Lake trout		1996	285
Lake trout		1996	196
Walleye	Bay De Noc	1996	67,730
Lake trout	Marquette	1997	470
Smallmouth bass		1997	1,301
Walleye	Bay De Noc	1997	62,462
Lake trout		1998	238
Lake trout		1998	5
Lake trout		1998	13
Lake trout		1998	23
Lake trout		1998	57
Lake trout	Apostle/Gull Is	1998	13
Lake trout	Apostle/Gull Is	1998	13
Lake trout	Green Lake	1998	23
Lake trout	Green Lake	1998	23

Lake trout	Lake Superior	1998	238
Lake trout	Lake Superior	1998	5
Lake trout	Marquette	1998	238
Lake trout	Marquette	1998	5
Lake trout	Seneca Lake	1998	57
Lake trout	Seneca Lake	1998	57
Smallmouth bass		1998	2,354
Smallmouth bass		1998	4,800
Lake trout	Marquette	1999	15,000
Lake trout	Marquette	1999	12,048
Lake trout	Marquette	1999	250
Northern pike		2000	96
Walleye	Bay De Noc	2003	23,269
Walleye	Bay De Noc	2003	15,250
Muskellunge	Northern	2004	611
Walleye	Bay De Noc	2004	11,677
Walleye	Bay De Noc	2004	12,243
Walleye	Bay De Noc	2004	1,610
Muskellunge	Northern	2008	1,700
Walleye	Bay De Noc	2008	650
Walleye	Bay De Noc	2009	650
Walleye	Bay De Noc	2010	680
Walleye	Bay De Noc	2011	18,000
Muskellunge	Great Lakes	2012	2,500
Walleye	Bay De Noc	2013	33,677
Walleye	Bay De Noc	2013	13,000
Muskellunge	Great Lakes	2014	2,002
Walleye	Bay De Noc	2015	46,000
Muskellunge	Great Lakes	2016	1,700
Walleye	Bay De Noc	2017	26,448
Walleye	Bay De Noc	2017	16,131

Table 2. Number captured, catch per unit effort, and total biomass of species captured during assessments conducted in1995, 2000, 2003, and 2014. Values listed in the table are from all gear types combined. Gear types included; electrofishing, gill net, fyke net, trap net, and seine haul.

	Total Captured				Catch Per Unit Effort				Total Biomass (lbs)			
Species	**1995**	**2000**	**2003**	**2014**	**1995**	**2000**	**2003**	**2014**	**1995**	**2000**	**2003**	**2014**
Cisco (Lake Herring)	42	15	36	48	0.86	0.37	0.71	0.91	11.80	6.10	9.60	7.50
White Sucker	222	82	88	145	4.53	2.00	1.73	2.74	365.20	181.10	134.60	246.60
Mottled Sculpin	0	0	0	2	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Johnny Darter	0	0	5	3	0.00	0.00	0.10	0.06	0.00	0.00	0.00	0.00
Logperch	0	1	22	104	0.00	0.02	0.43	1.96	0.00	0.00	0.90	1.20
Round Whitefish	104	0	0	0	2.12	0.00	0.00	0.00	18.30	0.00	0.00	0.00
Emerald Shiner	0	0	44	0	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.00
Sand Shiner	0	0	0	3,022	0.00	0.00	0.00	57.02	0.00	0.00	0.00	15.10
Spottail Shiner	0	0	14	1	0.00	0.00	0.27	0.02	0.00	0.00	0.20	0.00
Bluntnose Minnow	0	0	0	6	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00
Blacknose Dace	0	0	1	0	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Pumpkinseed Fish	2	0	4	32	0.04	0.00	0.08	0.60	0.70	0.00	0.20	3.40
Brook Trout	2	0	0	0	0.04	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Northern Pike	20	14	4	3	0.41	0.34	0.08	0.06	108.20	44.70	28.80	17.30
Rock Bass	610	137	415	2,366	12.45	3.34	8.14	44.64	332.60	68.40	40.20	208.40
Smallmouth Bass	23	45	37	31	0.47	1.10	0.73	0.58	44.90	64.00	12.80	15.90
Yellow Perch	83	49	2,242	526	1.69	1.20	43.96	9.92	16.40	17.10	103.60	75.70
Walleye	85	25	16	41	1.73	0.61	0.31	0.77	225.30	52.00	37.10	86.00
Largemouth Bass	1	0	0	0	0.02	0.00	0.00	0.00	1.70	0.00	0.00	0.00
Lake Trout	0	52	0	0	0.00	1.27	0.00	0.00	0.00	324.60	0.00	0.00
TOTAL	1194	420	2928	6330					1126	758	368	677