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Management Plan for Muskellunge in Michigan

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Introduction and Background

This plan focuses on the ecology and management of Muskellunge (*Esox masquinongy*) from the family Esocidae. Esocidae includes two of the more popular game fishes in the Midwest, the Northern Pike (*Esox lucius*) and Muskellunge, as well as one rarely caught and irregularly distributed esocid, the Grass Pickerel (*Esox americanus*). All three of these species share some biological characteristics, yet have unique features of their ecology that affect fishery management. Of the three species, Muskellunge are the most limited in distribution, but may be the most highly regarded as a “trophy” among all freshwater game fish in North America. The purpose of this document is to review the biology and ecology of Muskellunge and their recreational fisheries, and to use this information to guide Muskellunge management in Michigan.

The State of Michigan recognizes several treaties between the United States government and Tribes residing in Michigan. Tribal governments’ signatory to the 1836 Treaty of Washington and the 1842 Treaty of La Pointe retained hunting, fishing, and gathering rights for Tribal members. Tribal governments are sovereign nations, have their own regulations for fishing matters, and may view the management of Muskellunge differently than the state. This plan does not pertain to Tribal fishing rights under the 1836 and 1842 treaties and only describes the management of Muskellunge for state-licensed anglers.

Biology

Muskellunge are much less commonly distributed than Northern Pike in Michigan’s lakes and rivers. Muskellunge is the larger of the two species, and, in some regions of the Midwest, fisheries for large Muskellunge are popular and draw much tourist activity. At about 116, known Muskellunge populations are widely distributed throughout Michigan, but are relatively few compared to the

numerous inland and Great Lakes waters of the state (Appendix A). This may be due to the fact that adults can tolerate a wide range of environmental conditions from warm to cool water, but they typically enjoy only modest spawning success and are highly vulnerable to exploitation and habitat deterioration. Muskellunge populations were native to most of the Great Lakes waters of Michigan, some inland waters of the Upper Peninsula, and were relatively rare in Lower Peninsula inland waters. However, Muskellunge have been widely stocked throughout the state, and many current populations are the results of such stockings, particularly populations in the Lower Peninsula. In addition to Muskellunge, a hybrid of Northern Pike and Muskellunge (known as the Tiger Muskellunge for the pronounced vertical striped pattern) was stocked in many areas of the state in the past. Tiger Muskellunge was preferred for stocking because it was easier to rear in hatcheries, and since it demonstrated no natural reproduction, its populations could be controlled. Subsequent analyses of the fishery indicated there was a relatively small return for the cost of such stocking (Beyerle 1984). The Michigan Tiger Muskellunge stocking program ended in 1991. While uncommon, some hybridization also occurs naturally in waters where Muskellunge and Northern Pike co-exist.

Muskellunge are large top carnivores that inhabit a variety of habitats including vegetated lakes, lakes with drowned timber, and large-slow moving rivers. Muskellunge tolerate a wide range of water temperatures with an optimum of 77°F. Historically, Muskellunge also occurred commonly throughout the Great Lakes. In fact, at least one taxonomic researcher has suggested that Muskellunge inhabiting Great Lakes and connected waters are actually a different species than the native Muskellunge inhabiting land-locked inland lakes of Ontario, Quebec, Michigan, Wisconsin, and Minnesota (Lebeau 1992). However, the taxonomic status of these two groups remains disputed and controversial. For the present, in Michigan, Muskellunge are considered a single species, although there are three distinct color patterns (clear, barred and spotted) exhibited with different frequencies throughout the state. In general, Muskellunge in the Great Lakes and connecting waters exhibit the spotted pattern with greater frequency, while there is a slight tendency for inland Upper Peninsula populations to be characterized by clear markings and southern Michigan inland Muskellunge populations to exhibit the barred pattern. In Michigan, Muskellunge populations typified by the clear and barred color patterns are identified by the Michigan Department of Natural Resources (DNR) as “northern strain”, while populations exhibiting the spotted pattern are identified as “Great Lakes strain” Muskellunge. Throughout the remainder of this document, we will refer to these two strains as northern Muskellunge and Great Lakes Muskellunge. The issue of Muskellunge “strains” in Michigan has become more complex as stocking for fisheries management has occasionally resulted in mixing of the “strains.” One example is the Huron River in Wayne County, where northern strain Muskellunge stocked in Belleville Lake have emigrated downstream and been found co-mingling with wild Great Lakes Muskellunge migrating upstream from Lake Erie to the first fish passage barrier on the system at Flat Rock, Michigan (Scribner et al. 2015). Similar downstream movement of Muskellunge stocked in water bodies with outflows has been documented at other locations around the state and has genetic implications for native Muskellunge populations. In recent years, northern strain Muskellunge have also been obtained from other states (e.g., Iowa and Indiana) and stocked in some Michigan waters.

While populations of Northern Pike and Muskellunge co-exist in many locations throughout the Great Lakes and connecting waters, sympatric populations are less common for inland waters inhabited by northern strain Muskellunge. In some waters, such as Lac Vieux Desert in the Upper Peninsula, both species and their hybrids occur naturally, but in most inland lakes, one or the other species is common. A common observation in many lakes is that if Northern Pike were introduced into an area formerly occupied by Muskellunge, Muskellunge abundance became reduced or eliminated, while Northern Pike flourished (Inskip 1986). There are a variety of reasons why people believe Northern Pike are competitively superior to Muskellunge, mainly having to do with the timing of spawning, as well as the rapid early growth and consumption of young Muskellunge by Northern Pike (Diana 1995).

The number of waters supporting self-sustaining Muskellunge populations appears limited by habitat adequate for successful spawning and recruitment. Their spawning habitat is somewhat similar

to Northern Pike, but tends to be more offshore and in areas with less emergent vegetation. Muskellunge spawn over open substrate, often with woody debris from tree fall on the lake bottom (Zorn et al. 1998). Schrouder (1973) reported that in Michigan, Great Lakes Muskellunge spawned at the edges of river channels among logs and detritus, while northern Muskellunge spawned in shallow bays without current. In the St. Lawrence River, Muskellunge mostly spawned near shore (<5 ft. depth) in submerged aquatic vegetation (Farrell 2001). Muskellunge spawning tends to occur slightly later than Northern Pike, when water temperatures vary from about 40°F to 60°F. Female spawning Muskellunge have been caught in survey trap nets in Lake St. Clair during May with water temperatures ranging from 46°F to 64°F (Thomas and Haas 2009). In general, Great Lakes Muskellunge spawn much later than northern Muskellunge. In the Indian River and Antrim lake chains, Great Lakes Muskellunge spawn as early as May and as late as early June. Eggs are broadcast over suitable areas and settle on the substrate. Muskellunge eggs become embedded in substrate, and often sink into the substrate some distance, depending on substrate firmness. In cases with highly organic substrates, conditions in the spawning habitat may be very low in oxygen and, therefore, poor for Muskellunge egg survival (Dombeck 1986). Eggs that manage to settle on wood or aquatic vegetation, such as *Chara*, may be suspended in better water quality and may then survive (Zorn et al. 1998). Overall survival of Muskellunge eggs is very low, even under controlled conditions (Zorn et al. 1998). Minimum estimates of survival from egg to fall juvenile for St. Lawrence River Muskellunge were 0.03% and 0.10% in two consecutive years (Farrell 2001).

The major limitation of Muskellunge reproductive success is probably successful incubation of eggs, because survival from fry to yearling appears to be relatively high (Zorn et al. 1998). Development of shoreline areas is a major limitation to Muskellunge survival, as humans often alter shoreline around Muskellunge spawning sites, removing fallen trees and other woody debris that may be important to Muskellunge spawning, as well as disturbing the shoreline and soft sediment areas where Muskellunge tend to spawn (Dombeck 1986, Rust et al. 2002). Increasing development along the lakeshore has been shown to have strong negative correlation with Muskellunge spawning success (Rust et al. 2002). In these cases, clearing vegetation, building rip-rap and other structures on the shore, and controlling of lake water levels, all have negative effects on Muskellunge reproduction and survival.

Muskellunge is a top predator preying primarily on other fishes, but they are also known to consume mammals, birds, amphibians, and some reptiles that frequent aquatic environments. While Michigan Muskellunge diet information is limited, some diet studies have been conducted on Muskellunge populations in other waters. In Wisconsin lakes, the diet was diverse with 31 species of fish found in Muskellunge stomachs, along with 35 non-fish items (Bozek et al. 1999). The results of that study indicated that when available, Yellow Perch (*Perca flavescens*) and catostomids (suckers) would compose a large portion of the Muskellunge diet. In the New River, Virginia, Muskellunge under 35 inches in length preyed mainly on minnows, while larger fish shifted to a diet dominated by suckers (Brenden et al. 2004). Although Smallmouth Bass (*Micropterus dolomieu*) were abundant in the New River, they comprised a relatively minor component (4% by weight) of the Muskellunge diet. Other diet studies have shown that Muskellunge growth rates were positively related with abundance of minnows and suckers (Harrison and Hadley 1979, Hanson 1986). In spite of the evidence provided by such diet studies, some stakeholders continue to view Muskellunge as a predatory threat to other native game fish species. This perception has likely been fueled by incidents of Muskellunge attempting to “steal” fish off the hooks of anglers targeting other species such as bass, Walleye (*Sander vitreus*), or perch. The struggling behavior of hooked fish likely triggers a feeding response in Muskellunge that leads anglers to the misperception that Muskellunge normally forage on bass, walleye, or panfish.

Generally, Muskellunge grow rapidly over their first few years of life, but then growth slows considerably thereafter (Scott and Crossman 1973). There is also a strong sexual difference in growth rate, as males grow much slower than females, and males seldom reach an old age and large size. In Michigan, Muskellunge average about 32 inches at age 4 and exceed 40 inches at age 8 (Table 1). Casselman et al. (1999) evaluated growth indices and ultimate length for Muskellunge from 12 water

bodies spread across Ontario. They found a continuum of Muskellunge growth potential across the water bodies, based on the von Bertalanffy parameter L_{∞} (ultimate length) for females. Some water bodies produced large-bodied females (50–55 inch mean ultimate length range), while others produced medium-bodied (45–50 inch) or small-bodied (40–45 inch) females. Similar patterns of growth have been found in Michigan waters. The average age that a Muskellunge reaches a legal size of 42 inches was calculated between eight and eleven years for the majority of populations in Michigan. Some faster growth populations achieve a legal size of 42 inches by six years of age while slower growth populations attain this length at 18 years or simply do not achieve this size at all. Many factors could contribute to these differences in growth potential between water bodies, including population density, prey abundance, exploitation, and habitat features such as temperature. Muskellunge have an advanced age at first maturation: often males do not mature until they are three to four years old, and females until they are six or eight years old. From 2004 to 2006, the ripe male Muskellunge collected by DNR survey nets in Lake St. Clair ranged in age from 4 to 18 years old, while ripe females ranged from 6 to 19 years old (Thomas and Haas 2008). This relatively old age at maturity, coupled with low population densities, make Muskellunge highly vulnerable to exploitation.

Table 1.—Muskellunge mean length (inches) at age (years) for various waters across Michigan and statewide average. SWA = Michigan statewide average. NA = data not available.

Age	SWA	Water body			
		Lake St. Clair	Thornapple Lake	Lake Hudson	Cisco Chain of Lakes
0	6.8	—	—	—	—
1	15.7	—	—	—	—
2	19.9	—	23.2	—	18.6
3	25.4	—	28.8	28.5	—
4	31.9	—	32.6	31.6	29.4
5	34.7	35.9	36.0	32.3	33.5
6	36.8	38.7	37.5	33.5	—
7	39.2	39.0	39.3	34.1	—
8	41.7	40.6	40.1	34.8	35.4
9	45.3	42.7	42.3	35.5	39.7
10	48.7	44.2	41.3	36.3	—
11	NA	43.8	43.8	36.4	39.6
12	NA	44.1	45.6	—	45.6
13	NA	42.6	48.2	36.5	—
14	NA	44.5	—	37.5	43.2
15	NA	47.0	—	—	—

The older age at maturation, coupled with poor survival of young from egg through sac fry, result in Muskellunge having very low densities in most lakes. Unfortunately, because adult Muskellunge commonly occur at low densities, sampling efforts and statistical interpretation are difficult (Cornelius and Margenau 1999). As a result, estimates of abundance or densities for Muskellunge populations are sparse in the literature. At Bone Lake, Wisconsin, estimated adult Muskellunge density varied from 0.18 fish per acre in 1964 to a maximum of 0.99 fish per acre in 1995 (Cornelius and Margenau 1999). The increase in density was attributed to increased minimum size limits and voluntary catch and release. Siler and Beyerle (1986) reported that stocking in Iron Lake, Michigan resulted in high adult northern

Muskellunge densities of 0.84 per acre. They attributed declines in both Black Crappie (*Pomoxis nigromaculatus*) and White Sucker (*Catostomus commersonii*) populations in Iron Lake to predation pressure from an abnormally high density of Muskellunge. Population estimates in Wisconsin indicate that numbers from 0.2 to 1 adult fish per acre are common, with the average density being less than one half fish per acre (Hanson 1986). Comparable population densities are not available for rivers, but Muskellunge may be even less dense in river systems. This low population density means that in lakes of 1,000 acres the population of adult Muskellunge is probably less than 500 fish. Michigan DNR fish stocking guidelines set a goal of one adult fish per 3 surface acres, or 0.33 adult fish per acre (Dexter and O'Neal 2004).

Status of the Fisheries

Muskellunge have historically not been taken in such numbers as to give it any commercial significance. A single report from the St. Mary's River in 1885 reported a catch of 8,600 pounds (Michigan Fish Commission 7th Biennial Report). Currently the state operates a recreational fishery while the 1836 Treaty Tribes are permitted a recreational and subsistence fishery. Several treaties exist between the United States government and Tribes residing in Michigan. Tribal governments' signatory to the Treaties of 1836 and 1842 retained fishing rights for Tribal members and the Tribes may view management of Muskellunge differently than the state. Tribal governments' are sovereign nations and operate their fisheries pursuant to their own regulatory and management systems. The Treaty of Washington, signed in 1836, covers the eastern Upper Peninsula and the northern Lower Peninsula 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, including specific Muskellunge fishing restrictions in the Treaty of Washington area (U.S. v. Michigan, 2007). The Treaty of La Pointe, signed in 1842, covers the western Upper Peninsula and a portion of northern Wisconsin. Currently, there is no formal agreement in place between the Tribes and the state to define the extent of the Tribes' 1842 Treaty reserved rights within Michigan. However, the 1842 Treaty rights have been adjudicated in Wisconsin. Currently the Tribes of the Voigt Intertribal Task Force conduct inter-Tribal 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. A Tribally-regulated, spring subsistence spear fishery is present in the western portion of the Upper Peninsula within the 1842 Treaty area. The Tribes do not currently commercially harvest Muskellunge in Michigan.

Schrouder (1973) reported that recreational Muskellunge angling in Michigan was managed as a "trophy" fishery. However, managing for a "trophy" fishery has many associated challenges. The definition of "trophy" is subjective and can vary among anglers and even change for individual anglers as their experience level increases. Confounding this issue is the inherent difference between biological and social definitions of "trophy" management (Younk and Pereira 2003). Presently, the objective of Muskellunge management in Michigan is to provide anglers with the opportunity to catch large fish while promoting ecologically sustainable and balanced fish populations supported by natural reproduction or judicious supplemental stocking. Muskellunge are a top predator and can help maintain a healthy predator-prey balance, while providing additional diversity in the fishing opportunities available to Michigan anglers.

Michigan sport fishing regulations for Muskellunge have shown a trend of increasing minimum size limit (MSL) and reduced bag limit over the last 70 years. In 1939, the statewide regulations were a 30-inch MSL with no daily limit (unlimited). In 1970, the MSL was still 30 inches, but the daily limit had been reduced to 1 fish per day. Since 1995, the statewide regulations have been a 42-inch MSL with a one fish daily bag limit, designed to restrict harvest and promote the occurrence of large fish

in the population. This trend reflects management efforts to decrease fishing mortality and increase survival and potential recruitment, thus promoting optimum densities of large Muskellunge. These efforts result in two-fold benefits, increasing top-down predatory control of prey fish populations while providing fishing opportunities for memorably large Muskellunge (Table 2). In addition to these general regulations, Michigan-Wisconsin boundary waters have special angling regulations along with 19 inland waters that have special regulations that may include a 50” minimum size limit, shortened fishing season (last Saturday in April to November 30) or tackle restriction for artificial lures only. Statewide, 30 Muskellunge waters are also closed to all recreational spearing or Muskellunge spearing by non-Tribal members.

Table 2.–General recreational fishing regulations for Muskellunge in Michigan’s inland and Great Lakes waters, 2011.

Gear	Region	Season	Minimum size limit	Daily bag limit
Hook/line	Upper Peninsula	May 15 – March 15	42”	1
Hook/line	Lower Peninsula	Last Saturday in April to March 15	42”	1
Hook/line	Great Lakes	See note below table	42”	1
Spear ^a	Statewide	December 1 to March 15	42”	1

^a No muskellunge spearing on Lake St. Clair, Lake Erie, Detroit River, and St. Clair River.

Note: Upper Peninsula Great Lakes waters and St. Mary’s River (May 15 – February 28); Lower Peninsula waters of Lake Michigan, Lake Huron and Lake Erie (open all year); and Lake St. Clair, St. Clair River and Detroit River (1st Saturday in June – December 15).

A review of the statewide hook-and-line fishing regulations for the Great Lakes states in 2007 found that the Michigan statewide Muskellunge regulations were among the most conservative. Minimum size limit regulations varied from none in Ohio to 42” in Michigan. Daily bag limits were consistently one per day for all jurisdictions, except for Ohio where the daily limit was two fish. Ontario has established five benchmark values based on growth potential and management objectives for high-density populations, enhanced size fisheries, and for world class fisheries (Casselman et al. 1999). Similarly, Wisconsin has designated five minimum size limit standards so that the appropriate regulation can be applied based on characteristics of the Muskellunge population. Muskellunge regulations have increased in several jurisdictions since the original work on this plan began. Minnesota increased their statewide regulation to 48 inches and Wisconsin is currently reviewing minimum size limit regulations with the goal of increasing the statewide size limit. In 1986, recreational spear fishing for Muskellunge was allowed in four states (Ragan et al. 1986). Michigan is currently the only state that allows the opportunity for spearing of Muskellunge by recreational anglers.

Voluntary catch and release (C&R) has become a common practice among Muskellunge anglers. In fact, at Lake St. Clair, about 99% of all fish reported caught by Muskellunge anglers were released (Thomas and Haas 2004). Statewide, the popularity of catch-and-release fishing for Muskellunge is apparent in Master Angler program entries. Since 2000, catch-and-release entries have accounted for 73% to 86% of the Muskellunge registered in the Master Angler program annually. The DNR Master Angler program recognizes anglers who catch exceptionally large fish. The current Muskellunge entry requirements for the Master Angler program are 42 inches or longer in total length, or weight exceeding 20 pounds.

The Michigan recreational hook-and-line fishery is conducted primarily during the summer and fall open-water period. The winter ice fishery is largely a catch-and-keep spear fishery. In 2008, the statewide spear fishing season was extended to include December 1 to March 15. Previously, the statewide spear fishing season only included January and February. From 1994 to 2006, a total of 1,101 Muskellunge were registered for Master Angler recognition. About 4% of those were reported caught by ice fishing or spearing methods during January and February. Nearly 81% of the registered Muskellunge were caught by hook-and-line methods from June through October. For inland waters, May was also an important month, accounting for about 15% of the total entries.

Public concerns about the health effects of eating large piscivores such as Muskellunge could also be a factor in the popularity of catch-and-release fishing for Muskellunge in Michigan. The Michigan Department of Community Health (MDCH) issues advisories for consumption of sport-caught fish (MDCH 2008). A statewide advisory for consumption of Muskellunge, based on elevated levels of mercury, recommends that women of child-bearing age and children eat no more than one meal of Muskellunge per month, while the rest of the human population should restrict consumption to one meal per week. In 2008, an additional advisory recommending no consumption of Muskellunge, due to mercury contamination, continued for Lake St. Clair (Macomb County).

Michigan Muskellunge fisheries have not been well documented with standard creel surveys. The standard Michigan creel surveys are designed to collect data that will allow unbiased estimates of effort, harvest, and catch for the majority of the sport fishing effort on a water body. However, specialized fisheries such as those pursued by a relatively small proportion of the anglers, or fish populations spatially concentrated in a very limited area of the water body, or temporally different than most of the fishing activity, may not be well represented in the creel survey. Because Muskellunge fishing often accounts for only a fraction of the fishing effort and catch on a water body, the creel survey methods may not encounter them and thus fail to reflect their presence. Therefore, reliable estimates of targeted effort, harvest, and catch are not available for most Michigan Muskellunge fisheries. For example, creel surveys from 2002 through 2004 on the Michigan waters of Lake St. Clair, likely the location of the most intensive and productive Muskellunge fishery in the state, indicated that only about 5% of the boat anglers interviewed were seeking Muskellunge (Michigan Department of Natural Resources, unpublished data). During this time period, creel survey clerks collected biological data from almost 7,000 fish, but only encountered 6 Muskellunge. A 2002-03 creel survey on the Cisco Chain of Lakes along the Michigan-Wisconsin border could not generate a harvest estimate for Muskellunge because none were observed in the angler harvest during the open water fishery, but the survey estimated 316 Muskellunge were caught and released (Hanchin et al. 2008). Similarly, a Black Lake (Cheboygan County) creel survey in 2005 produced an estimated total catch of over 43,000 fish for all species combined, but the total estimated Muskellunge catch was only 3 fish (Michigan Department of Natural Resources, unpublished data). However local DNR fisheries biologists have observed or received angler reports of many more Muskellunge taken during the winter ice fishery. During the 2008-09 creel survey of Elk and Skegemog lakes (Antrim, Kalkaska, and Grand Traverse counties) anglers harvested 5 Muskellunge (all during winter) and released 82 Muskellunge (all during the open-water period). Because of the difficulties in monitoring Muskellunge fisheries with standard creel survey procedures, specialized methods such as angler diary programs have sometimes been employed to monitor trends in angler effort, success, and catch statistics for selected Muskellunge fisheries (Thomas and Haas 2004, Kerr 2007, Mosindy and Duffy 2007).

The DNR recognizes 116 inland and Great Lakes Muskellunge waters across the state (Appendix A). Seventy-seven of these waters have self-sustaining populations and the remainder is maintained with stocking. Large southern Michigan rivers represent an opportunity for expanding Muskellunge distribution in the state. Seelbach (1988) recommended this opportunity should be explored, and that Great Lakes Muskellunge would be the appropriate strain to use on an experimental basis. Similarly, restoration of Muskellunge populations to historical locations along the Great Lakes shorelines would expand fishing opportunities and restore a native predator. Wisconsin successfully reintroduced

Muskellunge to Green Bay, Lake Michigan, and created a fishery using Great Lakes strain Muskellunge (Kapuscinski et al. 2007). A Great Lakes Muskellunge program in Michigan was initiated in 2011 with stocking taking place for the development of both recreational fisheries and inland broodstock lakes.

Estimates of exploitation for Muskellunge fisheries in Michigan are limited. As discussed earlier, the characteristic low density of Muskellunge populations makes it difficult to assess fisheries metrics such as abundance, harvest, and exploitation. In many Michigan waters, standard surveys often don't capture enough Muskellunge to even provide adequate data for evaluating growth rates. Tagging efforts during recent large lake surveys have provided some indication of exploitation (Patrick Hanchin, Michigan Department of Natural Resources, personal communication). At Peavy Impoundment, seven legal-sized Muskellunge were tagged and released and one was reported harvested within the first year, for an annual exploitation rate of 14%. At Skegemog Lake, 4 out of a total of 11 tagged Muskellunge were known to have been harvested in less than a year, for a minimum annual exploitation rate of 36%.

For all Muskellunge populations, achieving maximum size potential requires low exploitation. For Muskellunge, a good recruitment level of 0.4 age-0 fish per acre would be reduced to only 0.07 fish per acre by age-8 (average size 42 inches) if only natural mortality occurred. Adding in annual fishing mortality at 16% (instantaneous fishing mortality at 0.18; Brenden et al. 2007) would lower the number at age 8 to 0.03 fish per acre. So in a population with 15 age-groups and the presence of fishing, the combined abundance of age-8 and older fish would be 0.10 fish per acre. Therefore, the age and size distribution of a Muskellunge population is very sensitive to even low levels of exploitation. As another example of this fragile nature, removing all fishing or hooking mortality from a normally exploited population would increase the abundance of large Muskellunge by only about 2 fish per 10 acres, and this would take 15 years to occur completely and at least 8 years to even be noticeable in the population. In contrast, a quality deer generally is accepted to be about 5 years of age, and elimination of hunting would be reflected in the population within about five years of the regulation change.

Michigan's Muskellunge Management Plan

The purpose of this management plan is to improve the quality of Muskellunge recreational fishing opportunities in Michigan by protecting and enhancing existing Muskellunge stocks and the environmental conditions upon which they depend, and by improving technical information and outreach, in partnership with the anglers of the state.

We propose that Muskellunge should be managed for recreational angling on a statewide basis with uniform management objectives that optimize the abundance of large fish, while ensuring the sustainability and ecological integrity of the rest of the fish community. Further classification of populations or habitat types does not seem necessary when only 116 populations are known to exist in the state. Of course, we do not rule out creating exceptions where certain individual waters could have special regulations and objectives. The recreational management objectives for Muskellunge should reflect the guiding mission statements for both the DNR and Fisheries Division. The DNR is committed to the conservation, protection, management, use, and enjoyment of the state's natural resources for current and future generations. It is Fisheries Division's mission to protect and enhance fish environments, habitat, populations, and other forms of aquatic life and promote optimum use of these resources for the benefit of the people of Michigan. Managing Muskellunge in Michigan to provide sustainable fisheries for these large predators, while fostering predator-prey balance, species diversity, and habitat quality meshes well with the missions of both Fisheries Division and the DNR.

Goals, Issues, and Objectives

This plan identifies current issues that prevent attainment of the goals, and provides suggestions of how best to address these issues.

Goal 1. Protect, restore, and enhance Muskellunge habitat on Michigan waters

Issues

- Michigan lakes exhibit a high diversity in chemical and physical characteristics across the state's large area. These differences need to be understood to successfully manage and protect Muskellunge populations.
- The simplification or loss of littoral and riparian habitat (e.g., seawalls, loss of large woody cover, conversion of vegetated littoral zones to sandy beaches, etc.), including incompatible aquatic plant management, is a major threat to the state's Muskellunge fisheries.
- Riparian land uses affect fisheries habitat, yet enforcement of existing rules and development of more appropriate measures to protect nearshore habitat is lacking.
- Fisheries Division has no regulatory authority for human activities affecting the littoral and riparian habitats required by self-sustaining Muskellunge populations.
- Education of lakeshore property owners on the importance of habitat to fisheries is not consistent across the state.
- Sedimentation, due largely to non-point-source runoff, negatively affects many of Michigan's waters.
- Barriers to fish passage including dams, lake level control structures, poorly designed stream crossings for roads, etc., can restrict Muskellunge spawning movements and reduce available spawning and nursery habitat.
- Invasive aquatic species have demonstrated the ability to drastically alter the habitat in inland waters. Examples include rusty crayfish, zebra and quagga mussels, and Eurasian milfoil.

Objectives and Strategies

- Locate, document, and protect existing functional littoral and riparian habitat through joint local, federal, and state efforts.
- Ensure that local concerns for the fishery are incorporated into decisions on proposed habitat alterations. Evaluate the current waterway, wetland, riparian, and aquatic plant management permitting procedures and ensure that fisheries biologists and angling-interests are included in the process.
- When requested by Department of Environmental Quality, Fisheries Division biologists should provide comments on proposed habitat alterations that reflect the established Fisheries Division policies for such activities.
- Review/develop educational material on the value of aquatic habitats for lake property owners associations and identify opportunities for interaction and input. O'Neal and Soulliere (2006) is an excellent resource that should be useful in this effort.
- Ensure that effective, cost-efficient habitat protection, restoration, and enhancement procedures are documented and used consistently throughout the state.
- Improve enforcement of existing habitat protection regulations.
- Support statewide and regional efforts to biologically control the spread of invasive aquatic species throughout Michigan's waterways.

Goal II. Ensure that adequate technical information is available for Michigan's Muskellunge fisheries.

Issues

- There is often insufficient information on Muskellunge populations and angler use in Michigan to make informed management decisions.
- The current Status and Trends inland lake monitoring program does not adequately sample Muskellunge population metrics.
- The 2011 Charter Boat reporting system does not capture complete information on catch-and-release charter fishing activity for Muskellunge.

Objectives and Strategies

- Promote/develop cooperative efforts with external partners to obtain information about specific fisheries.
 - Implement local voluntary creel or diary programs (using a standardized form for all areas within the state).
 - Work with private groups and Michigan's universities to set up a fund to support graduate students to work on specific esocid-related information needs (to be initiated by an external partner).
- Develop a statewide strategy to ensure sufficient information is available on Muskellunge fisheries.
 - Support the systematic monitoring of Michigan's inland waters through the Status and Trends Program and Large Lakes Monitoring Program, both of which provide valuable fish community data, while recognizing the need for additional sampling to effectively monitor Muskellunge population parameters.
 - Adopt a standard Muskellunge survey protocol for Michigan inland waters (See Appendix B for a proposed template).
 - Survey Michigan anglers to determine demand for various types of fishing opportunities for Muskellunge. This survey could be part of a statewide angler survey with specific questions targeting Muskellunge anglers.
 - Support the statewide inland waters creel survey program and explore options for improving the estimates of Muskellunge fishery targeted effort, harvest, and catch when Muskellunge waters are creel surveyed.
 - Modify the Michigan Charter Boat reporting system to collect complete information on Muskellunge charter fishing activity, including catch-and-release fishing.
- Maintain a standing Esocid Committee within Fisheries Division to foster continued attention to Esocid management issues. Initial assignments for this committee relating to Muskellunge include:
 - Development and maintenance of a statewide Muskellunge angler diary program.
 - Development of a sampling protocol for monitoring Muskellunge in Michigan's inland waters.
 - Evaluate Muskellunge stocking rates recommended in the DNR stocking guidelines (Dexter and O'Neal 2004) and pursue revision of the guidelines for stocking Muskellunge if appropriate.
 - Muskellunge fingerling production is quite variable. Sometimes stocking requests exceed fingerling production, while in other years; production can exceed the level of stocking

desired by managers. A system of prioritizing stocking requests to most effectively use the fingerling production each year should be developed.

Goal III. Protect, maintain, and enhance Michigan's recreational Muskellunge fisheries and associated fish assemblages and aquatic communities.

Issues

- Stocking of Muskellunge occurs to a limited degree by the department, mainly for the maintenance of existing populations with poor natural recruitment.
- Muskellunge fingerling production is quite variable. Sometimes stocking requests exceed fingerling production, while in other years; stocking rates have exceeded desires by anglers and the Esocid Committee.
- Muskellunge can potentially interact strongly with other components of the fish community, particularly soft-rayed fish species, but the outcomes are poorly documented.
- Escapement of stocked northern strain Muskellunge in watersheds with self-sustaining populations of Great Lakes Muskellunge poses a genetic threat to those populations.
- Great Lakes strain Muskellunge have not historically been reared for stocking in Michigan, yet management prescriptions do call for them in some locations. Fish production in the Fisheries Division should develop a capacity specifically for Great Lakes Muskellunge even if necessary at the cost of some existing capacity of northern Muskellunge.

Objectives and Strategies

- Maintain Michigan's existing self-sustained Muskellunge populations through habitat protection and enhancement, as well as management of fishing exploitation.
- Use stocking as a judicious means to maintain Muskellunge populations in waters where recruitment is limited. Also use stocking to re-establish formerly self-sustained Muskellunge populations that have been extirpated or severely depressed by catastrophic natural, inadvertent, or intentional sources of mortality (e.g., winterkill, fish kill, chemical reclamation, disease, etc.) including Great Lakes Muskellunge in the state's Great Lakes waters, particularly Saginaw Bay and the St. Marys River, which exhibit a high potential for that strain. See DNR Muskellunge stocking guidelines (Dexter and O'Neal 2004).
- Implement a broodstock and rearing plan for Great Lakes Muskellunge to support a stocking program for that strain in Michigan.
- Maintain the genetic integrity of Michigan's Muskellunge populations. Where stocking is used to establish or maintain a Muskellunge population, ensure that it does not have a negative effect on extant self-sustained Muskellunge populations in the receiving or connected waters. Implement the proposed guidelines within Michigan's Great Lakes basins by making every reasonable effort to obtain fish for stocking from: 1) the same water, or, if not available, 2) waters within the basin.
- Evaluate Muskellunge stocking rates recommended in the DNR stocking guidelines (Dexter and O'Neal 2004) and pursue revision of the guidelines for stocking appropriate strains of Muskellunge.
- Develop a system of prioritizing stocking requests to most effectively use the fingerling production each year.

Goal IV. Communicate with anglers and promote the recreational value of Michigan's Muskellunge fisheries.

Issues

- Muskellunge populations and fisheries can attract tourism with local economic benefits, but many communities haven't promoted the resource.
- Ecological differences between water bodies affect the potential management options available for Muskellunge fisheries and may warrant differences in fishing regulations.
- Better communication is needed between various stakeholder groups regarding conflicting values for Muskellunge fisheries (spearing interests versus no-kill proponents for example).
- The definition of "trophy" can be subjective and varies between anglers and angler groups.
- Identification of Northern Pike and Muskellunge can be problematic for some anglers.

Objectives and Strategies

- Develop a working stakeholders committee to accomplish the following:
 - Increase awareness of the economic benefits of Muskellunge fisheries to Michigan's economy.
 - Increase public awareness of the potential of Muskellunge as a top predator in maintaining balance in some aquatic systems in Michigan.
 - Facilitate communication between interest groups with various values for Muskellunge fisheries in Michigan (spearing interest versus no-kill proponents for example).
 - Increase education efforts on the identification, biology, and management of Muskellunge in Michigan.
 - Pursue outside funding for public education and outreach efforts.
 - Provide a forum for communication between anglers and staff within Fisheries Division.
 - Provide an opportunity to discuss regulatory decisions and non-regulatory issues affecting Muskellunge fisheries.

Goal V. Provide a variety of fishing opportunities for Muskellunge in Michigan.

Issues

- Conflicts exist between various user groups.
- Michigan is the only state that allows the opportunity for spearing Muskellunge by recreational anglers.
- Muskellunge remain absent or extremely rare in many waters that historically supported native Muskellunge populations.
- Until 2011, the lack of a Great Lakes Muskellunge broodstock and rearing program limited stocking options for many waters.

Objectives and Strategies

- Provide fisheries biologists with a simple regulatory framework for managing Muskellunge that includes fishing opportunities for memorably-large fish, while addressing the diverse interests of various Muskellunge fishing interest groups. Maintain a statewide minimum size limit of 42 inches, while using a 46 inch size limit to promote survival of quality sized fish where popular recreational fisheries exist. Use a 40 inch size regulation where populations that fail to exhibit a healthy size structure or conflicts occur with co-management of Muskellunge and other game fish. Maintain a possession limit of one fish per angler each fishing season.

- Increase Muskellunge fishing opportunities by
 - Introducing Great Lakes strain Muskellunge to large rivers in southern Michigan as recommended by Seelbach (1988).
 - Re-establishing Great Lakes Muskellunge in historical locations around the Great Lakes, including areas such as Thunder Bay and Saginaw Bay, Lake Huron and the drowned river-mouth lakes along the Lake Michigan shoreline.
- Manage stocked waters for adult Muskellunge densities of at least 0.3 fish per acre, while maintaining exploitation rates of state licensed anglers below 5% annually.
- Maintain target adult mean size of at least 38 inches.
- Prevent annual exploitation rates from exceeding 25% to prevent recruitment over fishing on naturally reproducing populations.
- Review classification of Muskellunge fisheries based on population genetic patterns between Great Lakes and northern strain that are supported by natural reproduction or supplemented through stocking.

Summary and Action Items

This document provides a review of the biology and ecology of Muskellunge, compiles the available knowledge of the Muskellunge fisheries in Michigan, and proposes a strategy for the future management of Muskellunge in Michigan. We propose that Muskellunge should be managed on a statewide basis with uniform management objectives that optimize the abundance of large fish, while ensuring the sustainability and ecological integrity of the rest of the fish community. Goals addressing the areas of habitat, technical knowledge, fish populations, and stakeholders are presented. Issues representing impediments to the achievement of those goals are identified and objectives and strategies to address those issues are included. A list of some of the strategies and objectives is presented here as action items.

- Maintain a standing Esocid Committee within Fisheries Division to foster continued attention to Esocid management issues (Goal II – Technical Information).
- Maintain the genetic integrity of Michigan’s Muskellunge populations. Where stocking is used to establish or maintain a Muskellunge population, ensure that it does not have a negative effect on extant self-sustained Muskellunge populations in the receiving or connected waters (Goal III – Muskellunge Fisheries).
- Develop a broodstock and rearing program for Great Lakes Muskellunge to support a stocking program for that strain in Michigan (Goal III – Muskellunge Fisheries).
- Maintain extensive rearing ponds for northern and Great Lakes strain Muskellunge to provide a stable annual production of fall fingerlings (Goal III – Muskellunge Fisheries).
- Survey Michigan anglers to determine demand for various types of fishing opportunities for Muskellunge. This survey could be part of a statewide angler survey with specific questions targeting Muskellunge anglers (Goal II – Technical Information).
- Develop a standard Muskellunge survey protocol for Michigan waters. Until developed, use the Northern Pike protocol (Goal II – Technical Information).
- Evaluate Muskellunge stocking rates recommended in the DNR stocking guidelines (Dexter and O’Neal 2004) and pursue revision of the guidelines for stocking Muskellunge if appropriate (Goal III – Muskellunge Fisheries).
- Develop a system of prioritizing stocking requests to most effectively use the fingerling production each year (Goal III – Muskellunge Fisheries).

- Facilitate communication between interest groups with various values for Muskellunge fisheries in Michigan (e.g., spearing interest versus no-kill proponents; Goal IV – Communicate with anglers).
- Maintain biological reference points for Muskellunge populations in Michigan as outlined in Goal V (Provide fishing opportunities).
- Re-establish Great Lakes Muskellunge in historical locations around the Great Lakes, including areas such as Thunder Bay, Saginaw Bay, St. Marys River, and the drowned river mouth lakes along the Lake Michigan shoreline (Goal V – Provide fishing opportunities).
- Re-introduce Great Lakes strain Muskellunge to large rivers in Southern Michigan as recommended by Seelbach (1988; Goal V – Provide fishing opportunities).
- Develop current regulations for Muskellunge that recognize the values of state-licensed anglers and is based on scientific objectives for these fisheries (Goal V – Provide fishing opportunities).

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Appendix A.–List of known Michigan Muskellunge waters. Muskellunge populations are designated as native (population known to have existed prior to any stocking programs), stocked (population established and maintained by stocking), and naturalized (self-sustaining Muskellunge populations believed to have originated from past stocking practices).

ID	Great Lake basin	Management unit	County	Water body	Surface acres	Stocked or naturalized	Strain	Special regulations
1	Erie	LEMU	Hillsdale	Lake Diane	283	stocked	Northern	no
2	Erie	LEMU	Lenawee	Lake Hudson	502	stocked	Northern	yes
3	Erie	LEMU	Macomb	Lake St. Clair	275,000	native	Great Lakes	yes
4	Erie	LEMU	Monroe	Lake Erie		native	Great Lakes	no
5	Erie	LEMU	St. Clair	St. Clair River		native	Great Lakes	yes
6	Erie	LEMU	Wayne	Belleville Lake	1,270	stocked	Northern	no
7	Erie	LEMU	Wayne	Detroit River		native	Great Lakes	yes
8	Erie	LEMU	Wayne	Huron River		stocked & native	Northern and GL	no
9	Huron	NLHMU	Alpena	Lake Winyah	1,530	stocked	Northern	no
10	Huron	NLHMU	Alpena	Thunder Bay River		native	Great Lakes	no
11	Huron	NLHMU	Cheboygan	Black Lake	10,130	native	Great Lakes	no
12	Huron	NLHMU	Cheboygan	Black River		native	Great Lakes	no
13	Huron	NLHMU	Cheboygan	Burt Lake	17,120	native	Great Lakes	no
14	Huron	NLHMU	Cheboygan	Cheboygan River		native	Great Lakes	no
15	Huron	NLHMU	Cheboygan	Indian River		native	Great Lakes	no
16	Huron	NLHMU	Cheboygan	Mullett Lake	17,360	native	Great Lakes	no
17	Huron	NLHMU	Chippewa	St. Mary's River		native	Great Lakes	no
18	Huron	NLHMU	Emmet	Crooked River		native	Great Lakes	no
19	Huron	SLHMU	Clare	Budd Lake	175	stocked	Northern	yes
20	Huron	SLHMU	Gladwin	Ross Imp.	294	stocked	Northern	no
21	Huron	SLHMU	Gladwin	Secord Imp.	815	stocked	Northern	no
22	Huron	SLHMU	Gladwin	Smallwood Imp.	232	stocked	Northern	no
23	Huron	SLHMU	Gladwin	Wixom Imp.	1,980	stocked	Northern	no
24	Huron	SLHMU	Midland	Sanford Lake	1,250	stocked	Northern	no
25	Michigan	CLMMU	Antrim	Benway Lake	127	native	Great Lakes	no
26	Michigan	CLMMU	Antrim	Elk Lake	7,730	native	Great Lakes	no
27	Michigan	CLMMU	Antrim	Ellsworth Lake	120	native	Great Lakes	no
28	Michigan	CLMMU	Antrim	Hanley Lake	38	native	Great Lakes	no
29	Michigan	CLMMU	Antrim	Intermediate	400	native	Great Lakes	no
30	Michigan	CLMMU	Antrim	Six-mile Lake	407	native	Great Lakes	no
31	Michigan	CLMMU	Antrim	St. Clair Lake	64	native	Great Lakes	no
32	Michigan	CLMMU	Antrim	Torch Lake	18,770	native	Great Lakes	no
33	Michigan	CLMMU	Antrim	Wilson Lake	90	native	Great Lakes	no

Appendix A.—Continued.

ID	Great Lake basin	Management unit	County	Water body	Surface acres	Stocked or naturalized	Strain	Special regulations
34	Michigan	CLMMU	Crawford	Lake Margrethe	1,920	stocked	Northern	no
35	Michigan	CLMMU	Grand Traverse	Long Lake	3,900	naturalized	Northern	no
36	Michigan	CLMMU	Grand Traverse	Skegemog	1,460	native	Great Lakes	no
37	Michigan	CLMMU	Manistee	Manistee River		naturalized	Great Lakes	no
38	Michigan	CLMMU	Mason	Hamlin Lake	4,982	stocked	Northern	no
39	Michigan	NLMMU	Baraga	Craig Lake	307	stocked	Northern	yes
40	Michigan	NLMMU	Baraga	Crooked Lake		stocked	Northern	yes
41	Michigan	NLMMU	Delta	Dana Lake	98	naturalized	Northern	yes
42	Michigan	NLMMU	Dickinson	Badwater Imp.	928	naturalized	Northern	yes
43	Michigan	NLMMU	Dickinson	Big Quinnesec Falls Imp.	257	naturalized	Northern	yes
44	Michigan	NLMMU	Dickinson	Cowboy Lake	34	naturalized	Northern	no
45	Michigan	NLMMU	Dickinson	East Lake	100	naturalized	Northern	no
46	Michigan	NLMMU	Dickinson	Island Lake	174	stocked	Northern	no
47	Michigan	NLMMU	Dickinson	Kingsford	595	naturalized	Northern	yes
48	Michigan	NLMMU	Dickinson	Little Quinnesec Falls Imp.	290	naturalized	Northern	yes
49	Michigan	NLMMU	Dickinson	South Lake	250	naturalized	Northern	no
50	Michigan	NLMMU	Dickinson	Sturgeon Falls Imp.		naturalized	Northern	yes
51	Michigan	NLMMU	Dickinson	West Lake	180	naturalized	Northern	no
52	Michigan	NLMMU	Dickinson	White Rapids Imp.	465	naturalized	Northern	yes
53	Michigan	NLMMU	Gogebic	Lac Vieux Desert	4,300	naturalized	Northern	yes
54	Michigan	NLMMU	Iron	Bass Lake	96	naturalized	Northern	no
55	Michigan	NLMMU	Iron	Brule Lake	251	naturalized	Northern	yes
56	Michigan	NLMMU	Iron	Chicagon Lake	1,100	stocked	Northern	yes
57	Michigan	NLMMU	Iron	Chief Edwards	34	naturalized	Northern	yes
58	Michigan	NLMMU	Iron	Crystal Falls Imp.	140	naturalized	Northern	no
59	Michigan	NLMMU	Iron	Erickson Lake	35	naturalized	Northern	no
60	Michigan	NLMMU	Iron	Lake Emily	320	naturalized	Northern	yes
61	Michigan	NLMMU	Iron	Lower Paint Impoundment	418	naturalized	Northern	no
62	Michigan	NLMMU	Iron	Michigamme Falls Imp.	505	naturalized	Northern	no
63	Michigan	NLMMU	Iron	Paint	332	naturalized	Northern	yes
64	Michigan	NLMMU	Iron	Paint Pond	774	naturalized	Northern	yes
65	Michigan	NLMMU	Iron	Peavy Imp.	3,500	naturalized	Northern	no
66	Michigan	NLMMU	Iron	Smoky Lake	590	stocked	Northern	yes
67	Michigan	NLMMU	Iron	Stanley	310	naturalized	Northern	yes
68	Michigan	NLMMU	Iron	Violet	40	naturalized	Northern	yes

Appendix A.—Continued.

ID	Great Lake basin	Management unit	County	Water body	Surface acres	Stocked or naturalized	Strain	Special regulations
69	Michigan	NLMMU	Mackinac	Brevoort Lake		native	unknown	no
70	Michigan	NLMMU	Mackinac	South Manistique Lake	4,001	Stocked	Northern	no
71	Michigan	NLMMU	Marquette	Lake Michigamme	4,360	naturalized	Northern	no
72	Michigan	NLMMU	Menominee	Chalk Hills Imp.	866	naturalized	Northern	yes
73	Michigan	NLMMU	Menominee	Menominee River		native	Great Lakes	yes
74	Michigan	NLMMU	Schoolcraft	Big Island Lake	130	stocked	Northern	yes
75	Michigan	NLMMU	Schoolcraft	Cusino Lake	140	stocked	Northern	no
76	Michigan	NLMMU	Schoolcraft	Grassy Lake	176	naturalized	Northern	yes
77	Michigan	NLMMU	Schoolcraft	McKeever Lake	140	stocked	Northern	yes
78	Michigan	SLMMU	Allegan	Osterhout	168	stocked	Northern	yes
79	Michigan	SLMMU	Barry	Gun Lake	2,680	naturalized	Uncertain	no
80	Michigan	SLMMU	Barry	Lower Crooked	417	stocked	Northern	no
81	Michigan	SLMMU	Barry	Thornapple Lake	409	stocked	Northern	yes
82	Michigan	SLMMU	Clinton	Lake Ovid	412	stocked	Northern	yes
83	Michigan	SLMMU	Kalamazoo	Austin Lake	1,090	stocked	Northern	yes
84	Michigan	SLMMU	Kent	Campau	125	stocked	Northern	yes
85	Michigan	SLMMU	Kent	Murray	320	stocked	Northern	yes
86	Michigan	SLMMU	Ottawa	Macatawa	1,780	stocked	Northern	yes
87	Michigan	SLMMU	St. Joseph	Long Lake	222	stocked	Northern	yes
88	Michigan	SLMMU	Van Buren	Bankson	217	stocked	Northern	yes
89	Michigan	SLMMU	Van Buren	Round Lake	194	stocked	Northern	yes
90	Superior	ELSMU	Alger	Kingston Lake	125	stocked	Northern	no
91	Superior	ELSMU	Chippewa	Tahquamenon	617	naturalized	Northern and GL	no
92	Superior	ELSMU	Luce	Tahquamenon	600+	naturalized	Northern	no
93	Superior	WLSMU	Gogebic	Big African Lake	86	naturalized	Northern	no
94	Superior	WLSMU	Gogebic	Big Lake	771	naturalized	Northern	yes
95	Superior	WLSMU	Gogebic	Cisco Lake	506	naturalized	Northern	no
96	Superior	WLSMU	Gogebic	Dream Lake	25	naturalized	Northern	no
97	Superior	WLSMU	Gogebic	East Bay Lake	277	naturalized	Northern	no
98	Superior	WLSMU	Gogebic	East Branch Montreal River		naturalized	Northern	yes
99	Superior	WLSMU	Gogebic	Eel Lake	52	naturalized	Northern	no
100	Superior	WLSMU	Gogebic	Fishhawk Lake	80	naturalized	Northern	no
101	Superior	WLSMU	Gogebic	Indian lake	129	naturalized	Northern	no
102	Superior	WLSMU	Gogebic	Lindsley Lake	156	naturalized	Northern	no
103	Superior	WLSMU	Gogebic	Little Oxbow Lake	92	naturalized	Northern	no

Appendix A.—Continued.

ID	Great Lake basin	Management unit	County	Water body	Surface acres	Stocked or naturalized	Strain	Special regulations
104	Superior	WLSMU	Gogebic	Mamie Lake	400	naturalized	Northern	yes
105	Superior	WLSMU	Gogebic	Montreal River		naturalized	Northern	yes
106	Superior	WLSMU	Gogebic	Morley Lake	59	naturalized	Northern	no
107	Superior	WLSMU	Gogebic	Plum Lake	215	naturalized	Northern	yes
108	Superior	WLSMU	Gogebic	Pomeroy Lake	303	naturalized	Northern	no
109	Superior	WLSMU	Gogebic	Poor Lake	106	naturalized	Northern	no
110	Superior	WLSMU	Gogebic	Record Lake	68	naturalized	Northern	no
111	Superior	WLSMU	Gogebic	Tamarack Lake	331	naturalized	Northern	no
112	Superior	WLSMU	Gogebic	Tenderfoot Lake	461	naturalized	Northern	yes
113	Superior	WLSMU	Gogebic	Thousand Island Lake	1,078	naturalized	Northern	no
114	Superior	WLSMU	Gogebic	West Bay Lake	191	naturalized	Northern	yes
115	Superior	WLSMU	Ontonagon	Victoria Dam Basin	282	naturalized	Northern	no
116	Superior	WLSMU	Ontonagon	Bond Falls Flowage	2,100	naturalized	Northern	no

Sampling Protocol for Adult Muskellunge Long-term Monitoring

Long-term monitoring for adult Muskellunge involves estimating primarily four parameters: population abundance, survival, relative condition, and growth.

Adult Muskellunge should be captured in two consecutive years using standardized entrapment gear during the spring spawning period. Electrofishing can be used to supplement capture of Muskellunge for population estimates, but fish sampled by electrofishing should not be used for length-frequency comparisons.

Muskellunge should be measured to the nearest tenth of an inch and marked with a half-finclip or PIT tag. The half-clip typically regenerates over the following year, but is very noticeable visually and by moving your fingers along the fin rays. Other marks or tags can also be used if adjustments are made for tag loss. Muskellunge during the marking period that measure less than 30 inches can be given a separate clip. This helps to differentiate fish during the recap period that recruit (become > 30 in) during the subsequent year of sampling. Determine sex by presence of milt or eggs, or by visual inspection of the urogenital pore. Fish that cannot be classified (unknowns) should be recorded separately and data should be collected in addition to known sex fish. Fish of unknown sex usually constitute a small portion of the total Muskellunge handled during spring spawning periods.

Age and growth information should be determined by the examination of dorsal fin rays. From each lake collect a minimum of 10 adult fish from each sex that is representative of that population's size structure. It is preferable to collect an age sample on all fish if possible. When low adult densities are suspected, these numbers can be adjusted accordingly. Abundance of adult Muskellunge (≥ 30 inches) is estimated using the appropriate population methods. Open populations should be estimated by using the Cormack-Jolly-Seber model. Closed populations should be estimated by using the Bailey modification of the Petersen method. Program Mark should be considered where unique populations are sampled or survey methods are different. Muskellunge captured the first year make up the marking run, and those the second years compose the recapture sample. Numbers in the recapture sample are adjusted for recruitment over a one-year period using sex-specific and lake-specific growth rates determined from dorsal fin ray interpretations.

Additional information on adult Muskellunge sampling protocol can be found in the following references:

Margenau, T. L., and S. P. AveLallemant. 2000. Effects of a 40-inch minimum length limit on muskellunge in Wisconsin. *North American Journal of Fisheries Management* 20:986-993.

Cornelius, R. R., and T. L. Margenau. 1999. Effects of length limits on muskellunge in Bone Lake, Wisconsin. *North American Journal of Fisheries Management* 19:300-308.

Juvenile Muskellunge Assessment: Fall electrofishing is intended to provide an indication of Muskellunge recruitment (young-of-year catch rate). The sampling is conducted at water temperatures from 50 to 60°F. Muskellunge lakes should be completed by the end of October as catch rates of Muskellunge young-of-year tend to increase as temperatures decline. The sampling should be conducted according to the following protocols:

- Boom shocker electrofishing is conducted at night. Two experienced people should dip fish. Dip nets should have 1/2" mesh bags. Shocking should be conducted at water temperatures from 50 to 60°F.

- If possible, survey the entire shoreline. If difficult to accomplish, survey at least 50% of the shoreline. This is done by dividing the shoreline into 2-mile segments and surveying at least 50% of them. The minimum coverage needed is as follows:

Total lake shoreline (miles)	Minimum sampling required (2-mile segments)
≤8	Entire shoreline
8–16	4 segments
>16	5 segments

- The first 2-mile segment should be selected at random and the remaining 2-mile segments should then be chosen at equally spaced intervals around the lake to achieve uniform coverage.
- Actual distance sampled will be recorded and may be determined by GPS or by shoreline landmarks; mark the sampled segments on a lake map. Also, be sure to record time sampled.
- Within each 2-mile segment, all Muskellunge (particularly those less than 20 inches) will be collected and measured. Record the data from each 2-mile segment separately.
- Aging structures should be collected from enough fish to determine the size-breaks between 1) young-of-year and yearlings; and 2) yearlings and age 2+ fish. See Appendix B in Fisheries Division’s Survey Manuals for details on aging.