



Long Range Plan for Muskellunge Through 2040

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Executive Summary

This document outlines the management plan for muskellunge (*Esox masquinongy*) in Minnesota through 2040, building on previous long-range plans from 1986, 1994, and 2008. It incorporates the latest research, management experience, and stakeholder input. The plan sets long-term goals for quality muskellunge populations, focusing on improving existing waters, evaluating and researching muskellunge populations, protecting habitats, and enhancing angling opportunities.

The goals of the muskellunge management plan focus on long-term outcomes over the next 15 years to ensure a successful program. Public input highlighted the importance of sustaining high-quality angling opportunities and improving stocked muskellunge survival, with an emphasis on maintaining existing populations rather than stocking new waters. The future of the muskellunge program will incorporate increased use of yearling muskellunge into stocking plans. The plan includes four key goals:

1. Sustain muskellunge populations for quality angling.
2. Improve fingerling and yearling production.
3. Manage hybrid muskellunge in the Twin Cities metro.
4. Enhance outreach and education on muskellunge's role in fish ecosystems.

There is also a strong focus on improving the fisheries in Mille Lacs, Vermilion, and Minnetonka lakes.

The plan was developed by the Minnesota Department of Natural Resources Muskellunge Technical Team with input from DNR staff, external stakeholders (including the Esocid Workgroup), and management partners (including tribal governments). Public input was gathered through surveys, webinars, and other outreach methods. Tribal coordination involved informing all 13 tribal entities in Minnesota of the planning process and incorporating their input.

Introduction

Purpose

The purpose of this plan is to guide muskellunge (*Esox masquinongy*) management in Minnesota through 2040. Building on the foundation of previous long-range plans (LRP) (MNDNR 1986, 1994, 2008), it incorporates the latest research, management experience, and input from angling interests. The plan revises and adds new objectives and strategies based on information and experience gained since 2008. Specific goals, objectives and strategies for managing quality muskellunge populations are included. The goals should be viewed as long-term targets, while the objectives and strategies are the avenues for achieving the goals. The document should be viewed as a guide for making decisions adaptively over time, not as decisions in and of themselves. In short, future management will focus on improving existing waters for quality angling opportunities (reasonable encounter rates of “trophy” specimens), evaluation and research, habitat protection, and increasing the opportunities for muskellunge angling when possible.

Plan Development

The plan was developed by the DNR Muskellunge Technical Team in collaboration with several internal and external partners, with input from a variety of stakeholder groups through various methods. Sections below describe the plan development process in further detail.

Internal Coordination

The plan was developed by the Muskellunge Technical Team within the DNR's Section of Fisheries. Goals, objectives, and strategies were thoroughly vetted within the Section of Fisheries, by managers in the Division of Fish and Wildlife, and by the DNR Commissioner's Office. Plan development included an iterative process of content development and review by DNR fisheries staff and leadership.

External Coordination

All management plan goals, objectives and strategies, including changes in stocking strategies, were vetted through the statewide Esocid Workgroup (EWG, a volunteer angler group focused on northern pike and muskellunge management) and tribal partners. The statewide EWG consists of 11 citizen members. It is one of five species workgroups collaborating with the DNR on individual species management. The EWG advised on and reviewed plan content. Tribal coordination is described below in further detail. Both parties were given opportunities to review the draft in all stages of the process, including prior to the public comment period in 2025.

Public Input

Throughout 2024 and 2025, the DNR used a variety of methods to inform and gather input from individuals and groups for this plan. Over 4,000 individuals participated in an online survey (open for six weeks in spring of 2024), where they provided input on issues or concerns regarding the future of muskellunge management in Minnesota. Additional public engagement occurred through the DNR website, press releases, DNR webinars, presentations to local and state resource groups, participation at Minnesota sport shows, social and local media posts, and individual email and phone correspondence with members of the public. The public had many opportunities to provide input and participate in the planning process. Although there was considerable interest in adding new waters to the statewide muskellunge stocking program, public input focused on first improving existing lakes, especially the key muskellunge fisheries of Mille Lacs, Vermilion and Minnetonka lakes.

Public Review

A draft of the plan was released for public review in Spring 2025. Staff reviewed comments and incorporated input into the final plan ([Appendix A](#)).

Tribal Coordination

Minnesota is a ceded territory state with multiple treaties in existence across the landscape. Two of which, the 1837 and 1854 treaties (located in east-central and northeastern Minnesota, respectively), retained tribal rights to hunt, fish and gather in the ceded territories as well as the right to regulate and enforce these activities.

Recognizing the statewide scope of this plan, all 13 tribal partners/entities in Minnesota were contacted in January 2024 to ensure awareness of the revision effort and provide opportunity for involvement in the process. Four tribal entities expressed interest in an open line of communication throughout the plan's development and in providing feedback on draft content. The Great Lakes Indian Fish and Wildlife Commission (GLIFWC), 1854 Treaty Authority, Fond du Lac Band of Lake Superior Chippewa, and Mille Lacs Band of Ojibwe were kept informed through regular process updates and were provided information and opportunity for discussion about significant plan content. All tribal partner feedback was considered and incorporated prior to release of the draft for public comment in 2025. Ongoing tribal coordination is expected throughout the duration of this plan.

Background and Current Knowledge

This section summarizes background on the social, historical and biological influences on Muskellunge management. A glossary is included in [Appendix B](#).

Historical Management

The earliest documented efforts of propagating and stocking muskellunge in Minnesota occurred in 1911 (Minnesota Biennial Report 1912) and continued with limited success throughout the early 1900s (Surber 1929). Carbart (1937) described muskellunge propagation techniques attempted at Lake Belle Taine and the Park Rapids State Fish Hatchery during the 1933 season (Minnesota 1934). Mature fish were seined and released into a shallow bay that served as a natural spawning ground. Eggs were stripped into a soupy mud solution, fertilized, and transported to Park Rapids. The use of natural spawning grounds by muskellunge on Lake Belle Taine was again attempted in 1935 and 1936 with limited success (Minnesota 1936) and continued into the 1940s when a hatchery was built on the shore of Lake Belle Taine. Continued failures in obtaining a reliable egg source from Lake Belle Taine and other nearby muskellunge waters resulted in a drastic shift in strategy. In 1950, adult muskellunge from Shoepack Lake, an isolated Canadian border water, were angled and airlifted to hatchery ponds in Park Rapids. The operation continued for more than 20 years while attempting to create local brood source lakes from the Shoepack Lake progeny.

After more than two decades of using muskellunge progeny with origins from Shoepack Lake, it became apparent fish resulting from those stocks rarely attained a large size. Data from the sport harvest coupled with DNR netting indicated most adult fish in those populations were less than 36 inches. Miller et al. (2012) further confirmed these observations using genetics. During the late 1970s and early 1980s attention was focused on native muskellunge waters in the Upper Mississippi River drainage basin. A

radio telemetry study resulted in successful spawn taking operations on Leech Lake beginning in 1981. Seven brood stock lakes were started in 1982 to maximize the probability of securing enough eggs to meet annual production needs. The selected brood lakes included Little Wolf, Elk, and Plantagenet in the Bemidji area; Owasso, Pleasant, and Rebecca in the metro area; and Island Lake near Hinckley. Rebecca, Elk, and Plantagenet lakes have been the most frequently used brood lakes. Pleasant Lake currently is under redevelopment. Owasso and Island lakes are no longer brood stock lakes.

The brood lakes are managed differently from other muskellunge waters, with emphasis placed on efficient spawn-taking operations each spring. Initial stocking rates on these lakes were considerably higher than other managed waters. While most of these brood stock lakes had stocking densities reduced over the past decade, most remain above the current program recommendations for stocked waters. The brood stock lakes receive fingerlings every other year, with fish directly from Leech Lake every fourth year. The strategy began in 2009 to maintain genetic diversity of adult muskellunge in the brood stock lakes.

Muskellunge eggs are incubated at the St. Paul, Waterville, and Park Rapids State Fish Hatcheries. Newly hatched fry are fed dry or live diet in rearing units. The live diet feeding program uses local zooplankton, and white sucker fry. The number of transplants produced has historically been limited to trough space available within the hatchery system. Once muskellunge reach transplant size (2-4 inches), they are transferred to drainable and natural ponds. Prior to stocking, the drainable ponds are filled with surface water and stocked with brood fathead minnows so their young can provide proper sized food. Fathead minnows of increasing size are fed throughout the growing season until the ponds are drained in the fall. Natural food is relied on for rearing success in natural rearing ponds, and fish are removed in fall by electrofishing or nets. Drainable ponds have been more reliable because growing conditions can be monitored, and all the fish produced can be collected. However, in recent years finding reliable sources for fathead minnows has been difficult and has likely negatively affected muskellunge fingerling production. Drainable ponds are programmed for use every year while the use of natural ponds is dependent on the availability of muskellunge transplants and suitable ponds. The goal of the fall fingerling production program has been to produce 10–14-inch fingerlings; however, failure to reach this goal in all rearing ponds is not unusual due to uncontrollable growing conditions (e.g., length of growing season, available forage, pond productivity).

The 2008 Long Range Plan (MNDNR 2008) further details the recorded history of muskellunge propagation in Minnesota.

Muskellunge Angling

Regulations

Muskellunge was one of the first sport fishes in Minnesota to be affected by over-exploitation as described by the numerous outdoors writers of the late 1800s and early 1900s. Evidence of increased exploitation coupled with changes in population size structure was documented for muskellunge in north-central Minnesota over a 58-year period starting in the 1930s (Olson and Cunningham 1989).

Muskellunge angling regulations remained largely unchanged until the 1980s (Table 1). Subsequent changes were made incrementally as anglers desired progressively larger fish. The first statewide minimum size limit for muskellunge was instituted in 1983 and has undergone three additional increases, culminating at 54 inches in 2015. Special regulations for individual waters and rivers were adopted over time as well. Minnesota has been a leader in muskellunge protection since the 1950s (Table 1).

Table 1. A chronology of Minnesota’s muskellunge regulations since 1956.

Year	Adjustment
1956	Daily possession limit of one statewide
1982	Season opener in June
1983	36” inch minimum size limit statewide
1990	48” inch minimum size limit in broodstock lakes
1993	40” inch minimum size limit statewide
2004	Catch and release only on Elk Lake
2007	48” inch minimum size limit on additional waters
2007	Catch and release only on Mississippi river
2008	December season closure statewide
2010	48” inch minimum size limit statewide
2015	54” inch minimum size limit

The Commissioner for the Minnesota Department of Conservation, the DNR’s predecessor agency, was given authority to close northern pike dark house spearing on up to 10 lakes designated for special muskellunge management in 1961. The purpose was to eliminate accidental and illegal killing of muskellunge by spearers. The authority was eventually expanded to 40 lakes by 1971. A review of all spearing closures was conducted in 2004, after which closures on 26 lakes remained. The regulation was revisited in 2015 and all but Baby Lake, Cass County was dropped the following year. The association of spearing bans as a management tool for muskellunge populations resulted in contentious relationships between the northern pike spearing and muskellunge angling communities.

Interest in Muskellunge

Interest in muskellunge fishing grew rapidly throughout the 1990s and 2000s as many of the introduced populations were producing high-quality angling opportunities. At that time, a survey of muskellunge anglers found above average satisfaction with the size and numbers of fish they encountered (Schroeder et al. 2007), with about 80% satisfied or very satisfied with their overall fishing experience. In contrast, they were less satisfied with the number of muskellunge fishing opportunities. Recent surveys did not investigate muskellunge anglers' satisfaction with the size and numbers of fish encountered or overall experience but documented similar interest in muskellunge fishing to what Schroeder et al. (2007) reported. Miller (2018) reported 11% of respondents fished for muskellunge in 2017, but 29% were likely to fish for muskellunge in Minnesota in the future. The study did not include non-resident anglers interested in muskellunge angling, so they reflect minimum estimates. Interest in muskellunge angling continues to be high relative to the opportunities available. Recent levels of interest have created concerns about crowding and long-term sustainability of muskellunge fisheries.

Muskellunge Research

The 1994 and 2008 LRPs described the role of muskellunge in fish communities, including their role as a large predator, factors in prey selection such as type and abundance, and potential interactions with other predators such as walleye and northern pike. Following is an update on those topics, including synthesis of new Minnesota-based research studies conducted by DNR and university partners (Bemidji State University and the University of St. Thomas) since the 2008 LRP.

Young Muskellunge Research

Young-of-year (YOY: fish less than one year of age) muskellunge nursery habitats were found in association with fish assemblages dominated by largemouth bass, pumpkinseed, and yellow perch (Craig and Black 1986). These nursery areas consisted of wide expanses of varying densities of emergent vegetation. The presence of a diverse aquatic plant community is an essential component, providing habitat for egg deposition and development, newly hatched and juvenile fish, and feeding. Boe (1992) documented YOY muskellunge rearing habitats in Cass Lake to be areas of floating bog near wild rice beds. YOY muskellunge and northern pike often occupy similar niches in lake and river environments. Osterberg (1985) documented separation of the two species with respect to time of spawning, spawning habitat, and location of YOY in the St. Lawrence River. Differential adaptation to river currents was cited as the most likely factor permitting coexistence of the two species (Harrison and Hadley 1978). The authors found no interaction between YOY muskellunge and YOY northern pike. For both lake and river systems, spawning and nursery habitat locations appear to be critical components in permitting both species to prosper.

Before muskellunge reach large sizes, they spend their lives at the prey end of the predator-prey spectrum. The danger of mortality is ever-present from egg to adult by other species of the aquatic community. Insects, insect larvae, and various fish species can consume large numbers of muskellunge eggs, fry, and fingerlings. Muskellunge fingerlings are especially vulnerable to piscivorous birds during

the first 18 months of their lives. One study demonstrated the predation of YOY muskellunge by YOY northern pike, whereas the converse did not occur (Caplan 1982). This type of predation may occur in the wild and severely limit muskellunge recruitment to the fishery. Cannibalism is also a risk throughout the early life stages of muskellunge (Parsons 1959).

Adult Muskellunge Research

Muskellunge populations are rarely abundant in any lake or river, but healthy populations are often found in assemblages dominated by percids, coregonids, and catostomids. Various field studies have found muskellunge diets to be dictated by the individual water's fish community. Hourston (1952) described muskellunge as general carnivores, preying mainly on fish over six inches in length with yellow perch being the most frequently observed prey of muskellunge from Canadian waters. In an experimental study of two small (<44 acres) Wisconsin lakes, yellow perch were also most frequently consumed by muskellunge, and the stunted perch populations in these lakes were ultimately reduced by the introduction of yearling muskellunge (Gammon and Hasler 1965). Soft-rayed species such as suckers, lake whitefish, and cisco were found to be preferred prey in native Wisconsin muskellunge waters (Oehmcke et al. 1958). Based on a diet study conducted on northern Wisconsin lakes, Bozek et al. (1999) found yellow perch along with white sucker to be the primary food of muskellunge. River and stream muskellunge were also found in association with soft-rayed fish, suckers, redhorse, and cyprinids (Harrison and Hadley 1979; Brewer 1980; Axon and Kornman 1986).

Food habits change during the life of muskellunge due to changes in prey species abundance, availability, or preferred size. The availability of large prey items is thought to be critical in supporting good growth of top predators (Porter 1977; Diana 1979; Harrison and Hadley 1979). Harrison and Hadley (1979) implied that a lack of suitable prey at all life stages resulted in poor growth in certain riverine populations, thus a stable and diverse prey base is likely required to support a healthy muskellunge population.

The DNR initiated a food web study on Elk Lake, one of the muskellunge stocking program's brood lakes, where researchers used stable isotopes to quantify niche overlap and diets of muskellunge, northern pike, and walleye in this deep lake containing a robust cisco population (Herwig et al. 2022). Stable isotope signatures of carbon and nitrogen in predator tissues reflect those of their prey because isotope signatures are transferred up the food webs in a predictable "you are what you eat" fashion. The technology is also useful to understand the degree to which fish feed on and derive energy from nearshore (littoral) versus offshore (pelagic) food sources. Herwig et al. (2022) found muskellunge and northern pike niches overlapped very little (<10%), while both walleye and muskellunge, and walleye and northern pike overlapped more extensively (15%–60%). It was determined that adult muskellunge diets focused on cisco (~50% of their diet), with white sucker also being important (~20-50% of the diet). All other prey fish combined constituted <30% of muskellunge diets. In this study, walleye diets primarily consisted of non-cisco prey fish (80%) while northern pike diets were comprised of non-cisco prey fish (45%) and invertebrates (40%). The authors hypothesized that in Elk Lake, the presence of a cisco population and the flexibility of northern pike to use invertebrate resources may decrease potential competition among these predators.

A follow-up study was designed to examine the feeding ecology and niche overlaps of muskellunge, walleye, northern pike, and largemouth bass in a broader set of lakes. Glade et al. (2023) used gastric lavage to collect stomach content data from the predators in five lakes with muskellunge and five lakes without muskellunge. Data from two additional muskellunge lakes were analyzed since publication. Results across all 12 lakes remained consistent with the findings of Glade et al. (2023), except for higher cisco consumption in Cass and North Star lakes in the summer and fall sampling periods. A total of 631 muskellunge stomachs were examined across all the lakes. The study concluded that muskellunge had broad diets, consisting of over 20 different prey items. The top eight diet items included yellow perch, unidentified fish, suckers, invertebrates, sunfish, northern pike, bullheads, and black basses ([Appendix C](#)). Walleye were not an important component of muskellunge diets, with only four walleyes found in the 350 muskellunge stomachs examined in this study that had identifiable prey.

Isotope results from the muskellunge diets study found that muskellunge have unique niches and occupy the highest trophic positions (i.e., have the most fish-based diets), along with walleye (Brian Herwig and Kyle Zimmer, unpublished data). In lakes with cisco, muskellunge tend to be consistently more pelagic (i.e., likely eating proportionally more cisco than other predators). In lakes without cisco, muskellunge tend to derive more of their energy from littoral prey fishes (like bullheads, white suckers, etc.). One observation from the isotope diet data is that gastric lavage data appears to underestimate the importance of cisco to muskellunge diets. It is possible there is a bias for missing cisco in the diets of muskellunge using gastric lavage because sampling is restricted to shallow offshore humps and nearshore areas. Stable isotopes are integrated over longer time scales, so muscle tissue samples collected when muskellunge are sampled nearshore may be better able to detect previous offshore consumption of cisco. Plans are in place to conduct specific modeling to corroborate these hypotheses.

In another related study, DNR staff examined how much food muskellunge populations eat compared to walleye, northern pike, and largemouth bass populations by combining diet information with population estimates for each predator in three lakes. Population estimates among lakes were remarkably consistent where largemouth bass were the most abundant (47-50% of the total predator population), followed by northern pike (31-34%), walleye (17-18%), and muskellunge (1-4%). Of all the food eaten by these top predators in each lake, northern pike populations consumed the most (38-50%), followed by largemouth bass (23-29%), walleye (15-23%) and muskellunge (6-16%). Although muskellunge consumed more on an individual basis, total consumption remained low due to their smaller population size. Muskellunge ate many different prey resources, such as white sucker, northern pike, and bullheads, compared to the other predators. Walleye and northern pike consumed primarily yellow perch and bluegill while largemouth bass ate mostly crayfish.

The coexistence of muskellunge and northern pike in fish communities has often been a topic of concern. Opposite trends in relative abundance of muskellunge and northern pike have been reported by numerous studies in various lakes, and in each case, muskellunge appeared to decrease while northern pike appeared to increase (Oehmcke 1951; Johnson 1981; Inskip and Magnuson 1986). Predation, competition, and hybridization are possible mechanisms of negative interaction between the two species (Inskip 1986). Northern pike have been suggested to outcompete muskellunge by preying

on YOY muskellunge, spawning earlier in the spring, being more aggressive, having greater food conversion efficiency, shorter generation times, and higher relative abundances.

Muskellunge management in native and introduced waters has created trophy angling opportunities in Minnesota, but the interaction of muskellunge with other fish species in the community had received limited assessment. Knapp et al. (2012) examined information from stocked muskellunge waters in Minnesota to determine if muskellunge had a noticeable effect on fish communities. The authors reported a lack of consistent negative trends across all species, lakes, and lake classes, and the tendency for most lakes to be within or above the lake class normal range, suggesting the fish species considered in their study have coexisted well with muskellunge, in the types of lakes, and at the densities the DNR manages muskellunge. Knapp et al. (2021) re-examined the question of whether muskellunge are affecting fish communities in the waters where they have been introduced. Similar to the Knapp (2012) study, the authors investigated seven species commonly found in Minnesota using a stronger study design. In this second look at the potential influence of muskellunge introductions on fish communities, Knapp et al. (2021) again concluded their results are evidence the introduction and management of muskellunge in the study lakes has not adversely affected game fish populations. In fact, the data indicates muskellunge management may have contributed to a stabilizing effect in these fish communities since northern pike catches were stable while average weights increased, in contrast to reference waters that experienced substantially higher catches and smaller northern pike. The muskellunge and northern pike relationship also seems to explain the increase in yellow perch catches observed in the stocked muskellunge waters relative to the reference waters.

Observations from the muskellunge diet and consumption studies and Knapp et al. (2021) provide some insight into the role muskellunge appear to play within fish communities. Yellow perch was the most important fish species consumed by all four predators examined in Minnesota lakes. Although, muskellunge shared key prey resources such as yellow perch with other predators, the varied diet of muskellunge resulted in low overlap of diets with walleye, northern pike, and largemouth bass. The diverse diet of muskellunge included consumption of northern pike and largemouth bass, and though their relative importance was not high these prey items were in the top eight food resources in terms of importance. When comparing consumption of food by muskellunge, walleye, northern pike, and largemouth bass populations, consumption by the muskellunge population remained a relatively small percentage of the total food consumed in each of three study lakes. Muskellunge also ate many different prey resources, such as white sucker, northern pike, and bullheads, compared to the other predators, which even further minimizes any impacts or potential competition resulting from muskellunge populations. When considering these four research projects together, the evidence strongly indicates muskellunge are not negatively affecting fish communities in Minnesota waters.

Population Assessments

Population assessments are the foundation for all fisheries management in Minnesota because they provide information on important population characteristics and how they change over time.

Understanding how many fish are in a population, how many recruit or die, how fast they grow, and what size and age they are, are critical for evaluating the health of fish populations. Regular monitoring

in response to changing environmental conditions or various management tools like stocking and regulations allows for adaptive management. Early surveys in the muskellunge program focused on collecting length data and trap net catch information. By the time of the 2008 LRP, several Area Fisheries Offices had conducted adult (≥ 30 inches) muskellunge population estimates on 10 water bodies. The 2008 LRP prioritized establishing standardized sampling protocols with a goal to conduct a minimum of 40 spring surveys having population estimates and expand the use of PIT tags to provide critical information on age, growth, and recruitment/mortality.

Spring muskellunge surveys using internal PIT tags and mark-recapture estimate methods have become standard within the last 15 years. A total of 220 population estimates were conducted on 37 muskellunge waters where muskellunge are stocked with Leech Lake strain fish or contain native or naturalized (non-stocked) populations ([Appendix D](#)). Several waters had multiple population estimates calculated per year to compare and evaluate methods (e.g., sampling gears, timing, mathematical models). Stocked populations have been the focus of the sampling because they are actively managed with Leech Lake strain fish. Stocked waters averaged 0.18 adults per surface acre or one adult for every 5.6 acres. Population estimates have been conducted on waters classified as Shoepack and Introduced Shoepack but are not presented in [Appendix D](#). The introduced Shoepack waters contain populations established many decades ago and are currently sustained by natural reproduction. Shoepack Lake is known for producing relatively high-density muskellunge populations dominated by small fish (Frohnauer et al. 2007). Shoepack Lake served as the parent lake for the muskellunge production program from the 1950s through the early 1980s and the progeny have displayed similar population attributes. These waters averaged 0.797 adults per surface acre or one adult for every 1.3 acres.

Muskellunge population estimates in Minnesota reflect the low-density nature of the species. Despite various methods, population estimates seldom averaged more than one adult for every four acres, particularly for Leech Lake strain populations ([Appendix D](#)). From initial observations of the data, it appears that muskellunge populations follow basic ecological principles. For instance, there appears to be a carrying-capacity that limits muskellunge from attaining high densities despite the various stocking strategies deployed around the state. Also, smaller waters tended to have higher densities and smaller size structure than large waters. Finally, developing populations appear to have higher densities and smaller size structure, but once established, density moderates and size structure increases. Additional research of these relationships may help identify the mechanisms.

Estimates of adult muskellunge recruitment and mortality can be attained using advanced computer software (program MARK) when at least three years of mark-recapture data are available. Estimates of total annual mortality of adult male and female muskellunge were calculated for 16 Minnesota lakes ([Appendix E](#)). Estimated total annual mortality for females averaged 17% though ranged from 8 to 31%. Estimated total annual mortality for males averaged 14% and ranged from 7 to 21%. Documenting higher female mortality may be important for future management considering they attain larger sizes and are more desired by anglers. The similarity in the mortality estimates among the waters investigated is noteworthy considering the differences in ecosystems and management strategies among those waters. The estimates of mortality from Minnesota waters were relatively low compared to previously published estimates before 1990 that were above 30% (Lyons and Margenau 1986; Bimber 1982;

Spangler 1968). The higher mortality estimates from the older studies likely reflect an era of higher angler harvest before catch-and-release became popular and size limits increased. Expanding mark-recapture population estimates to include three or more consecutive years of sampling on additional waters would increase understanding of adult recruitment and mortality. Additionally, this increased sampling effort in conjunction with investigations into size specific survival of stocked muskellunge should improve stocking efficiencies.

Creel Survey Metrics

Muskellunge are notoriously difficult to catch, as evidenced by the long-held moniker “the fish of 10,000 casts.” However, advancements in angler knowledge and species management have led both anglers and fishery managers to no longer believe this to be the case. Muskellunge numbers in even the best waters are far below other popular sport fish populations, meaning low angler catch rates. Angler creel surveys have been performed on numerous muskellunge waters over the past 20 years. These creel surveys sampled the open water seasons during daylight hours. Summary creel data for anglers targeting muskellunge from 18 waters is presented in [Appendix F](#). Some creel surveys performed on a muskellunge water were excluded due to inconsistencies in data reporting statistical software used, or a high volume of data. For example, annual creel data are available from Lake Mille Lacs since 1998, but only six surveys spanning that time are presented in the interest of brevity. The amount of effort expended by an individual angler to catch one muskellunge ranged from 11 to 200 hours, with an average of 40 hours. No discernable pattern of catch rates can be found among the creel surveys listed. Estimates of the percent of total angling effort directed towards muskellunge from Elk (58%) and Detroit (46%) lakes were more than double the remaining waters, which ranged from 3-22%. Interestingly, the mean percent of total effort directed towards muskellunge across these creel surveys was 14%, which is very similar to the 2017 and 2023 angler surveys (Miller 2018, Lovelace 2024) where 11% and 13% of respondents indicated they had fished for muskellunge in the past year.

Muskellunge Habitat

Native and introduced muskellunge populations have thrived in a diversity of lake habitats in Minnesota. Lakes where maintenance stocking is required to provide a viable fishery lack specific habitat characteristics for successful natural recruitment. Stocking is a tool that can often allow fisheries managers to overcome these limiting factors, but identifying barriers to natural recruitment can help guide habitat restoration and protection measures to ensure a successful management program. Protection of critical habitat on lakes with sufficient natural reproduction to sustain populations should remain a top priority.

Researchers in Minnesota have conducted several projects attempting to identify muskellunge spawning habitat. Strand (1986) used radio telemetry to identify spawning areas and seasonal distribution and movements of muskellunge in Leech Lake. Spawning areas were generally found in 3.3-6.6 feet of open water containing dense beds of *Chara* spp. over flocculent marl substrates. Miller’s Bay on Leech Lake has since been identified as an important spawning area and is the location of a DNR egg-take operation. *Chara* spp. is the predominant bottom cover-type of the bay though unlike Strand (1986), the

habitat is not exposed to the main lake. Pierce et al. (2007) used oviduct radio telemetry in female muskellunge to determine potential spawning sites and habitat characteristics on two northern Minnesota lakes. The authors found expelled transmitters in an average of 3.6 feet of water with variable vegetative cover in Elk Lake, but *Chara* spp. was common to most sites. Moose Lake results were similar in that *Chara* spp. beds were the predominant substrate where transmitters were expelled, generally in 2.0 to 6.9 feet of water. Shavlik (2018) also used oviduct transmitters in Big Mantrap Lake to identify near-shore spawning habitat for potential future protection. Emergent vegetation was found at 13 of the 15 expelled transmitter sites but no one species was common or preferred. Expelled transmitter locations were found in front of private property (67%), State of Minnesota parcels (20%), and 3M Corporation parcels (13%) in similar proportions to their availability. Females may have avoided disturbed parts of a property since expelled transmitters were not found in front of docks. These projects identified spawning habitat characteristics, yet recruitment success can only be inferred from the resulting adult populations.

DNR staff have noted several recurring habitat attributes for juvenile muskellunge in lakes with moderate to excellent natural recruitment. Boe (1992) documented YOY muskellunge rearing habitats to be areas of floating bog near wild rice beds on Cass Lake. Spring yearling muskellunge have been sampled closely related to sedges (*Carex* spp.) with an over-hanging bog edge, near woody cover, and emergent vegetation on North Star Lake (Steve Mero, personal communication). Juvenile muskellunge, in general, are found closely associated with bulrushes that are common in Elk and North Star lakes. The linear structure of bulrushes and other emergent or floating leaf vegetation appears to be important habitat for the juveniles to avoid predation by fish and birds.

Climate Change and Habitat Alteration

Minnesota's climate and habitat are changing. Air temperatures have warmed by about 3.0°F between 1895 and 2023, and annual precipitation has increased by an average of 3.4 inches. The largest temperature changes have been observed over the past several decades, particularly during winter <https://arcgis.dnr.state.mn.us/ewr/climatetrends/>. These trends suggest Minnesota lakes will experience shorter periods of ice coverage and warmer water temperatures. Warmer water during the open water period will lengthen the period of thermal stratification in stratified lakes. Climate and land use changes, including watershed and shoreline development, are also contributing to changes in aquatic plant communities, water levels, connectivity, and other in-lake habitat. Many of these changes will affect muskellunge habitat, prey resources, behavior, and management.

Although temperatures vary considerably across their native range, which extends latitudinally from Ontario to Tennessee, muskellunge are a cool-water species that require certain water temperatures to persist. Water temperature preferences also vary by life stage, with larger muskellunge selecting cooler water than juvenile and sub-adult fish, and generally avoiding water over 77°F (Cole and Bettoli 2014). Critical maximum temperatures for adults are not well known. If similar to northern pike, the critical threshold is likely around 86-88°F but may be closer to 90°F (Becker 1983). Lethal water temperatures are likely even higher, with lethality dependent on the duration of exposure to high temperatures as fish can usually withstand short term exposures. Juvenile muskellunge and hybrid muskellunge prefer water

temperatures closer to 79°F, but negative physiological effects can occur around 84°F depending on a fish's condition, with death (either acute or from starvation) occurring at temperatures near 88-90°F (Scott 1964, Snow et al. 2018). In Scott's (1964) study, juvenile muskellunge and hybrid muskellunge were exposed to and tolerated temperatures up to 95°F for short time periods, but hybrid muskellunge appeared to show enhanced thermal resistance compared to muskellunge. Hybrid muskellunge have also been shown to grow faster than muskellunge under Ohio thermal regimes and likely experience optimal growth at higher temperatures than muskellunge (Bevelhimer et al. 1985).

In addition to direct effects of warmer water temperatures on muskellunge physiology, prey resources could also be affected. Cisco, a cold-water fish species, are an important high-energy food source for muskellunge that likely promotes trophy growth potential. Warming summer air temperatures and changing land use can reduce suitable habitat of cisco and reduce thermal refugia for cool-water predators (e.g., muskellunge) as well. As water temperatures increase, the layer of warm, well-oxygenated water in stratified lakes deepens, and in lakes where nutrient levels are too high, microbes use up more oxygen in deeper water, resulting in a thinner layer of sufficiently cold and oxygenated habitat needed for cisco to survive. In some lakes, cisco could get 'squeezed' into a narrow layer of suitable habitat, experience summerkill, and become extirpated. Muskellunge have exceptionally broad diets (Glade et al. 2023) and are adept at switching to and using alternative prey resources, but loss of this key prey source could affect growth.

Like other cool-water species, muskellunge may be forced to seek thermal refuge at deeper depths where it is available, particularly in stratified lakes. While muskellunge are less susceptible to barotrauma than other species due to their physiology (i.e., the presence of an air duct connecting the swim bladder and stomach that allows them to deal with pressure changes better), if muskellunge are increasingly using and being caught from deeper, cooler depths, there would be more risk of barotrauma injuries. Shallow, mixed lakes that lack a thermal refuge would be more vulnerable to increasing summer water temperatures. Anglers may voluntarily reduce fishing during these conditions over concerns of barotrauma or handling stress from high temperatures; however, this period may begin earlier and last longer into the angling season should climate trends continue.

Muskellunge production and stocking may also be influenced by changing climate and land use patterns. Fingerling and yearling production challenges would be exacerbated by reduced winterkill events and increased wetland basin interconnectivity due to changing drainage patterns and increased precipitation. Predator (e.g., largemouth bass) and undesirable fishes (e.g., black bullhead, common carp) could colonize basins and survive the winter more frequently, thus reducing survival of transplant muskellunge through predation and competition. These same processes could reduce the availability of fathead minnows from natural ponds used for forage in muskellunge rearing operations. This will likely require DNR to focus increasingly on drainable ponds and indoor recirculating aquaculture systems to control rearing conditions and improve production of fingerling and yearling muskellunge. The absence of winterkill events in Minnesota would provide challenges but less frequent winterkills would also allow strategic use of natural ponds for raising yearling and older muskellunge.

Minnesota has successfully created and managed muskellunge from shallow prairie lakes in the south to the northeastern Canadian Shield lakes. The diversity of habitat and fish communities within the

muskellunge program is extensive. Fortunately, the evaluation of these diverse fisheries has allowed the DNR to understand their potential resiliency to changes in climate. Long-term monitoring of the fisheries using standardized lake surveys is the foundation to the program. Recent research has specifically investigated the role of muskellunge in fish communities by analyzing the lake survey data, diets and niche overlap of predators, and consumption of food by predators at the population level. Each of the study designs considered how the presence or absence of cisco may influence the results and potentially the fish communities. The totality of the information indicates muskellunge exist at low levels compared to other species, have more diverse diets and consumes less food than other predators at the population level, and even in the absence of a preferred prey species like cisco does not negatively influence the fish community. These data are the foundation for our confidence that quality muskellunge fisheries can be maintained in the face of changing environmental conditions for the foreseeable future.

Because negative effects of climate change can be exacerbated by watershed and shoreline development, efforts to maintain forested watersheds and protect or restore natural shorelines should be prioritized where practical. Shoreline alterations and aquatic plant removal can significantly alter fish habitat through direct destruction, or through erosion and sedimentation. Activities below the ordinary high-water level require permits that consider fisheries impacts and are regulated by the US Army Corps of Engineers, the DNR, and other agencies. Work above the high-water level is primarily regulated by county land services agencies and other local governmental units. The DNR's shoreline habitat program (dnr.state.mn.us/waters/watermgmt_section/shoreland/) assists landowners with habitat restoration and improvement projects.

Habitat Protection

The protection of muskellunge habitat should focus on areas where a distinct survival bottleneck exists. For instance, mortality is highest for natural and cultured muskellunge from egg to later juvenile stages (approaching 30 inches). The presence of diverse aquatic vegetation containing emergent species (e.g., wild rice and bulrushes) appears to be critical for protection against predation. Likewise, thick beds of *Chara* spp. are important for spawning habitat and early fry stages. Therefore, protecting natural shorelines that have more diverse habitat than developed shorelines should be the priority.

The DNR has several methods to protect nearshore habitats for fish and wildlife. The Section of Fisheries administers the Aquatic Plant Management program that is responsible for permitting removal of nearshore vegetation. Lakeshore property owners are allowed, by law, to have reasonable access to navigable water but there are restrictions on how much vegetation and by what method it can be removed, particularly without a permit. The Aquatic Management Area program has protected specific nearshore habitats like the muskellunge spawning areas of Kocemba Bay on Deer Lake and Miller's Bay on Leech Lake by purchasing land to remain undeveloped. Shoreland protection via land purchase or conservation easement is the most effective strategy in protecting habitat because it is permanent, but it is expensive and requires on-going maintenance by the property owner (e.g. signage, trash, nuisance species control). Finally, education and outreach could be used to encourage property owners to leave

nearshore and adjacent upland areas more natural if the importance and role those habitats play in an ecosystem are better understood and valued.

Muskellunge Management

Muskellunge Waters

A previous list of muskellunge waters was presented in the 2008 LRP. A review of the list was necessary for several reasons: new waters have been added, some waters have seen changes in management from hybrid muskellunge to pure-strain muskellunge, and management has been discontinued in some lakes. The previous list also contained historical waters where muskellunge no longer exist. Perhaps most importantly, the previous list did not serve anglers well as it included waters without public access and many waters containing muskellunge populations so low (because there was no directed management) there was little reasonable expectation of encountering one ([Appendix G](#)). The 2025 List of Muskellunge Waters ([Appendix H](#)) better reflects where legitimate angling opportunities exist. Waters were included if muskellunge populations met at least one of three criteria in that water: 1) they are stocked, 2) they are routinely sampled in that water, or 3) they represent an important component of the lake's fishery. The eight rivers identified in the 2008 LRP were included even though some did not have Stream Management Plans, and the abundance of muskellunge in these rivers is unknown. Legacy waters not included in the revised list can be found in [Appendix I](#).

DNR manages about 4,285 lakes and rivers, or "waters," (excluding Lake Superior) for fishing that total 2,285,978 surface acres. Muskellunge are actively managed, as identified in individual Lake Management Plans, in 101 waters totaling 492,312 surface acres ([Table 2](#)). Muskellunge waters comprise 2.4% of the total number of waters and 21.5% of the total surface acres managed for fishing. Of the 101 waters, 91 are managed for pure-strain muskellunge, and 10 are managed for hybrid muskellunge in the Twin Cities Metro Area. The 91 pure-strain waters include 35 lakes or lake systems and eight rivers that are considered natural waters, meaning muskellunge existed there historically, and 48 waters where muskellunge were introduced and are maintained through stocking. Muskellunge stocking in Pleasant Lake, Ramsey County, was resumed in 2019 with the goal of creating an additional brood stock population. Pleasant Lake has no public access and is closed to angling because it serves as the municipal water source for the City of St. Paul. As such, Pleasant Lake is not included within the muskellunge Managed Waters list. Muskellunge have been found in small numbers (in some cases a single observation) in another 56 waters, but these are not actively managed and the likelihood of catching a muskellunge in these waters is very low. Many of these waters are small, connected waters that do not support fishable populations, may be the result of illegal fish movement by anglers, and some were discontinued in the muskellunge program due to a lack of success in achieving the management goals.

Table 2. Number, size and type of actively managed muskellunge waters, 2025.

Type of waterbody	Number of Surface acres	Percent of Surface acres	Number of lakes	Percent of lakes
Waters managed for fishing ¹	2,285,978	-	4,285	-
Non-stocked waters	212,287	9.3	35	0.8
Stocked muskellunge waters	276,974	12.1	48	1.1
Stocked hybrid muskellunge waters	3,027	0.1	10	0.3
All stocked waters	280,025	12.3	58	1.4
All waters excluding hybrids	489,285	21.4	83	1.9
All waters	492,312	21.5	93	2.2
Rivers	-	-	8	0.2
Total waters managed for muskellunge ²	492,312	21.5	101	2.4

¹ Waters managed for recreational fishing is limited only to those lakes that are surveyed by DNR Fisheries; these include border waters that are available to Minnesota anglers without a separate angling license. Lake Superior is not included.

² Includes hybrid muskellunge.

Muskellunge Stocking

A program review of muskellunge stocking had yet to be performed at the time of the 2008 LRP publication, as adaptive management of individual waters was preferred. As such, managers developed individual lake management plans to address lake-specific needs. Various stocking rates had been attempted and examined for many introduced populations. The most common stocking rate of one fall fingerling per littoral acre provided good recruitment in a wide variety of waters. Most waters had stocking rotations ranging from annual to one-of-three years, with the majority on alternate years. Alternate year stocking provided steady recruitment on many waters. Therefore, the 2008 LRP recommended waters be stocked at one fingerling per littoral acre in alternate years.

Evaluating muskellunge stocking presents unique challenges. Muskellunge can be difficult to sample and their catch rates from surveys can be unreliable measures of abundance. Muskellunge are also

notoriously difficult to accurately age. Attempts at stocking evaluations were further confounded by historically loose adherence to stocking plans. Many lakes received more or fewer fingerlings, an alternate life stage, received fish in back-to-back years, or had years skipped all together, particularly during years of insufficient or surplus fingerling production statewide. Further, a common management strategy for establishing new waters was to stock them annually for a up to ten years before transitioning to biennial stocking. As a result, contributions of stocked fish and the efficacies of various stocking rates were poorly understood.

A program review in 2015 attempted to better position fisheries managers to understand the contribution of stocked fish. The review recommended stocking rates be streamlined into four options, where possible. The recommended standard stocking rates were 1) 1.0 fingerling per littoral acre biennially, 2) 0.5 fingerlings per littoral acre biennially, 3) 0.5 fingerlings per littoral acre annually, and 4) 0.25 fingerlings per littoral acre biennially. Unique stocking rates were recommended to remain on some waters for evaluation purposes or to maintain brood stock populations. Furthermore, the statewide stocking priorities were updated to improve long-term consistency. This priority ensures lakes of statewide importance receive their quota in years when program production is insufficient. Equally important, the priority ensures waters do not exceed their established quota in years when surplus fish are available. The priorities build off the recommendations from the 2008 LRP and collectively takes into consideration importance of each water to the brood lake program, statewide evaluations, the regional fishery it provides, and age of the fishery. The adopted stocking priority creates 1) a list of waters that must be fully stocked when they are scheduled, and 2) a list of waters that should be skipped or receive surplus fish as to not violate the first condition, when fingerling production fails or exceeds targets. The priority list also identifies waters eligible to receive alternate life stages for stocking. Stocked waters are prioritized by their managed category:

1. **Brood:** Waters managed for brood stock populations
2. **Core:** Mille Lacs, Vermilion, and Minnetonka lakes
3. **Historical:** Historically consistent stocking in number, frequency, and life stage. These will provide opportunity for long-term assessment of different stocking plans.
4. **Premier:** Waters with reputations for producing exceptional fisheries.
5. **Recent Introduction:** Waters established after 2008. These populations are still developing.
6. **Metro:** Waters receiving significant angling pressure, located near metropolitan areas.
7. **Program:** Waters with one of four recommended standard stocking rates.
8. **Other:** Waters with variable stocking histories, are stocked temporarily to inject genetics into naturalized populations, large rivers. These waters may receive alternate life stages.

Future Management

Fingerling Production Limitations, Stocking Ratios, and a Phased Implementation of Yearling Stocking

A successful stocking program requires hatchery-reared fish to survive at sufficient rates to recruit to the fishery. Muskellunge eventually become top-level predators within fish communities, but as juveniles,

they face the same challenges as most sport fish. The goal of hatchery-rearing is to bypass many of the hurdles that early life stages experience in the wild. The DNR muskellunge production and stocking program is based primarily on fall fingerlings, which average 10 to 11 inches and are stocked in October. On an annual basis, approximately 27,000 fall fingerlings must be produced to meet the existing statewide quotas. The production of fall fingerlings relies on a combination of using natural rearing ponds, 30 smaller drainable hatchery ponds at the New London and Waterville State Fish Hatcheries, and 10 larger drainable ponds distributed throughout Minnesota. Unfortunately, meeting the fall fingerling quotas has been challenging given the natural variability in production. Consequently, the availability of fall fingerlings has limited the muskellunge program and resulted in the creation of a complex prioritization system that stresses the production/stocking program in years of shortfalls. The current system has resulted in some lower priority waters receiving less than their programed quotas or even missing consecutive years of stocking altogether.

Growing evidence has indicated the number of stocked fall fingerlings is not the most important factor in sustaining muskellunge recruitment. Muskellunge are particularly vulnerable to bird and fish predation post-stocking; thus, the probability of survival improves with increased length at stocking. In the northern range of muskellunge, the maximum size fall fingerlings can achieve using extensive production techniques is limited by the short growing season. For example, while the average length of fall fingerlings produced in Minnesota has consistently remained near 10 to 11 inches, the maximum length seldom exceeds 13 inches. The inability of hatchery managers to produce larger fall fingerlings using a single year of growth strategy has pushed MN DNR and agencies in other states to investigate the effects of length at stocking on recruitment. The results have persuaded several agencies in other states to incorporate yearlings into their stocking programs, which involves holding or growing fish over winter into the second growing season (spring or fall). For DNR, given the challenges in consistently meeting the fall fingerling production quotas and inability to produce fish large enough to survive well, it is apparent the muskellunge stocking program should shift to producing yearlings. Ideally, any plan to meet existing stocking quotas would include a mix of fall fingerlings and yearlings. Intentionally incorporating yearlings into the stocking program would offer continuous information to steer future production/stocking efforts, inform investments, and to assure muskellunge recruitment is improved or sustained.

A review of the available information is vital for considering incorporating yearlings into the muskellunge production and stocking program. A mix of published and unpublished studies have demonstrated larger fingerlings survive better than smaller fingerlings. DNR evaluated size-specific returns from Floy-tagged fall fingerlings stocked in three Metro Area waters. Angler recaptures were low, but the results mirrored past studies in that larger fish survived better. Muskellunge fingerlings less than 11 inches were underrepresented in the recaptured sample. In fact, fall fingerlings stocked at less than 10 inches generally were not reported.

In this same study, DNR conducted a paired evaluation of fall fingerlings (11.1 inches) and fall yearlings (16.9 inches) stocked from 2008 through 2012 on Bald Eagle, Minnetonka, and White Bear lakes. Survival of fall yearlings was consistently better than fall fingerlings based on recaptures of PIT tags in spring surveys on Bald Eagle Lake and angler returns of Floy tags from all three waters. The results

varied among the study waters but on average, it required 11 stocked fall fingerlings to achieve similar recruitment as one fall yearling.

In neighboring states, the Wisconsin DNR stocked three lakes with fall fingerlings and spring yearlings of the same year-class. Spring yearlings survived 4.5 times better (19%) than fall fingerlings (4.2%) to 18 months of age. Ratios of spring yearling to fall fingerling captured during sampling ranged up to 6:1. Similarly, the Iowa DNR transitioned to stocking spring yearling muskellunge after decades of stocking fall fingerlings, and recent studies have indicated improved success with yearlings. Iowa DNR has found a stocking ratio of 4:1 fall fingerlings to spring yearlings to achieve similar short-term survival to age 2 (Jonathan Meerbeek, Iowa DNR, personal communication).

All muskellunge stocked in French Lake (Rice County, Minnesota) since 2015 were marked with PIT tags. Additionally, Waterville Fisheries purposefully stocked a wide range of fall fingerlings anticipating differential survival based on length at stocking. Spring muskellunge surveys on French Lake from 2022 – 2024 discovered survival to age 5 was substantially influenced by length at stocking. This pilot project on French Lake was the inspiration for the DNR to develop recruitment curves (survival to age 5) for muskellunge stocked lakes. At the time of this writing, adequate data was available to develop preliminary recruitment models for French, Rebecca, Elk, and Bald Eagle lakes. Although the survival of stocked muskellunge was variable among lakes, the pattern was similar, demonstrating a positive relationship between length at stocking and recruitment. These findings offer evidence to support an equivalency stocking ratio of at least a 5:1 for fall fingerlings to fall yearlings.

Sufficient evidence exists that muskellunge yearlings survive better than fall fingerlings in Wisconsin, Iowa, and Minnesota with equivalency stocking ratios of at least 5:1. As a result, the DNR implemented a 5:1 stocking equivalency ratio for fall fingerlings to fall yearlings in 2024. The stocking ratio shall remain unchanged until sufficient data from long-term monitoring finds lower or higher survival of stocked yearlings that would justify adjustments to the stocking ratio. Eventually the stocking rate may be tailored to an individual lake should sufficient data become available. Until more data is available though, the 5:1 stocking ratio optimizes the limited supply of yearlings into the stocking program, while expanding the ability to stock yearlings in more waters.

Continuous evaluation is needed to assess size-specific survival of fall fingerlings and fall yearlings on more waters in Minnesota. Fortunately, an ever-growing database of PIT tagged muskellunge with lengths at stocking will provide a foundation for these evaluations. Still, a limitation within the existing program is that within any given year, within or among lakes, the range of lengths of the stocked fall fingerlings is often narrow, which impedes the ability to gain insight into length effects on recruitment using a random stocking approach. The systematic incorporation of PIT-tagged yearlings into the program appears promising, providing important insight into understanding recruitment that will guide future muskellunge production and stocking programs.

Stocking of yearling muskellunge into designated waters will occur in a phased approach. This approach is necessary as DNR is undertaking a new initiative that is dependent upon infrastructure improvements at Waterville SFH, yet to be constructed. As such, the yearling muskellunge production capacity is unknown. In other words, DNR anticipates the number of yearlings available for stocking to increase as

staff learns and adapts to the proposed new systems. Available yearling muskellunge will be prioritized for important muskellunge fisheries that are underperforming (low recruitment), based on individual lake management plans either in place or that are being developed. A priority list for these waters has been amended into the current overall muskellunge stocking priority that was developed in 2015. The Core Lakes (Mille Lacs, Minnetonka, Vermilion) will be first in priority for yearling muskellunge. Changes to Lake Vermilion will only occur after completion of the next Lake Management Plan. As yearling production capacity grows, the preferred approach for implementation will be to convert 20% of statewide muskellunge fall fingerling stocking plans to fall yearlings. The across-the-board implementation of yearlings into the program allows broader assessment of yearling recruitment for all stocked muskellunge waters. The strategy provides a baseline 20% conversion to yearlings stocking goal that can be adjusted as the yearling production program develops. The statewide approach to stocking yearling muskellunge also alleviates potential social pressures to stock specific lakes with yearlings, as most lakes will be treated similarly.

Minnesota has produced yearling muskellunge in the past but were never the focal point of the program. In general, the production of yearling muskellunge has only been achieved when carryover occurred in natural rearing ponds. Yearling muskellunge will continue to be produced in natural ponds, and use of natural ponds to produce fall yearlings should be expanded to accommodate a multi-pronged approach to achieving yearling production goals. DNR has also reared fall yearlings in drainable ponds following the private purchase of spring yearlings from a private grower, as well as overwintered fall fingerlings in drainable ponds and indoors in Recirculating Aquaculture System for subsequent grow out in drainable ponds for a second summer. Rearing success in all these systems has been variable, but the higher survival rate of those yearlings that are produced and stocked should be highly valuable towards creating an improved program that will ultimately be noticed by anglers.

Conceptual and logistical plans have been discussed regarding a transition from mainly fall fingerling production to one with greater focus on fall yearlings. These plans will be further developed as new infrastructure is designed, built or improved, and as knowledge is gained. The goal of providing a more consistent and better product will remain steadfast while being adaptable to year-to-year changing conditions (e.g. environmental, successes or failure, cost), especially during this period of transition.

Lakes Mille Lacs, Vermilion and Minnetonka

Lakes Mille Lacs, Vermilion, and Minnetonka are essential to the quality of Minnesota's muskellunge program; as such, these will be categorized as Core Lakes. The Core Lakes also represent the three largest stocked muskellunge waters in Minnesota. Mille Lacs and Minnetonka lakes are located near the Twin Cities Metro Area, while Lake Vermilion is located within the Iron Range of Northeastern Minnesota. Lake Vermilion is unique in that it provides an angling experience typically found within the Canadian Shield ecoregion. Although muskellunge populations within all three lakes are well known to have big fish potential, Mille Lacs and Vermilion lakes have demonstrated their ability to consistently produce world-class trophy specimens. In fact, the state record muskellunge, which stood for 64 years, was broken in 2021 by a Lake Mille Lacs muskellunge. These waters historically absorbed substantial fishing pressure due to their unique size, habitat characteristics, geographic locations, and the

exceptional fisheries contained within them. These lakes have many access points and nearby services anglers may desire such as fuel, restaurants, and retail. Vermilion and Mille Lacs lakes also have a storied history, economically driven by the many vacation resorts on their shores. Together, these aspects make these waters desirable destinations for anglers seeking extended vacations with family or just a simple angling outing for a day.

In the last 15 years, anglers and the citizen northern pike/muskellunge species workgroup have increasingly voiced displeasure with muskellunge fishing in Mille Lacs, Vermilion, and Minnetonka lakes. During the spring of 2024, the Muskellunge Long Range Plan planning process gathered public input on the state of muskellunge fishing and directions of future management. In addition to survey questions, participants were encouraged to share their thoughts in two essay-style sections of the survey, resulting in 3,782 comments being received. Respondents frequently mentioned fishing pressure for muskellunge has increased, lakes were often crowded, and the populations of muskellunge had declined in most waters. Lakes Mille Lacs, Vermilion, and Minnetonka were specifically mentioned by name, far greater than any other lakes, as waters in need of specific management action or fishery improvement. Sufficient input has also been provided to suggest perceived increases in fishing pressure and reduced angling success on smaller waters was, at least in part, due to the decline in the quality of the muskellunge fisheries in these three core waters. More specifically, the large number of anglers that historically utilized the Core Lakes changed fishing habits and locations as the angling experience declined, which concentrated a disproportionate number of anglers onto the remaining smaller waters, resulting again in negative angling experiences.

Based on strong angler support, this plan specifically prioritizes the muskellunge fisheries of lakes Mille Lacs, Vermilion, and Minnetonka and focuses efforts on improving existing waters before considering creating any additional muskellunge waters. One of the main tools for improving fisheries will be to prioritize stocking larger fingerlings or yearling muskellunge. Each of the Core Lakes are unique and will continue to be managed under the individual lake management planning process. Each are also at different stages within the lake planning process; Mille Lacs management is focused on working with Mille Lacs Band of Ojibwe and Great Lakes Indian Fish and Wildlife Commission to evaluate increased Muskellunge fingerling or yearling stocking levels; Lake Vermilion is nearing the end of the current lake management plan with a planned population estimate that will inform any adjustments to stocking; and management in Lake Minnetonka has already seen more use of yearlings in the stocking strategy. Adaptive management of the Core Lakes will continue as new information, rearing techniques, and survey data become available.

Hybrid Muskellunge Management

Background

Minnesota creates hybrid (tiger) muskellunge by crossing female muskellunge with male northern pike. The original intent of the hybrid muskellunge program was to provide anglers an opportunity to catch a large fish in waters where they were not common. Hybrid muskellunge grow faster than both northern pike and pure strain muskellunge and are more readily caught than muskellunge (Bregre 1986; Storck

and Newman 1992). Hybrid muskellunge were initially stocked in Minnesota waters in 1983. Since then, they have been stocked in 29 different waters. Introduction has been limited to waters within the Twin Cities Metropolitan Area (Dakota, Ramsey, Washington, Carver, Hennepin, and Scott counties). DNR produced all the hybrid muskellunge fingerlings until 2000. Beginning in 2001, private vendors have purchased hybrid muskellunge fry hatched in the St. Paul State Fish Hatchery for growing out at their private facilities. Resulting fall fingerlings are purchased back by DNR for stocking. Through 2006, hybrid muskellunge were managed in 21 lakes with stocking rates ranging from 1 to 5.9 fish per littoral acre every three years. An internal review of the hybrid muskellunge program in 2006 led to changes in the number of waters managed and associated stocking rates and frequencies. Of the 21 lakes in the program, staff recommended dropping management on seven and switching from hybrid muskellunge management to pure strain muskellunge management on another three ([Appendix I](#)). Stocking rates on the remaining 10 lakes ranged from 1 to 5.7 fingerlings per littoral acre while stocking frequencies were increased to every other year. The statewide minimum length limit for hybrid muskellunge is currently set at 40 inches.

Management

No substantial changes to the hybrid muskellunge management program are proposed. However, future management should focus on more in-depth assessments of hybrid muskellunge fisheries, particularly measuring angler effort and interest. Existing data is limited to relatively few fish sampled from standard lake survey nets and an occasional fish captured with electrofishing gear while sampling largemouth bass populations. Additional sampling effort should be directed towards hybrid muskellunge and attempts should be made to obtain statistically valid population estimates in a portion of the managed waters. Suggested sampling techniques include electrofishing and organized angling events targeted at hybrid muskellunge. For most lakes, existing creel data are from the 1990s and do not reflect the increased interest and angling pressure on muskellunge waters.

Goals, Objectives and Strategies

The goals in this plan are long-term (15 year) outcome-oriented purpose statements, supporting DNR's ongoing efforts to sustain a successful muskellunge management program. Public and stakeholder input was critical in formulating these goals. An overarching goal has always been to create and sustain high-quality muskellunge angling opportunities in Minnesota. With restrictive harvest regulations already in place, voluntary catch and release commonplace, and declining populations in some lakes, improving survival of stocked muskellunge is a key strategy in this plan. While there is considerable public interest in stocking new waters, there was overwhelming support for DNR to focus first on sustaining and improving existing muskellunge populations. Another strong desire among the muskellunge angling community was a request that DNR focus efforts and resources to improve the muskellunge fisheries in Mille Lacs, Vermilion, and Minnetonka lakes.

- Goal 1 – Maintain muskellunge populations for high-quality angling opportunities through sustainable management
- Goal 2 – Maintain and improve muskellunge fingerling and yearling production capacity

- Goal 3 – Manage hybrid (tiger) muskellunge populations in select lakes within the Twin Cities Metro area
- Goal 4 – Conduct outreach and education efforts centered on the role of muskellunge in fish communities

Below each of these goals, this plan lists objectives and strategies:

- Objectives are activities that support plan goals that can be tracked to determine progress through the life of the plan.
- Strategies are specific, actionable statements describing how DNR will achieve its goals and objectives. Harvest regulations, stocking, and public outreach are the primary strategies involved in the management of the fishery.

Goal 1 — Maintain muskellunge populations for high-quality angling opportunities through sustainable management

Objective 1A. Improve survival of stocked fish through increased use of yearling stocking

Sufficient evidence now exists that yearlings survive better than fall fingerlings in Wisconsin, Iowa, and Minnesota with equivalency stocking ratios of at least 5 fingerlings to 1 yearling. These higher survival rates should result in higher recruitment into the adult population, thus improving both muskellunge fisheries and program efficiencies (e.g., use less space, less staff time).

Strategies:

- Beginning in 2025, DNR will begin a phased implementation of incorporating yearling stocking, as production capacity allows. DNR will work towards converting 20% of statewide muskellunge fall fingerling stocking quota to fall yearlings at a 5:1 stocking ratio by 2030.
- Utilize both short- and long-term research/monitoring to provide continuous information feedback. This will allow ongoing evaluation and adjustments to stocking ratio and other production/stocking considerations, as well as provide updates and information to public.
- As production and stocking efficiencies are realized adjust stocking allocation of fingerlings and yearlings based on individual lake management plan recommendations and priorities.
- Seek new and refine current production methods to accommodate a yearling production program while also sustaining a fall fingerling production program.

Objective 1B. Sustain and improve muskellunge fisheries on Mille Lacs, Minnetonka and Vermilion lakes

These three core stocked lakes have been identified as critical to the quality of the muskellunge program in Minnesota. These waters historically contained exceptional fisheries that absorbed substantial fishing pressure due to their large size, habitat characteristics, and geographic locations. Anglers around the state have noted increased fishing pressure and reduced success on smaller waters as the quality of the muskellunge fisheries declined in these core waters.

Strategies:

- In Lake Mille Lacs, continue to work with the Mille Lacs Band of Ojibwe and Great Lakes Indian Fish and Wildlife Commission co-management partners to evaluate muskellunge fingerling or yearling stocking levels to improve the muskellunge fishery.
- In Lake Vermilion, continue stocking 3,000 fingerlings annually (with option for supplemental stocking of up to 2,000 additional fingerlings in any two-year window) until the proposed population estimate in 2027–2028, after which stocking plans, rates, and life stages will be re-evaluated.
- In Lake Minnetonka, the preferred and prioritized life stage for fulfilling the stocking quota will be yearlings.

Objective 1C. Manage for trophy angling opportunities

The use of Leech Lake strain of muskellunge as its brood source is foundational to Minnesota’s muskellunge program. The combination of these genetics and waters with diverse fish communities and habitats has enabled the muskellunge program to be a successful trophy destination for anglers.

Strategies:

- Manage muskellunge populations through size regulations and season closures, and voluntary catch and release.
- Collaborate with the Fisheries Technology Workgroup to share information about the real and perceived impacts of live-imaging sonar to help anglers make decisions about practicing ethical behaviors, including strategies that minimize impacts of barotrauma, water temperatures, hooking mortality, and improper fish handling on fish survival.
- Encourage and engage in studies investigating the potential influences of fishing practices, including use of technology (e.g., live imaging sonar) on catch rates, fish behavior, and population-level impacts to muskellunge populations. Some examples include: 1) ongoing population modeling simulating increased catch and mortality rates, 2) ongoing Leech Lake muskellunge telemetry study on post-spawn and angled fish assessing behavior and survival fates being led by Bemidji State University, and 3) a study recently funded by LCCMR being led by the University of Minnesota that will evaluate the impact of forward-facing sonar on angler catch rates and fish mortality across multiple species (including muskellunge) and lake types to inform sustainable management of fish populations.

Objective 1D. Maintain critical habitat so natural and introduced muskellunge populations are preserved

Native and introduced muskellunge populations have thrived in a diversity of lake habitats. Diverse aquatic vegetation is an important part of successful muskellunge management. Undisturbed shorelines with *Chara spp.* (muskgrass) and emergent vegetation are particularly important for spawning, nursery, and juvenile habitat, whether it be a native or stocked water.

Strategies:

- Identify and quantify critical muskellunge spawning and nursery habitat.
- Protect muskellunge spawning and nursery habitats by purchasing aquatic management areas as properties and funding are available. Native or stocked waters with documented natural reproduction would receive the highest priority.

Objective 1E. Identify muskellunge populations that appear to be underperforming

Metrics used to determine muskellunge populations that could be improved include, but are not limited to, DNR survey catch rates, population modeling, and angler satisfaction. Specific investigations are further detailed in *Objective 1H*.

Strategies:

- Conduct spring targeted surveys on waters where data are limited.
- Work with all partners to improve muskellunge populations on waters of concern.
- Adjustment to stocking strategies will likely be the primary action used.

Objective 1F. Increase muskellunge recruitment in waters that appear to be underperforming

Muskellunge recruitment in both stocked and native waters may be insufficient for a number of factors including poor spawning and rearing habitat, lack of preferred prey, and predators. Insufficient adult densities may be a limiting factor in native waters.

Strategies:

- Adjust some combination of stocking rates and size in waters currently stocked.
- Supplement recruitment in historically native waters through stocking at a reduced traditional rate (i.e., 0.5 fingerlings per littoral acre) when production capabilities have been improved, or during years of surplus production.

Objective 1G. Consider adding new muskellunge waters after management of existing waters and production capabilities have been improved.

While there is interest in expanding the muskellunge program, public input suggests the primary focus should be sustaining and improving the existing waters. New waters will only be considered 1) after substantial progress in production capabilities have occurred, and 2) if local opportunities and public support exists.

Strategy:

- Use the public input process while considering biological and physical characteristics of candidate lakes.

Objective 1H. Conduct research and continue refining evaluation methods to monitor muskellunge population characteristics.

New techniques in sampling design and population modeling combined with additional years of data will continue to advance the understanding of Minnesota muskellunge populations.

Strategies:

- Continue using passive integrated transponder (PIT) tags to provide critical information on muskellunge population structure (numbers, age, and size) and dynamics (recruitment, growth, and mortality).
- Increase funding for more PIT tagging operations.

- Explore available research on fishing technology and how fisheries managers and biologists can use the technology (e.g., live-imaging sonar) to improve fish surveys and inform future research.
- Using the Muskellunge Sampling Guidelines, conduct spring surveys that include mark and recapture population estimates to evaluate stocking effectiveness and population status for each managed water by 2040. Areas with several waters should consult the Muskellunge Technical Team to help prioritize sampling.
- Prioritize consecutive, multi-year surveys (3-5 years) to estimate recruitment and mortality on representative waters around the state. Expand collaboration among Areas to meet high priority needs.
- Utilize adult population estimates in conjunction with estimates of recruitment and mortality to refine lake-specific stocking quotas.
- Investigate the relationship among adult muskellunge biomass, density, and size structure. Monitor these metrics in newer waters as they move from a developing to an established population.
- Investigate the relationship among adult muskellunge biomass and density with lake size, productivity, and lake morphometry.
- Conduct spring/fall sampling for juvenile muskellunge on natural and stocked waters to identify critical juvenile habitat and to classify waters according to reproductive status.

Objective 1I. Pursue avenues for acquiring/appointing a topical expert to assist management personnel and synthesize muskellunge data.

A topical expert will provide the resources and knowledge to summarize and compile muskellunge management techniques and research across the species range, as well as advise DNR on ways to advance the muskellunge program.

Strategies:

- The topical expert will be a member of the Muskellunge Technical Team and help direct the statewide priorities outlined in the Muskellunge Long Range Plan.
- Assist Area management with study designs, spring field work, and problem solving.
- Help design, populate, analyze, and report on a PIT tag database.
- Maintain long-term datasets (production, population estimates, etc.), analyze, and report on the findings.
- Lead the design, implementation, and reporting on muskellunge production related research to improve efficiencies.
- Determine the status of the various muskellunge acoustic tagging projects. Complete any unfinished analysis and produce an Investigational Report.
- Encourage, coordinate, and participate in outreach efforts to inform the public about role of muskellunge in balanced fish communities, how to safely handle muskellunge, and their management in Minnesota.

Goal 2 — Improve muskellunge fingerling and yearling production capacity

Objective 2A. Strengthen existing protocols to consistently achieve production goals

Minnesota’s muskellunge program has been built on decades of incremental improvements in raising fish. Maintaining successful protocols while building in redundancies in the program should allow the production goals to be achieved more frequently.

Strategies:

- Continue to manage muskellunge brood lakes with suitable year-classes to meet annual egg needs.
- Ensure genetic diversity in the brood stock waters by stocking fish from Leech Lake every four years.
- Establish Pleasant Lake as an alternative brood lake.
- Expand the use of natural ponds as transplants are available for fingerling and yearling production.

Objective 2B. Evaluate muskellunge rearing procedures to improve efficiencies and quality of product

Continued evaluation of fish rearing procedures is necessary to maintain an effective program. The establishment of an evaluation process that standardizes and records the variables that effect growth and survival of muskellunge will assist in improving quality angling opportunities.

Strategies:

- Continue to evaluate the dry diet feeding program for producing transplants.
- Create a drainable rearing pond database to evaluate methods and pond performance.
- Expand the evaluation of size-specific survival of fall fingerlings and fall yearlings.

Objective 2C. Invest in infrastructure to increase production capacity

Individual Lake Management Plans generate stocking quotas that near maximum production capacity in most years. Additional production capacity is needed to increase the frequency of meeting current production goals. Strategic investments in infrastructure will be necessary as the program continues to evaluate the most efficient methods for raising a quality product.

Strategies:

- Add the New London State Fish Hatchery to the transplant program.
- Invest in and evaluate the use of recirculating aquaculture systems in the production of yearlings.
- Construct, renovate or split larger ponds into smaller drainable ponds.
- Seek funding for new drainable ponds if the program review identifies a need.
- Optimize cost efficiency and reliability of forage minnow capture and purchase to optimize reared muskellunge survival and growth.

Objective 2D. Shift management and production focus from simply the number of fish raised to a strategy that optimizes recruits to the fishery

Strong evidence from numerous management agencies across the muskellunge range found survival of stocked fish is strongly linked to the size of the individual at time of stocking. Stocking fewer, but larger fish (yearlings) should improve production efficiencies while also increasing muskellunge recruitment.

Strategies:

- Evaluate the capacity to incorporate more fall yearling muskellunge into the production program (pond capacity, minnow availability, staff, logistics, cost-effectiveness, etc.).
- Increase infrastructure to overwinter small, fall fingerlings so they can be grown-out to fall yearlings.

Objective 2E. Diversify muskellunge production

DNR historically contracted the purchase of privately raised muskellunge fingerlings. Re-examine the feasibility of purchasing fingerlings or yearlings from the private sector to help consistently achieve stocking quotas.

Strategies:

- Explore funding to purchase young muskellunge to supplement and safeguard DNR's annual production quota when the cost-benefit balance is favorable.
- Develop standards and protocols for accepting and utilizing private gifts of muskellunge whether that be for direct stocking into waters or into DNR's production facilities for further grow-out.

Goal 3 — Manage hybrid (tiger) muskellunge populations in select lakes within the Twin Cities Metro area

Objective 3A. Continue managing and stocking 11 lakes in the Metro area with hybrid (tiger) muskellunge

These waters provide a unique opportunity for anglers to pursue large fish in waters that are unsuitable to traditional muskellunge due to habitat constraints. These waters are also located within population centers and provide increased accessibility to such fish due to their relatively small size.

Strategies:

- Continue spawn-take operations to meet annual stocking goals.
- Waters are traditionally stocked every other year, with approximately half of the lakes stocked in even years, and half stocked in odd years.

Objective 3B. Determine interest in expanding the hybrid (tiger) muskellunge management program

Information collected as part of this planning process indicated support to expand hybrid muskellunge opportunities. While there is considerable public interest in stocking new waters with hybrid

muskellunge, there was overwhelming support for DNR to focus first on sustaining and improving existing muskellunge populations, thus expanding the number of hybrid lakes will likely be a lower priority compared to other objectives.

Strategies:

- Use results of human dimensions surveys and engage with constituents to determine whether to expand the number of hybrid muskellunge lakes.
- Explore partnerships to purchase additional hybrid muskellunge fingerlings.

Objective 3C. Provide better information on hybrid (tiger) muskellunge populations and their utilization by anglers

Information about angler utilization of hybrid muskellunge fisheries would inform DNR on whether expanding the program to new waters is warranted.

Strategies:

- Develop sampling methods to assess hybrid muskellunge populations.
- Obtain angler effort and catch statistics through creel surveys or other non-traditional means.

Goal 4 — Outreach and education efforts centered on the role of muskellunge in fish communities

Objective 4A. Develop communication plans to reach diverse stakeholders

Highlight the substantial Minnesota-based research regarding the role of muskellunge in fish communities. Numerous investigations have demonstrated the introduction of muskellunge have not negatively affected fish communities.

Strategies:

- Work with popular media outlets to inform anglers about muskellunge fisheries.
- Attend angler and lake association meetings to share results of research and evaluations of muskellunge management.
- Continue updating web content and informational materials.

Literature Cited

- Axon, J. R. and L. E. Kornman. 1986. Characteristics of native muskellunge streams in eastern Kentucky. American Fisheries Society Special Publication 15:263-272.
- Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press. Madison, WI, U.S.A.
- Bevelhimer, M.S., R.A. Stein, and R.F. Carline. 1985. Assessing significance of physiological differences among three esocids with a bioenergetics model. *Can. J. Fish. Aquat. Sci.*, 42, 57–69.
- Beyerl, B. 2016. Mille Lacs Creel Survey Report for open water season of 2015 and winter season of 2014-2015. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-32, Jobs 936, 969.
- Bimber, D. L. 1982. Longevity, growth and mortality of muskellunge in Chautauqua Lake, New York. *New York Fish and Game Journal* 29:134-141.
- Boe, S. 1992. Cass Lake. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-12.
- Bozek, M. A., T. M. Burri, and R. V. Frie. 1999. Diets of muskellunge in northern Wisconsin lakes. *North American Journal of Fisheries Management* 19:258-270.
- Brege, D. 1986. A comparison of muskellunge and hybrid muskellunge in a southern Wisconsin lake. American Fisheries Society Special Publication 15:203-207.
- Brewer, D. L. 1980. A study of native muskellunge populations in eastern Kentucky streams. Kentucky Department of Fish and Wildlife Resources, Fisheries Bulletin Number 64, Frankfort.
- Caplan, D. L. 1982. An experimental study of interactions between young of the year pike *Esox lucius* and muskellunge *Esox masquinongy*. Master's thesis. University of Wisconsin, Madison.
- Carbart, A. H. 1937. More muskies. *Field & Stream* (September):71-72.
- Cole, A.J., and P.W. Bettoli. 2014. Thermal ecology of subadult and adult muskellunge in a thermally enriched reservoir. *Fisheries Management and Ecology* 21:410-420
- Craig, R. E., and R. M. Black. 1986. Nursery habitat of muskellunge in southern Georgian Bay, Lake Huron, Canada. American Fisheries Society Special Publication 15:79-86.
- Diana, J. S. 1979. The feeding pattern and daily ration of a top carnivore, the northern pike (*Esox lucius*). *Canadian Journal of Zoology* 57:2121-2127.
- Derks, J. 2020. Summer creel survey for Little Boy and Wabedo lakes, 2020. Minnesota Department of Natural Resources, Section of Fisheries, Study 4, Job # 1100.
- Frohnauer, N., C. L. Pierce, and L. W. Kallemeeyen. 2007. Populations dynamics and angler exploitation of the unique Muskellunge population in Shoepack Lake, Voyageurs National Park, Minnesota. *North American Journal of Fisheries Management* 27:63-76.

- Frohnauer, N. 2008. Estimating Creel Statistics and Walleye Exploitation on Island Lake Reservoir (DOW # 69-037200), Minnesota using a Stratified Random, Roving Creel Survey and Walleye Tagging. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-27, Job 802.
- Gammon, J. R. and A. D. Hasler 1965. Predation by introduced muskellunge on perch and bass, I: years 1-5. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 54:249-272.
- Glade, K.C., B.R. Herwig, T.D. Ahrenstorff, J.R. Reed, and A.W. Hafs. 2023. Diet patterns and niche overlap of Muskellunge and co-occurring piscivores in Minnesota lakes. North American Journal of Fisheries Management. <https://doi.org/10.1002/nafm.10880>
- Gorton, J. 2014. Creel Survey of Lake St. Croix, Dec. 27, 2012-Oct. 31, 2013. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-31, Job 922.
- Habrat, M. 2015. Creel Survey of Bad Medicine and Many Point Lakes, Becker County, Minnesota, Summer 2014. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-31, Job 931.
- Habrat, M. 2020. Creel Survey of Detroit Lake, Becker County, Minnesota, Summer 2019. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-34, Job 1075.
- Hanson, D. A., M. D. Staggs, S. L. Serns, L. D. Johnson, and L. M. Andrews. 1986. Survival of stocked Muskellunge eggs, fry, and fingerling in Wisconsin lakes. Pages 216–228 in Hall (1986).
- Hanson, D. A., and T. L. Margenau. 1992. Movement, habitat selection, and survival of stocked Muskellunge. North American Journal of Fisheries Management 12:474-483.
- Harrison, E. J., and W. F. Hadley. 1978. Ecological separation of sympatric muskellunge and northern pike. American Fisheries Society Special Publication 11:129-134.
- Harrison, E. J., and W. F. Hadley. 1979. Biology of muskellunge (*Esox masquinongy*) in the Upper Niagara River. Transactions of the American Fisheries Society 108:444-451.
- Heinrich, T. 2021 Mille Lacs Creel Survey Report for winter season of 2019-2020 and open water season of 2020. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-34, Job 1092.
- Herwig, B.R., K.D. Zimmer, and D.F. Staples. 2022. Using stable isotope data to quantify niche overlap and diets of muskellunge, northern pike, and walleye in a deep Minnesota lake. Ecology of Freshwater Fish 31:60-71. DOI: 10.1111/eff.12608
- Hourston, A. S. 1952. The food and growth of the maskinonge (*Esox masquinongy*) in Canadian waters. Journal of Fisheries Research Board of Canada 8:347-368.
- Inskip, P. D. 1986. Negative associations between abundances of muskellunge and northern pike: evidence and possible explanations. American Fisheries Society Special Publication 15:135-150.

- Inskip, P. D., and J. J. Magnuson. 1986. Fluctuations in growth rate and condition of muskellunge and northern pike in Escanaba Lake, Wisconsin. American Fisheries Society Special Publication 15:176-188.
- Jensen, E. 2011. Mille Lacs Lake creel survey report for open water season of 2010 and winter season of 2009-2010. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-29, Jobs 836, 858.
- Johnson, L. D. 1982. Factors affecting short-term survival of stocked Muskellunge fingerlings in Wisconsin. Wisconsin Department of Natural Resources, Research Report 117, Madison.
- Jones, T. 2001. Mille Lacs Lake creel survey report for open water season of 2000 and winter season of 1999-2000. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-19, 20, Jobs 535, 536.
- Jones, T. 2006. Mille Lacs Lake creel survey report for open water season of 2005 and winter season of 2004-2005. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-24,25, Jobs 679, 716.
- Kelling, C.J., D.A. Isermann, B.L. Sloss, and K.N. Turnquist. 2016. Diet overlap and predation between Largemouth Bass and Walleye in Wisconsin lakes using DNA barcoding to improve taxonomic resolution. North American Journal of Fisheries Management 36:621-629.
- Kennedy, T. 2016. Cass Lake Open Water Creel Survey. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-32, Job 964.
- Knapp, M.L., S.W. Mero, D.J. Bohlander, D.F. Staples, and J.A. Younk. 2012. Fish community responses to the introduction of Muskellunge in Minnesota lakes. North American Journal of Fisheries Management 32:191-201.
- Knapp, M.L., S.W. Mero, and D.F. Staples. 2021. Are Muskellunge affecting fish communities in waters where they have been introduced? A re-examination of Minnesota's stocked Muskellunge waters. North American Journal of Fisheries Management 41:229-241.
- Larscheid, J.G. 2008. Natural Lakes Investigations. Iowa Department of Natural Resources. Federal Aid in Sport Fish Restoration, Project F-160-R, Annual Performance Report, Des Moines.
- Lovelace, S. 2024. Fishing in Minnesota: A Study of Angler Participation and Activities in the 2022-23 Season. University of Minnesota, Minnesota Cooperative Fish and Wildlife Research Unit, Department of Fisheries, Wildlife, and Conservation Biology.
- Lyons, J., and T. Margenau. 1986. Population dynamics of stocked adult muskellunge (*Esox masquinongy*) in Lac Court Oreilles, Wisconsin 1961-1977. Wisconsin Department of Natural Resources, Technical Bulletin 160, Madison.
- Margenau, T. L. 1992. Survival and cost-effectiveness of stocked fall fingerling and spring yearling Muskellunge in Wisconsin. North American Journal of Fisheries Management 12:484-493.

- Margenau, T. L. 1993. An evaluation of In-lake enclosures for increasing short-term survival of stocked Muskellunge. Wisconsin Department of Natural Resources, Research Report 158, Madison.
- Margenau, T. L. 1999. Muskellunge Stocking Strategies in Wisconsin: The First Century and Beyond, North American Journal of Fisheries Management, 19: 223-229.
- Meerbeek, J. R. 2021. Short-term stocking survival of yearling Muskellunge raised in a recirculating aquaculture system. Iowa Department of Natural Resources. Federal Aid in Sport Fish Restoration, Study 7060 Completion Report, Des Moines.
- Miller, L. M., S. W. Mero, and J. A. Younk. 2012. The impact of stocking on the current ancestry in twenty native and introduced Muskellunge populations in Minnesota. Transactions of the American Fisheries Society 138:602-615.
- Miller, H. M. 2018. Fishing in Minnesota: A study of angler participation and activities – 2018 Final Report. University of Minnesota, Minnesota Cooperative Fish & Wildlife Research Unit. Department of Fisheries, Wildlife, and Conservation Biology.
- Moen, T. 2017. Winter and Summer Creel Surveys of Itasca State Park Lakes, Clearwater and Hubbard Counties, From December 2015 through September 2016. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-32, Job 990.
- Minnesota, State of. 1912. Biennial report of the Board of Game and Fish Commissioners of Minnesota for the biennial period ending July 31st. 1912.
- Minnesota, State of. 1934. Second biennial report of the Conservation Commission of the State of Minnesota for the Department of Conservation fiscal years 1933-1934, December 1934.
- Minnesota, State of. 1936. Third biennial report of the Conservation Commission of the State of Minnesota for the Department of Conservation fiscal years 1935-1936, December 1936.
- MNDNR (Minnesota Department of Natural Resources). 1986. 1987 Strategic planning fish. Minnesota Department of Natural Resources, Division of Fish and Wildlife, St. Paul.
- MNDNR (Minnesota Department of Natural Resources). 1994. Fisheries long range plan Muskellunge. Minnesota Department of Natural Resources, Division of Fish and Wildlife, St. Paul.
- MNDNR (Minnesota Department of Natural Resources). 2008. Long range plan for Muskellunge and large Northern Pike management through 2020. Minnesota Department of Natural Resources, Division of Fish and Wildlife, St. Paul.
- Oehmcke, A. A. 1951. Muskellunge yearling culture and its application to lake management. Progressive Fish-Culturist 13:63-70.
- Oehmcke, A. A., L. Johnson, J. Klingbiel, and C. Wistrom. 1958. The Wisconsin muskellunge – its life history, ecology, and management. Wisconsin Conservation Department, Publication 225.
- Olson, D. E., and P. K. Cunningham. 1989. Sport-fisheries trends shown by an annual Minnesota fishing contest over a 58-year period. North American Journal of Fisheries Management 9:287-297.

- Osterberg, D. M. 1985. Habitat portioning by muskellunge and northern pike in the international portion of the St. Lawrence River. *New York Fish and Game Journal* 32:158-166.
- Owensby, D. P., J. A. Rice, and D. D. Aday. 2017. Mortality, dispersal, and habitat use of stocked juvenile Muskellunge in two western North Carolina rivers. *North American Journal of Fisheries Management* 37:108-121.
- Painovich, N. 2025. Mille Lacs Creel Survey Report for winter season of 2023-2024 and open water season of 2024. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-36, Job 1191.
- Parsons, J. W. 1959. Muskellunge in Tennessee streams. *Transactions of the American Fisheries Society* 88:136-140.
- Pedersen, C., and D. Schultz. 2017. Summer creel survey report for Leech Lake 2016. Minnesota Department of Natural Resources, Section of Fisheries, F-29-R(P)-32, Job 994.
- Pedersen, C., and D. Schultz. 2020. Summer creel survey for Leech Lake, 2019. Minnesota Department of Natural Resources, Section of Fisheries, F-29-R(P)-34, Job 1078.
- Pierce, R. B, J. A. Younk, and C. M. Tomcko. 2007. Expulsion of miniature radio transmitters along with eggs of muskellunge and northern pike – a new method for locating critical spawning habitat. *Environ Biol Fish* 79:99-109. DOI 10.1007/s10641-006-9063-y
- Porter, L. R. 1977. Review of selected literature on muskellunge life history, ecology and management. Minnesota Department of Natural Resources Special Publication 119, St. Paul.
- Schroeder, S. A., D. C. Fulton, and R. A. Dodd. 2007. Managing muskie in Minnesota. Report to the Minnesota Department of Natural Resources. Minnesota Cooperative Fish and Wildlife Research Unit. Department of Fisheries, Wildlife and Conservation Biology. University of Minnesota, St. Paul.
- Scott, D.P. 1964. Thermal resistance of pike (*Esox lucius* L.), muskellunge (*Esox masquinongy* Mitchell), and their F₁ hybrid. *Journal of the Fisheries Board of Canada* 21:1043-1049.
- Serns, S. L., and L. M. Andrews. 1986. Comparative survival and growth of three sizes of Muskellunge fingerlings stocked in four northern Wisconsin lakes. Pages 229–237 in Hall (1986).
- Sewell, D. 2006. Creel Surveys of Sturgeon Lake (58-0067) and Island Lake (58-0062) During the 2005 Open Water Angling Season. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-29, Job 728.
- Sewell, D. 2013. Creel Surveys of East and West Rush Lake (13-0069) and Goose Lake (13-0083) During the 2012 Open Water Angling Season and the 2012-2013 Winter Angling Season. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-30, Job 892.

- Sewell, D. 2015. Creel Surveys of Cross Lake (58-0119) and Pokegema Lake (58-0142) During the Ice and Open Water Angling Seasons, 2013-2014. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-31, Job 955.
- Shavlik, C. 2018. Muskellunge spawning habitat in Big Mantrap Lake. Minnesota Department of Natural Resources, Section of Fisheries Completion Report F17A00190, Study IV, Job 1020.
- Snow, R.A., D.E. Shoup, and M.J. Porta. 2018. Effects of starvation on thermal tolerances of juvenile tiger muskellunge. *Journal of the Southeastern Association of Fish and Wildlife Agencies* 5:17-22.
- Soupir, C. 2009. Creel Survey of Fox Lake During the Open-water Angling Season, 2008. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-28, Job 827.
- Spangler, G. R. 1968. Angler harvest and mortality of *Esox masquinongy* in Pigeon and Sturgeon lakes. *Journal of the Fisheries Research Board of Canada* 25:1145-1154.
- Stein, R. A., R. F. Carline, and R. S. Hayward. 1981. Largemouth bass predation on stocked tiger Muskellunge. *Transactions of the American Fisheries Society* 110:604–612.
- Stevens, T., and M. Ward. 2015. Summer creel survey report for Leech Lake 2014. Minnesota Department of Natural Resources, Section of Fisheries, F-29-R(P)-31, Job 934.
- Storck, T. W., and D. L. Newman. 1992. Contribution of tiger muskellunge to the sport fishery of a small centrarchid-dominated impoundment. *North American Journal of Fisheries Management* 12:213-221.
- Strand, R. F. 1986. Identification of principal spawning areas and seasonal distribution and movements of muskellunge in Leech Lake Minnesota. *American Fisheries Society Special Publication* 15:62-73.
- Surber, T. 1929. Fish propagation in Minnesota. *Fins, Feathers and Fur* 72 (April):85-86.
- Varian, A., D. Hendrickson, K. Olson, and P. Piszczek. 2017. Access Based Creel Survey of the Open Water and Winter Fishery 2015-2016 and Walleye Population Estimate on the St. Louis River Estuary, St. Louis County, Minnesota and Douglas County, Wisconsin. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-32, Job 998.
- Ward, M., and D. Schultz. 2012. Summer creel survey report for Leech Lake 2011. Minnesota Department of Natural Resources, Section of Fisheries, F-29-R(P)-29, Job 860.
- Weber, R. E. and M. J. Weber. 2020. Yearling Muskellunge poststocking behavior and survival in two central Iowa reservoirs with contrasting habitat availability. *North American Journal of Fisheries Management* 40:1263-1275.
- Wendlandt, J. 2006. Creel survey report for Lake Miliona for the open-water season of 2004 and winter season of 2004-2005. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries, Study 4 Report, Job 677, St. Paul.

- Wiering, A. 2014. Creel survey of Lake Bemidji, Beltrami County, Minnesota Summer 2013 and Winter 2013-14. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Completion Report, F-29-R(P)-31, Job 906.
- Williams, D. 1997. Lake Vermilion 1996 summer creel survey. Minnesota Department of Natural Resources, Section of Fisheries Completion Report, F-29-R(P)-16.
- Williams, D. 1998. Lake Vermilion 1997 summer creel survey. Minnesota Department of Natural Resources, Section of Fisheries Completion Report, F-29-R(P)-17.
- Williams, D. 2003. Lake Vermilion 2002 summer creel survey. Minnesota Department of Natural Resources, Section of Fisheries Completion Report, F-29-R(P)-22.
- Williams, D. 2004. Lake Vermilion 2003 summer creel survey. Minnesota Department of Natural Resources, Section of Fisheries Completion Report, F-29-R(P)-23.
- Williams, D. 2009. Lake Vermilion 2008 summer creel survey. Minnesota Department of Natural Resources, Section of Fisheries Completion Report, F-29-R(P)-28.
- Williams, D. 2010. Lake Vermilion 2009 summer creel survey. Minnesota Department of Natural Resources, Section of Fisheries Completion Report, F-29-R(P)-29.
- Williams, D. 2015. Lake Vermilion summer creel survey 2014. Minnesota Department of Natural Resources, Section of Fisheries Completion Report, F-29-R(P)-31, Job 944.
- Williams, D. 2016. Lake Vermilion open water creel survey 2015. Minnesota Department of Natural Resources, Section of Fisheries Completion Report, F-29-R(P)-31, Job 973.
- White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46(Supplement): 120– 138.

Appendices

Appendix A - Draft Plan Public Review Summary

A draft version of the DNR update of the long-range Muskellunge management plan through 2040 was released for public review in May 2025. The draft was published on the DNR's muskellunge webpage and was posted on social media and followed with a press release to notify the public of their ability to comment. Most comments were submitted on the "Engage with DNR" webpage through a survey that was provided. The survey sought to determine the level of support or opposition for the plan objectives and allowed respondents to share their opinion via an open-ended response. In total, the public review period extended from May 12th to June 30th. During the review period, a total of 1,314 people filled out the online survey regarding the draft management plan and 33 people emailed comments about the plan. Additionally, an informational Webinar was held on May 28th.

The survey results indicated public support was strong for the vision of the Muskellunge program presented in the draft Long Range Plan. Objectives related to pure strain muskellunge had at least 82% "strongly agreeing" or "agreeing" and averaged 91% agreement while the three objectives related to hybrid (tiger) muskellunge management were somewhat lower. It appeared respondents were more indifferent to hybrid (tiger) muskellunge management compared to muskellunge management based on the higher proportion of "neither agree nor disagree" responses observed. These differences likely reflect that hybrid muskellunge are only managed in the Metro and do not attain the same trophy potential as muskellunge. Despite these differences, the responses to the hybrid muskellunge objectives still received 75 to 78% support.

The strong support for the direction of the plan is likely related to the relationship the MNDNR has with anglers on the Northern Pike/Muskellunge Species Workgroup and the MNDNR incorporating over 4,000 responses to the initial public input survey on the Muskellunge program prior to developing the plan. The open-ended comments were combined with email responses and comments were analyzed and sorted according to frequency. Comments were generally supportive and were related to a few key topics such as stocking and management, outreach and communication, emerging technology, and suggestions for partnerships and regulations.

Comments that resulted in plan changes or additions

- Research and consideration into the impacts Forward Facing Sonar is having on muskellunge populations.
- Additional education, outreach and communication on the importance of Muskellunge in balanced fish communities and how to safely handle Muskellunge.

Comments that were considered but outside the scope of the plan

- Bans on types of fishing (e.g., fishing with Forward Facing Sonar, fishing at depth, fishing in late summer, fishing in early summer, fishing with live bait, fishing with barbed hooks, catch and release only)
- Comments related to stocking a specific waterbody/geographic area more (or start stocking a specific waterbody).
- Discontinue Muskellunge or Tiger Muskie management on either existing or new waters.

Appendix B - Glossary

Abundance: The quantity of fish in a population. Abundance is usually expressed as a catch rate from standardized assessment gear when actual population size is unknown.

Adult: individuals that have reached sexual maturity. Often assigned to muskellunge greater than 30 inches in length.

Biomass: Measure of the total pounds of species in a population.

Brood source/lake: Waters containing a population of adults which provide eggs used within the hatchery system.

Electrofishing: The use of electricity to sample fish. Fish are temporarily stunned, netted, and held in a livewell. The effectiveness of electrofishing is limited to less than 4' of water, size of the fish within the shock field, and conductivity of the water.

Exploitation: The harvest or catching of fish and other aquatic organisms for commercial, recreational, or subsistence purposes. Muskellunge fisheries are dominated by recreational angling. High levels of exploitation can deplete fish populations.

Fingerling: A term used to describe small fish before they reach one year of age. Fall fingerling Muskellunge usually range from 8 – 13 inches and average about 10 inches.

Gastric lavage: A non-lethal method for obtaining dietary information. Water is pumped into a stomach of a fish to remove the contents so the number and species of food items can be identified and quantified.

Genetic diversity: The variation in genetic material within a population of fish. It can influence the survival, adaptability, and overall health of fish species. High genetic diversity allows populations to adapt to changing environmental conditions, resist diseases, and maintain healthy ecosystems.

Juvenile: individuals yet to reach sexual maturity. Often assigned to muskellunge less than 30 inches in length.

Lake morphometry: The physical characteristics and dimensions of a lake, including its shape, size, depth, volume, and bottom structure.

Littoral: Refers to the nearshore zone of a body of water. It typically includes the area from the high-water mark (the furthest point reached by water) down to the limit of light penetration in the water. Minnesota has for decades used a general definition of littoral to be the water 15' deep and shallower. The littoral zone provides important feeding, spawning and nursery habitat for most fish species.

Mark-recapture: Used to estimate the size of muskellunge populations. It is based on the idea of capturing a sample of individuals from a population, marking them in a harmless way, releasing them back into the population, and then sampling the population again later. By comparing the proportion of marked individuals in the second sample to the proportion of marked individuals in the entire population, researchers can estimate the total population size.

Mortality: The rate at which fish die. Can also be expressed as a percentage of the fish in the population that died since the beginning of a defined time-period. Mortality is typically divided into natural mortality (e.g., disease or being eaten by a predator) and fishing mortality (removed by harvest or hooking mortality).

Pelagic: Refers to the open water of a lake, typically away from the shore and above the lake bottom. It is used to describe the zone of the water column that is not influenced by the bottom (benthic zone) or the shore (littoral zone).

PIT tag: A Passive Integrated Transponder (PIT) tag is a small (about the size of a wild rice grain), electronic device inserted under the skin to identify and track individual animals. Often used to help researchers understand migration patterns, spawning habits, survival, growth. Since they are small and relatively non-invasive, PIT tags do not harm the animal.

Progeny: Refers to the offspring or young produced by a fish, particularly in the context of breeding and reproduction. It encompasses the descendants of a particular adult fish or group of fish. For example, if a particular fish species is stocked in a lake, the progeny of those stocked fish would be the offspring that hatch and grow from the eggs laid by those adult fish.

Pure strain: Refers to Muskellunge that are not hybrids.

Radio telemetry: A method used to monitor fish behaviors by attaching or implanting a radio tag in a fish and using a receiver to detect its radio signals. Radio telemetry is often employed to study fish migration patterns, habitat use, survival rates, and movement behaviors.

Recruitment: The number of fish surviving to a defined size or age. Commonly defined recruitment to size- or age-classes are when they first become vulnerable to the predominant fishing gear (e.g., the size at which they can be caught in a gill net or the size at which anglers begin to harvest them).

Stable isotopes: Different versions of chemical elements that can be used to understand where in a lake fish are eating (via Carbon isotopes) and what trophic position fish are eating (via Nitrogen isotopes). Often collected from fish using muscle samples.

Trap net: A sampling gear designed to capture fish by leading them to a confined area from which they cannot escape. Trap nets use a funnel-like structures that guide fish into a "trap" or "bag" but prevents

them from swimming back out. Trap nets can be effective for capturing fish in shallow waters, particularly during times when fish tend to congregate like spring.

Trophic position: The position of an organism in a food chain or food web, based on its feeding relationships and what it consumes. Generally measured through diet information and Nitrogen isotopes. Adult muskellunge generally have the highest trophic position in a lake.

Yearling: a term used to describe a fish that has completed one full year of life up to its second year. Fall yearlings have completed two summers of growth (roughly 18 months old). Fall yearling muskellunge usually range from 14 – 20 inches and average about 17 inches.

Appendix C - Muskellunge Diet Summary

Muskellunge diet summary based on 326 stomach samples from 12 Minnesota lakes during 2019-2022. The index of relative importance (IRI) is based on the percent by number, percent by weight and the percent frequency of occurrence (% FO) of the diet items observed. Note that %FO is based on a group of fish diets and not the diet of an individual fish. *Prey items are sorted by % IRI from highest to lowest values.*

Prey Group	% by number	% by weight	% FO	% IRI
Yellow perch	38.773	5.131	26.380	43.557
Unidentified fish	8.218	22.192	20.859	23.855
Suckers, Buffalos, Redhorses	3.241	25.607	8.282	8.985
Invertebrates	17.824	0.011	9.202	6.172
Sunfishes	6.250	2.463	11.350	3.719
Northern pike	2.315	13.640	6.135	3.681
Bullheads (yellow, brown, or black)	3.935	6.378	7.975	3.093
Black Basses	3.009	6.836	7.669	2.839
Cisco	2.894	4.562	7.055	1.978
Black crappie	2.315	2.010	5.521	0.898
Muskellunge (cannibalism)	0.694	3.145	1.840	0.266
Crayfish	1.157	0.697	2.761	0.193
Darters	3.009	0.025	1.534	0.175
Amphibians	1.852	0.294	1.840	0.149
Birds	0.579	1.449	1.534	0.117
Rock bass	0.694	0.390	1.840	0.075
Minnows	0.926	0.042	1.840	0.067
Burbot	0.231	2.349	0.613	0.060
Bowfin	0.231	1.580	0.613	0.042
Muskrats	0.347	0.854	0.920	0.042
Walleye	0.347	0.332	0.920	0.023
Central mudminnow	0.347	0.005	0.307	0.004
Logperch	0.347	0.004	0.307	0.004
Banded killifish	0.231	0.002	0.307	0.003
Sculpins	0.116	0.003	0.307	0.001
Tadpole madtom	0.116	0.001	0.307	0.001

Appendix D - Adult Population Estimates

Summary of estimated densities of adult (≥ 30 inches) muskellunge for 36 waters through 2024. Population estimates were calculated using several methods and models including modified Schnabel, Peterson, and various models using Program Mark and R. Surface acres were derived from the GIS database. Estimates are separated based on whether the waters were Stocked or Non-stocked (native or naturalized).

Waters	Muskellunge Origins	Surface acres	Number of years	Number of estimates	Average density (adults/acre)	Density range (adults/acre)
Alexander	Stocked	2,709	7	7	0.17	0.13 - 0.24
Bald Eagle	Stocked	1,047	1	1	0.14	-
Bemidji	Stocked	6,596	2	4	0.06	0.05 - 0.09
Big	Stocked	3,592	2	2	0.03	0.03 - 0.03
Cross	Stocked	925	4	5	0.10	0.06 - 0.17
Detroit	Stocked	3,083	3	3	0.13	0.12 - 0.13
Eagle	Stocked	287	1	1	0.57	-
East Rush	Stocked	1,481	6	7	0.13	0.02 - 0.34
Elk	Stocked	303	8	23	0.26	0.12 - 0.53
Forest	Stocked	2,271	1	1	0.08	-
Fox	Stocked	951	6	17	0.25	0.19 - 0.36
French	Stocked	876	6	7	0.32	0.23 - 0.43
Harriet	Stocked	341	1	1	0.32	-
Island	Stocked	536	4	5	0.29	0.06 - 0.39
Island Reservoir	Stocked	8,001	5	12	0.06	0.04 - 0.10
Little Wolf	Stocked	528	2	2	0.22	0.14 - 0.31
Lobster	Stocked	1,329	3	3	0.19	0.15 - 0.26
Big Mantrap	Stocked	1,618	3	3	0.20	0.13 - 0.27
Many Point	Stocked	1,701	1	1	0.23	-
Mille Lacs	Stocked	128,226	1	2	0.02	0.01 - 0.02
Miltona	Stocked	5,724	3	3	0.12	0.12 - 0.13
North Star	Stocked	1,071	5	10	0.22	0.06 - 0.32
Oscar	Stocked	997	1	1	0.12	-
Pelican	Stocked	4,640	1	1	0.05	-
Plantagenet	Stocked	2,531	3	3	0.15	0.13 - 0.17
Shamineau	Stocked	1,434	6	6	0.22	0.12 - 0.35
St. Louis River Estuary	Stocked	10,255	5	12	0.14	0.08 - 0.32
Sugar	Stocked	1,020	4	4	0.19	0.11 - 0.26
West Rush	Stocked	1,579	5	6	0.15	0.10 - 0.18
White Bear	Stocked	2,428	1	1	0.16	-

Waters	Muskellunge Origins	Surface acres	Number of years	Number of estimates	Average density (adults/acre)	Density range (adults/acre)
Baby	Non-stocked	737	1	2	0.41	0.35 - 0.47
Baby/Man	Non-stocked	1,228	1	7	0.28	0.26 - 0.32
Cass	Non-stocked	15,958	3	3	0.05	0.04 - 0.06
Deer	Non-stocked	4,094	5	8	0.13	0.074 - 0.18
Little Moose	Non-stocked	285	1	1	0.10	-
Man	Non-stocked	491	1	2	0.17	0.13 - 0.21
Moose	Non-stocked	1,274	13	42	0.17	0.07 - 0.38
Woman	Non-stocked	5,520	1	1	0.01	-

Appendix E. Estimated Total Annual Mortality for Adult Muskellunge from 16 Minnesota Waters

Corresponding 95% confidence intervals (CI) are presented in parentheses (MN DNR Steve Shroyer unpublished data).

Lake	Years	Female % mortality	Female mortality 95% CI	Male % mortality	Male mortality 95% CI
Bald Eagle	2011-2023	31	(19 - 47)	18	(11 - 29)
Cross	2009-2019	13	(7 - 24)	15	(9 - 25)
Detroit	2019-2025	20	(10 - 38)	17	(11 - 27)
East Rush	2011-2024	14	(3 - 51)	13	(2 - 49)
Elk	2003-2024	17	(13 - 22)	11	(8 - 14)
Fox	2011-2017	19	(13 - 26)	11	(7 - 17)
French	2016-2024	17	(10 - 28)	19	(13 - 27)
Island	2010-2022	13	(4 - 33)	15	(6 - 35)
Island Lake Reservoir	2008-2022	8	(4 - 15)	7	(4 - 13)
Mantrap	2015-2024	21	(10 - 37)	10	(0 - 49)
Moose	2008-2018	14	(10 - 21)	14	(10 - 21)
North Star	2008-2024	18	(13 - 26)	14	(10 - 18)
Pelican	2016-2024	14	(1 - 69)	6	(0 - 45)
Rebecca	2008-2025	22	(19 - 26)	23	(19 - 26)
Roosevelt	2018-2024	17	(1 - 81)	18	(2 - 73)
West Rush	2012-2018	22	(8 - 48)	16	(5 - 41)

Appendix F - Historical Creel Survey Metrics for Anglers Targeting Muskellunge

Water surveyed	Year	Acres	Effort (hrs.)	Hours per acre	Percent of total angling effort	Catch rate (#/hr.)
Elk ¹	2016	271	2,703	9.97	58%	- ^a
Cass ²	2014	15,596	15,033	0.96	9%	0.034
Cass ²	2015	15,596	17,079	1.10	10%	0.029
Cross ³	2014	925	2,967	3.21	8%	0.032
Detroit ⁴	2019	3,083	16,156 ^c	5.24 ^c	46% ^c	0.033
East Rush ⁵	2012	1,486	3,417	2.30	14%	0.013
Fox ⁶	2008	1,041	4,672	4.49	18%	0.064
Island Lake Reservoir ⁷	2006	8,280	3,902	0.47	6%	0.018
Island ⁸	2005	510	4,190	8.22	22%	0.006
Bemidji ⁹	2013	6,581	7,287	1.11	17%	0.019
Lake St. Croix ¹⁰	2013	8,209	11,304	1.37	6%	0.015 ^b
Leech ¹¹	2011	111,527	59,729	0.54	9%	0.017
Leech ¹²	2014	111,527	35,482	0.32 ^c	5%	0.039
Leech ¹³	2016	111,527	51,616 ^c	0.46 ^c	7%	0.018
Leech ¹⁴	2019	111,527	61,344 ^c	0.55 ^c	7% ^c	0.016
Little Boy ¹⁵	2020	1,452	5,317 ^c	3.66 ^c	14% ^c	0.011
Many Point ¹⁶	2014	1,737	4,527	2.67	17%	0.093
Mille Lacs ¹⁷	2000	128,250	84,019	0.66	7%	0.025
Mille Lacs ¹⁸	2005	128,250	137,038	1.07	12%	0.012
Mille Lacs ¹⁹	2010	128,250	60,920	0.48	6%	0.005
Mille Lacs ²⁰	2015	128,250	40,823	0.32	10%	0.008
Mille Lacs ²¹	2020	128,250	66,417	0.52	9%	0.009
Mille Lacs ²²	2024	128,250	16,329	0.13	4%	0.006
Miltona ²³	2005	5,724	16,549	2.90	23%	0.046
St. Louis River Estuary ²⁴	2015	11,500	7,963	0.69	7%	0.030
Vermilion ²⁵	1996	39,272	18,773 ^c	0.48 ^c	5% ^c	0.062
Vermilion ²⁶	1997	39,272	12,222 ^c	0.31 ^c	3% ^c	0.047
Vermilion ²⁷	2002	39,272	64,956 ^c	1.65 ^c	11% ^c	0.016
Vermilion ²⁸	2003	39,272	89,749 ^c	2.29 ^c	14% ^c	0.020
Vermilion ²⁹	2008	39,272	113,525 ^c	2.89 ^c	19% ^c	0.013

Vermilion ³⁰	2009	39,272	92,856 ^c	2.36 ^c	16% ^c	0.010
Vermilion ³¹	2014	39,272	74,887 ^c	1.91 ^c	16% ^c	0.014
Vermilion ³²	2015	39,272	69,873 ^c	1.78 ^c	14% ^c	0.024
Wabedo ¹¹	2020	1,226	7,091 ^c	5.78 ^c	20% ^c	0.008
West Rush ⁵	2012	1,578	6,071 ^c	3.85	13%	0.018

¹Moen 2017; ²Kennedy 2015; ³Sewell 2015; ⁴Habrat 2020; ⁵Sewell 2013; ⁶Soupir 2009; ⁷Fronhauer 2008; ⁸Sewell 2006; ⁹Wiering 2014; ¹⁰Gorton 2014; ¹¹Ward and Schultz 2012; ¹²Stevens and Ward 2015; ¹³Pederson and Schultz 2017; ¹⁴Pederson and Schultz 2020; ¹⁵Derks 2020; ¹⁶Habrat 2015; ¹⁷Jones 2001; ¹⁸Jones 2006; ¹⁹Jensen 2011; ²⁰Beyerl 2016; ²¹Heinrich 2021; ²²Painovich 2025; ²³Wendlandt 2006; ²⁴Varian et al. 2017; ²⁵Williams 1997; ²⁶Williams 1998; ²⁷Williams 2003; ²⁸Williams 2004; ²⁹Williams 2009; ³⁰Williams 2010; ³¹Williams 2015; ³²Williams 2016.

^a Catch rates for targeted anglers not listed in final report. The overall catch rate was 0.0148 fish/hour.

^b Mean of the reported monthly catch rates as the final report did not list a season catch rate for targeting anglers.

^c Estimates for effort should be considered approximations as they were not reported but calculated by multiplying the percent of angling parties targeting muskellunge and total angling effort.

Appendix G - Differences in Managed Waters Lists

Summary of the number and size of waters in the 2008 list of managed muskellunge waters.

Management focus	Surface Acres	Number of waterbodies
All lakes	808,729	108
Non-stocked lakes	540,976	44
Stocked lakes ¹	267,753	64
Rivers	-	8

¹Includes hybrid muskellunge.

Summary of the number and size of waters in the new 2025 list of managed muskellunge waters.

Management focus	Surface Acres	Number of waterbodies
All lakes	492,312	93
Non-stocked lakes	212,287	35
Stocked lakes ¹	280,025	58
Rivers	-	8

¹Includes hybrid muskellunge.

Appendix H - Waters Managed for Muskellunge

Minnesota's actively managed muskellunge waters, 2025. Current listing of Stocked muskellunge waters.

Water body	County	Acres¹	Managed Category²
Alexander	Morrison	2,709	I
Bald Eagle	Ramsey	1,047	I
Beers	Otter Tail	200	I
Bemidji	Beltrami	6,596	NS
Big	Beltrami	3,592	NS
Blandin	Itasca	490	NS
Bde Maka Ska	Hennepin	419	H/I
Cedar	Aitkin	1,745	I
Cedar	Hennepin	164	H/I
Cross	Pine	925	I
Detroit	Becker	3,067	I
Eagle	Hennepin	287	I
East Rush	Chisago	1,481	I
Elk	Clearwater	303	I
Forest	Washington	2,271	I
Fox	Martin	951	I
Fairmont Chain	Martin	1,179	I
French	Rice	876	I
Gull	Cass	10,010	I
Harriet	Hennepin	341	I
Independence	Hennepin	832	I
Island	Pine	536	I
Island Lake Res.	St. Louis	8,001	I
Lake of the Isles	Hennepin	112	H/I
Little Wolf	Cass	528	I
Lobster	Douglas	1,329	I
Mantrap	Hubbard	1,618	NS
Many Point	Becker	1,701	I
Mille Lacs	Aitkin	128,226	I

Water body	County	Acres¹	Managed Category²
Miltona	Douglas	5,724	I
Minnetonka	Hennepin	14,730	I
North Star	Itasca	832	I
Oscar	Douglas	997	I
Owasso	Ramsey	375	I
Pelican	Otter Tail	3,962	I
Plantagenet	Hubbard	2,531	I
Pokegama	Itasca	6,710	NS
Rebecca	Hennepin	263	I
Roosevelt	Cass	1,511	I
Sauk River Chain	Stearns	2,539	I
Shamineau	Morrison	1,434	I
Sugar	Wright	1,020	I
Vermilion	St. Louis	39,273	I
Waconia	Carver	3,080	I
West Battle	Otter Tail	5,565	I
West Rush	Chisago	1,579	
White Bear	Washington	2,428	I
Zumbro	Olmsted	715	I

¹GIS acres were used unless specified by the Fisheries Management Area.

²I = Introduced: currently stocked

NS = Natural stocked: historic occurrence, now stocked

H/I = Introduced hybrid lakes switched to pure strain (2010)

Minnesota’s actively managed muskellunge waters, 2025. Current listing of Non-Stocked muskellunge waters.

Water body	County	Acres¹	Status²
Andrusia	Beltrami	1,590	N
Baby	Cass	737	N
Bad Axe	Hubbard	303	N
Big Wolf	Beltrami	1,073	N
Boulder	Cook	129	SP
Boy	Cass	3,452	N
Cass	Cass	15,958	N
Child	Cass	285	N
Crescent	Cook	755	SP
Deer	Itasca	4,094	N
Dumbbell	Lake	406	SP
Girl	Cass	428	N
Harris	Lake	122	SP
Homestead	Lake	44	SP
Inguadona	Cass	1,125	N
Kid	Cass	168	N
Kitchi	Beltrami	1,858	N
Leech	Cass	102,948	N
Little Boy	Cass	1,452	N
Little Moose	Itasca	285	N
Little Shoepack	Lake	51	N
Man	Cass	491	N
May	Cass	143	N
Mckeown	Cass	168	N
Moose	Itasca	1,274	N
Orange	Itasca	104	SP
Pike Bay	Cass	4,751	N
Shoepack	St. Louis	299	N
Spider	Itasca	1,392	SP
Steamboat	Cass	1,756	N
Swift	Cass	357	N
Wabedo	Cass	1,226	N

Water body	County	Acres¹	Status²
Winnibigoshish	Cass	56,470	N
Woman	Cass	5,520	N
Wolf	Cass	1,073	N

¹GIS acres were used unless specified by the Fisheries Management Area.

²N = Natural: historic occurrence

SP = Introduced Shoepack: historically stocked Shoepack strain

Minnesota’s actively managed muskellunge waters, 2025. Current listing of muskellunge rivers.

Rivers	County	Status¹
Mississippi R.	Various	NS
St. Croix R.	Washington	NS
St. Louis R.	St. Louis	NS
Big Fork R.	Itasca	N
Kettle R.	Pine	N
Little Fork R.	Koochiching	N
Prairie R.	Itasca	N
Snake R.	Pine	N

¹N = Natural: historic occurrence

NS = Natural stocked: historic occurrence, now stocked

Minnesota’s actively managed muskellunge waters, 2025. Current listing of Stocked hybrid muskellunge waters.

Water body	County	Acres¹	Managed Category²
Bryant	Hennepin	178	H
Cedar	Scott	793	H
Clear	Washington	429	H
Crystal	Dakota	289	H
Elmo	Washington	257	H
Gervais	Ramsey	235	H
Johanna	Ramsey	212	H
Nokomis	Hennepin	201	H
Orchard	Dakota	235	H
Phalen	Ramsey	198	H

¹GIS acres were used unless specified by the Fisheries Management Area.

²H = Introduced hybrid: stocked hybrid muskellunge

Appendix I - Legacy Muskellunge Waters

Previously categorized muskellunge (MUE) and hybrid muskellunge (TME) waters not included in the actively managed muskellunge waters, 2025. Waters were not included because they were no longer being stocked, discontinued active management or they did not provide a fishery for anglers.

Water body	County	Acres	Type
Belle Taine ¹	Hubbard	1,442	MUE
Big Sand ¹	Hubbard	1,635	MUE
Buck	Beltrami	360	MUE
Carr	Beltrami	42	MUE
Emma ¹	Hubbard	78	MUE
Ida ¹	Hubbard	74	MUE
Lake of the Woods ²	Lake of the Woods	305,535	MUE
Little Sand ¹	Hubbard	410	MUE
Little Winnibigoshish	Itasca	932	MUE
Lower Bottle ¹	Hubbard	641	MUE
Mule	Cass	525	MUE
Pleasant	Ramsey	607	MUE
Spider ¹	Hubbard	570	MUE
Stocking ¹	Hubbard	100	MUE
Upper Bottle ¹	Hubbard	459	MUE
Bush	Hennepin	186	TME
Crystal	Hennepin	79	TME
Eagle	Carver	183	TME
Island	Ramsey	59	TME
Pierson	Carver	297	TME
Silver	Ramsey	75	TME
Wasserman	Carver	165	TME
Weaver	Hennepin	152	TME

¹These waters contained historic natural populations and in some cases were vital to the state’s muskellunge program during the early 20th century. Some of these waters may represent viable opportunities for muskellunge restoration.

²The Minnesota portion of Lake of the Woods is not managed for muskellunge as lake habitats supporting muskellunge are nearly entirely located within Ontario, Canada.

Appendix J - Hybrid Muskellunge Management

Waters that are (A) currently stocked with hybrid muskellunge, (B) species management changed to pure strain muskellunge, and (C) hybrid muskellunge management was discontinued, as described in the 2008 long range plan for muskellunge (MNDNR 2008).

Water body	County	Acres	Stocking frequency	Stocking quota	Most recent year stocked ¹	Management ¹
Bryant	Hennepin	178	Even years	128	2023	A
Cedar	Scott	793	Even years	793	2024	A
Clear	Washington	429	Odd years	401	2021	A
Crystal	Dakota	289	Even years	432	2024	A
Elmo	Washington	257	Odd years	257	2021	A
Gervais	Ramsey	235	Odd years	234	2021	A
Johanna	Ramsey	212	Even years	318	2024	A
Nokomis	Hennepin	201	Even years	200	2024	A
Orchard	Dakota	235	Even years	468	2024	A
Phalen	Ramsey	198	Odd years	120	2016	A
Bde Maka Ska	Hennepin	419	Even	123	2022	B
Cedar	Hennepin	164	Even	63	2022	B
Isles	Hennepin	108	*	*	*	B
Bush	Hennepin	186	-	-	2006	C
Crystal	Hennepin	79	-	-	2017	C
Eagle	Carver	183	-	-	2007	C
Island	Ramsey	59	-	-	2008	C
Pierson	Carver	297	-	-	2006	C
Silver	Ramsey	75	-	-	2008	C
Wasserman	Carver	165	-	-	2006	C
Weaver	Hennepin	152	-	-	2016	C

* Lake of the Isles is not stocked directly, rather managed through the close connection to waters on either side.

¹Management categories of A are stocked hybrid muskellunge waters, management categories of B are waters converted from hybrid to pure strain waters, and management categories of C are waters where hybrid muskellunge management was discontinued