Muskellunge Stocking Guidelines

Background (based on Oehmcke 1969).- Little was known about the abundance of muskellunge in Wisconsin at the turn of the 20th century; at that time, native muskellunge were apparently confined to lakes and streams at the headwaters of the Chippewa, Flambeau, Black and Wisconsin Rivers. About 20 counties were believed to contain muskellunge. The artificial propagation of muskellunge in Wisconsin was initiated in 1899 at Woodruff. For over 25 years, little effort was directed toward rearing muskellunge beyond the sac fry stage. Up until about 1941, 18 seasonal hatcheries in northern Wisconsin produced from several thousand to 28 million fry annually. Nearly all muskellunge were stocked shortly after hatching from eggs incubated in jars. The rearing of muskellunge to fingerling size in ponds was attempted sporadically from 1926 to 1938, with little success.

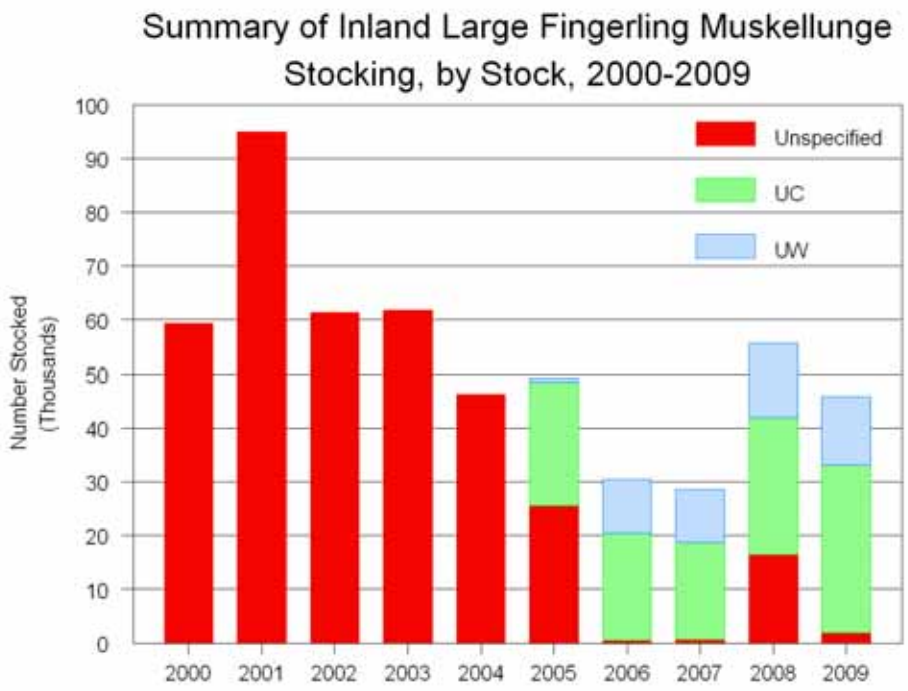
A decline in muskellunge populations was observed concurrent with the growth of sport fishing activity following World War II. Although the exploitation of muskellunge populations by anglers was not documented, it was generally believed that the annual harvest exceeded recruitment to populations through natural reproduction. From 1940 to 1970, improvements in the propagation program helped contribute to the recovery and maintenance of fishable muskellunge populations. Systematic procedures for pond rearing of fingerlings were developed in the 1940's and the two major muskellunge hatcheries went into full production by about 1950. The shift to raising larger fingerlings (8 to 15 inches) occurred in 1954, when 2 to 6 inch fingerlings were cropped off and remaining fish were reared to a larger size and stocked by October.

By 1970, about 30% of the muskellunge waters were stocked annually with large fingerlings. Refinements in stocking procedures resulted in targeted plantings in critical problem waters. These specialized stocking situations included waters faced with heavy depletion by angling, excessive competition with northern pike, loss of spawning areas, natural catastrophes, and stocking waters that had been reclaimed with toxicants. When actual catch from a given lake was known, a fingerling stocking of twice the annual harvest was recommended. Otherwise, a standard rate of 2 fingerlings per acre was used. A certain amount of stocking at this rate was conducted to assure adequate spawning stock in prime waters and to remediate for the loss of spawning habitat. By 1970, the species inhabited about 33 counties in all geographic areas except the extreme southwest. This expanded range was primarily a result of stocking.

Current stocking practices

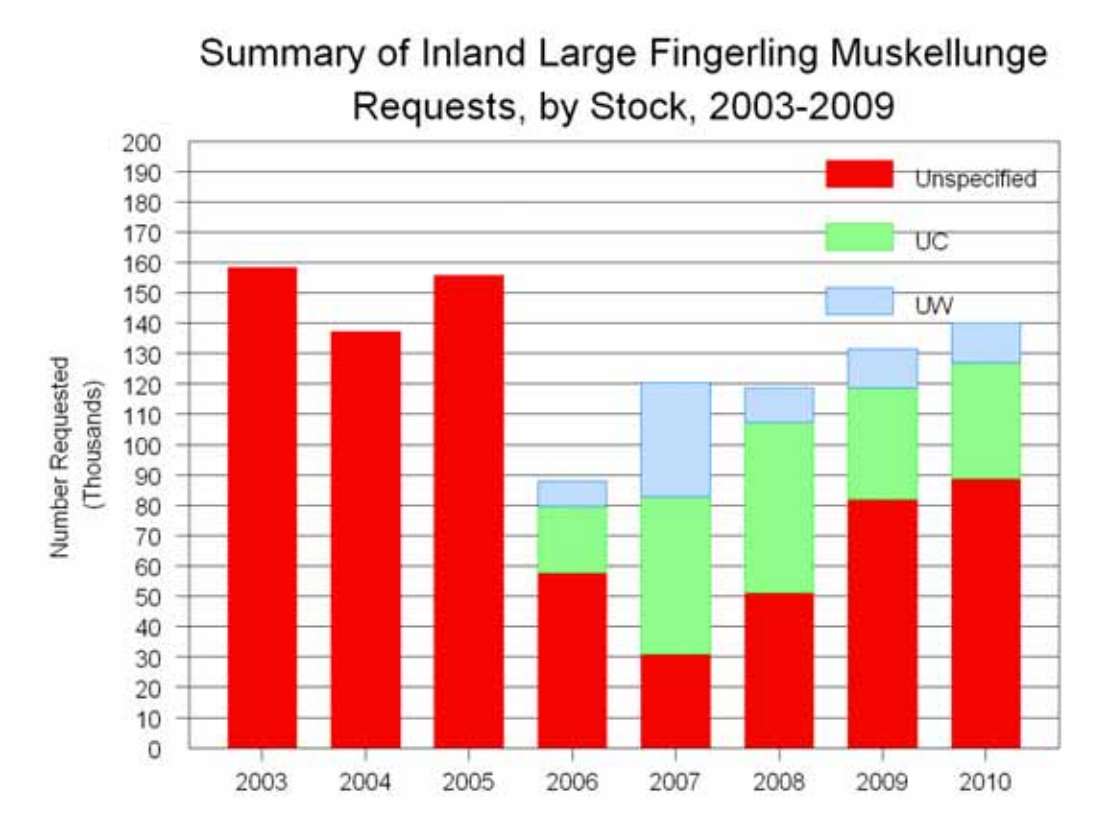
Inland Muskellunge

At present, approximately 178 waters (22% of Wisconsin's 804 muskellunge waters) are regularly stocked with muskellunge to maintain the fishery, down from 216 (27%) in 1999. From 2000 to 2009, an average of 53,326 large fingerlings were stocked annually in inland waters, compared to an average of about 72,000 from 1995-1999, following major renovations of the two primary muskellunge hatcheries. From 1970 t0 1999, an average of 128,747 muskellunge were stocked annually.



This figure shows production of muskellunge over the last decade. The completion of a brood stock management plan in 2005 resulted in the development of 2 inland stocks, aligned by watershed boundaries – the Upper Chippewa Basin (UC) and the Upper Wisconsin River Basin (UW). This initially impacted production due to minor difficulties, e.g., identifying new brood source waters, etc.

Actual requests for inland, large fingerling muskellunge from 2003 to 2010 averaged 131,228 (projected demand in 1999 was 138,000), whereas requests for muskellunge from 1995 to 1999 averaged about 141,000 annually. Requests from 1983 to 1993 averaged about 157,000. A low level demand for yearling muskellunge of about 350-400 fish has existed through recent years (not shown).

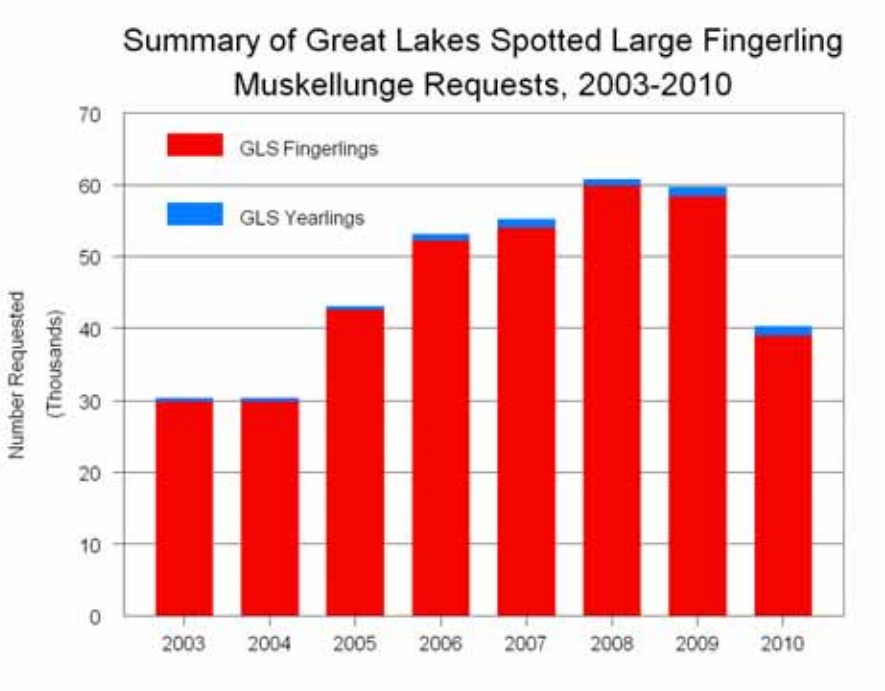


The demand for muskellunge (about 140,000 large fingerling/year) has not been met for many years. This demand is a measure of the "biological quotas" (quotas submitted without regard for limitations in production capabilities) and were not necessarily expected to be met. The demand is "tiered" to ensure that all requested waters get some fish, rather than a few large waters getting all the fish. We are closer to meeting tier I stocking levels (about 90,000 fish/year), but still typically all short of that goal. Substantial changes in brood stock management guidelines in 2005 have undoubtedly impacted production.

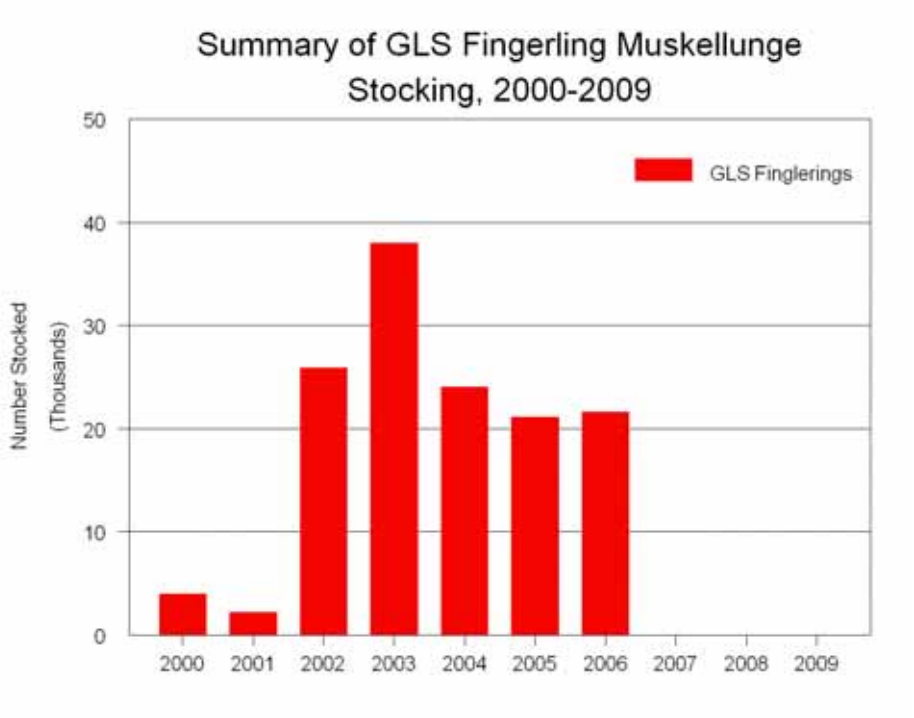
The increased demand for muskellunge in recent years can largely be attributed to higher requests of "unspecified" fingerlings (outside the native range). Demand for fingerlings within the native range has remained stable and may even decline through time.

Great Lakes Spotted Muskellunge

In 1999, we did not include the projected stocking needs for Great Lakes spotted (GLS) muskellunge. Actual requests for large fingerling GLS muskellunge from 2003 to 2010 averaged 45,816. Demand for yearling GLS muskellunge has increased from 350 in 2003 to 1,200 in 2010. An evaluation by Kapuscinski et al. 2007, found that yearlings stocked in Green Bay contributed to the adult population at a higher rate than fingerlings, suggesting higher survival and cost effectiveness.



The demand has tailed off the last couple years because these fish are presently not available from the hatcheries, due to concerns over taking eggs from VHS-positive waters.



However, in the future, these concerns should be addressed by 1) approved egg disinfection; and 2) developing inland sources of brood stock. Therefore demand is expected to remain at levels consistent with the last few years (60,000 fish). Further, the Musky Team has previously recommended that all inland quotas within the Lakes Michigan and Superior basin also be stocked with GLS muskellunge. This would amount to about 5,000 additional GLS fish being produced and an equal number of an inland stock that would no longer need to be produced. So, overall demand for GLS muskellunge over the longer term is expect to be 65,000 fish annually.

Current inland stocking practices are listed in Appendix A. Existing stocking practices under the Remediation and Recreation strategies, by far the most common strategies, are presented in the following table, along with the number of waters within each stocking strategy.

In order to obtain the information needed to sufficiently evaluate our stocking practices, we established this management framework to allow a comprehensive evaluation of our stocking practices. We assigned each of the approximately 220 stocked muskellunge waters to a specific stocking practice for 10 years. During this period, we are assessing these fisheries through existing survey efforts. This will allow us to evaluate the effectiveness of various rates (number of muskellunge per acre) and frequencies (annual, alternate years, etc.) for large fingerling stocking events in a variety of waters. This evaluation was initiated in 2001 and is scheduled to be completed by 2011. We are in the process of scheduling surveys of these populations over the next couple of years.

Muskellunge stocking framework for large fingerlings under the Remediation and Recreation strategies (priority 3). Note: 6 waters under the Rehabilitation and Research strategies are not included. Stocking was terminated in 28 randomly selected remediation waters (*), beginning in 2001. These waters are not included in the totals.

	Nominal stocking rate (number/acre)				
Strategy	0	0.5	1	2	Total
Remediation	28*	45	37	9	91
Recreation	0	28	35	18	81
Total	28*	73	72	27	172

This approach was designed to: 1) allow long term, consistent application of experimental treatments, 2) provide a long-term production target for the hatchery system, 3) aid the hatchery system in development of basin-specific stocks, and 4) greatly reduce annual workload related to quota requests. Also, this framework has remained somewhat flexible so that biologists could respond to interim changes in populations with timely changes in management strategies. Serious concerns were reviewed annually and addressed prior to the spawning period.

Specific Muskellunge Management Goals and Objectives.-

I. Protect and enhance Wisconsin's naturally reproducing (category 1) populations.

A. Identify Wisconsin's self-sustained muskellunge populations.
B. Identify and protect existing spawning and nursery habitat.
C. Protect the genetic integrity of self-sustained muskellunge populations.
D. Protect adult muskellunge from harvest to full maturity.

II. Manage muskellunge for a variety of unique fishing opportunities (including trophy, quality action, and harvest) within balanced aquatic communities.

A. Trophy Fisheries - Manage Class A1 waters to increase the catch of 50" and larger muskellunge.

B. Action Fisheries - Manage Class A2 waters for a catch rate of 1 muskellunge (any size) per 25 hours of muskellunge angling.

C. Improve Existing Fisheries - Rehabilitate former muskellunge waters that have experienced substantial declines in the muskellunge population and improve class B and C fisheries, particularly in southern Wisconsin.

D. Simplify the regulations framework.

III. Improve the information available for muskellunge populations and educational efforts to inform anglers about the status and management of muskellunge fisheries.

A. Monitoring - Conduct long-term trend sampling to track muskellunge abundance, size-structure and relative abundance of the associated fish community. Conduct mail surveys every 10 years to track angler attitudes and to evaluate program goals. Pilot an Angler Diary program for possible broad-scale coverage. Update Category and Class designations.

B. Evaluation – Evaluate the comprehensive muskellunge stocking framework to determine relative contribution of stocked fish in Category 2 waters and stocking success in category 3 waters.

C. Education - Continue to focus on the value of catch and release to the fishery - provide technical assistance to partners in their efforts to educate anglers on C&R. Emphasize that muskellunge are components of aquatic ecosystems, and as such, interact with other species via predation and competition. Evaluate the reliability and adequacy of existing information from the fishery.

IV. Minimize User conflicts - provide a unique, aesthetic experience.

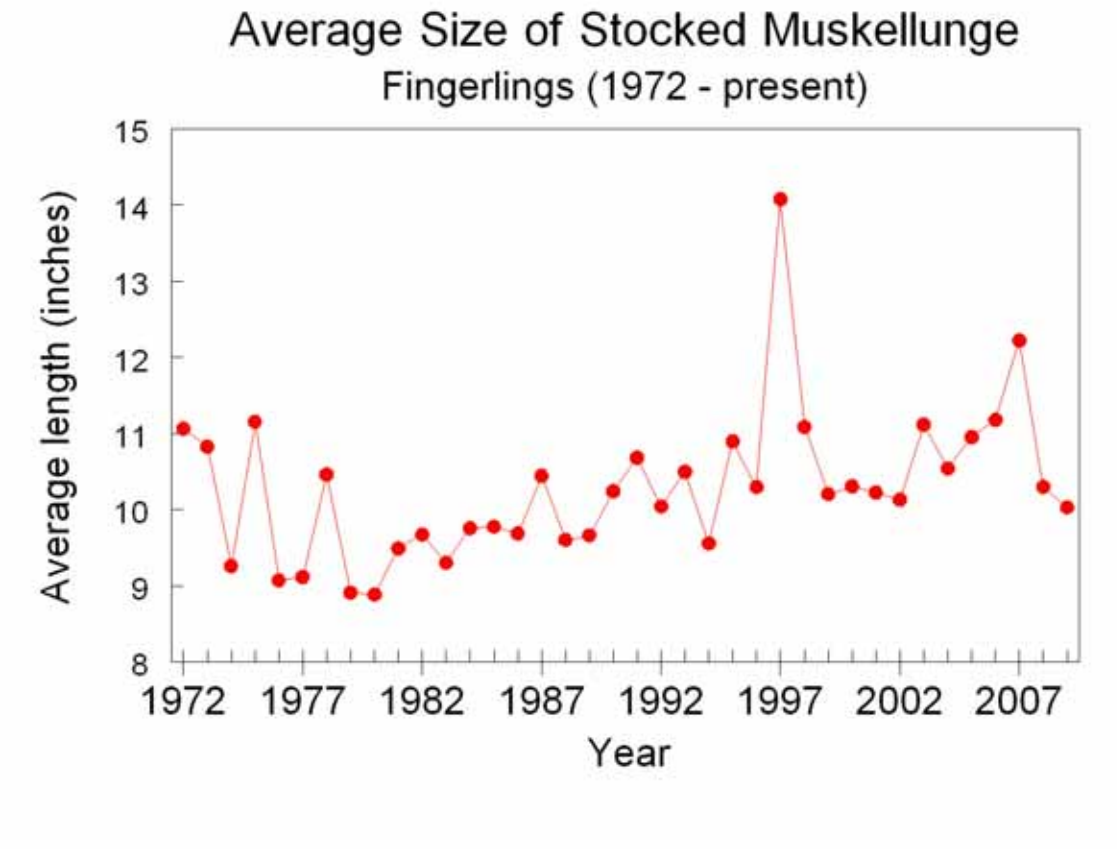
Costs and Cost-effectiveness of muskellunge stocking (from 1999 report) - The cost to produce and stock muskellunge increases considerably with size, from about $1.36/1000 fry (WLAB 1997) to about $5.20/spring yearling (Margenau 1992); production costs can also vary considerably from year to year (Margenau 1992). Cost-effectiveness is measured as the cost per stocked fish that is recruited to the fishery (i.e., of catchable size). Cost-effectiveness could also be measured as the cost per fish caught or harvested by anglers. The cost-effectiveness of stocking various sizes of muskellunge varies considerably among waters and years due to variability in survival and variability in production costs.

In general, stocking fewer large fish has been shown to be more cost-effective than stocking many small fish. For example, with muskellunge fry stocking, the costs are relatively low but the survival of fry is highly variable and the likelihood of any muskellunge surviving at all in any given year is very low (Hanson et al. 1986). Given a survival rate of 0.004% to fall (Hanson et al. 1986) and a survival rate of 4.2% from the first fall to the next fall (at 18 months of age; Margenau 1996), 588,235 fry would need to be stocked to result in 1 surviving muskellunge, at a cost of about $800.00 per muskellunge. Cost effectiveness of fall-stocked fingerlings to 18 months of age averages about $70.75 per surviving muskellunge. Cost per spring-stocked yearling muskellunge surviving to 18 months of age averages about $27.42 per muskellunge.

Estimated cost-effectiveness of stocking different sizes of muskellunge.

Size of muskellunge	Production Cost per fish	Survival rate to 18 months of age	Number stocked/ survivor	Cost per survivor to 18 months
Fry	$1.36/1000	0.00017%	588,235	$800.00
Fall fingerlings	$2.83	4%	25	$70.75
Spring yearings	$5.21	19%	5	$27.42

These estimates are based on averages: because survival and production costs vary considerably from year to year, the cost-effectiveness should be evaluated over several years on an individual water in order to get an accurate estimate. Also, WDNR Fisheries Biologists routinely use professional judgment when they determine what size of fish is most appropriate for stocking on specific waters. Their primary concern is to maximize survival of stocked fish, which obviously improves cost-effectiveness. For this reason, the department often uses fry stocking in winterkill or reclaimed lakes that are free of predators, and stocks larger sizes in waters having well established fish communities with a variety of natural predators. The reason stocking is even economical at all rests in the fact that the cost per survivor can be very inexpensive in certain years when survival of stocked fish is excellent and production costs are low, so it is cost-effective over a longer time period. A further benefit of stocking larger fish rather than smaller fish is that the variability in survival for larger fish is lower from year to year (i.e., more likely to have at least some survival; e.g., Hanson et al. 1986), providing a more consistent return on investments in stocked fish. The less time the fish is at-large when it is small and vulnerable to a whole host of sources of mortality, the higher its chances of survival and eventual contribution to the fishery.



Brood Stock Management Plan. We completed a Brood Stock Management Plan in 2005 which guides many of our spawning operations of wild brood stocks and hatchery practices based on the best available genetic principles of fish culture.

Recommended Stocking Guidelines. - To fully attain the above objectives that relate to stocking (I.C, II. A, B, C, and D), we recommended obtaining better information on the efficacy of our stocking practices (goal III.B.). This evaluation is ongoing and should be completed by 2013. One of the key goals of the 1979 management plan (WDNR 1979) was to evaluate our stocking practices (stocking rates and frequencies), yet we have very little additional information available at this time. The recommended stocking strategies and practices listed in priority order and summarized in Appendix B, are as follows:

1. Rehabilitation: *Waters* – Winter-kill lakes should not be stocked if serious mortality occurs more frequently than once in 15 years unless a plan to minimize the risk of future winter-kills is developed and approved.

Size of Fish – Either fry or small fingerlings (4"-6") the first year, followed by large fingerlings (> 7") or adult transfers in subsequent years.
Source of fish – Basin stock.
Stocking rate – Fry – 500/acre; small fingerlings up to 5/acre; Large fingerlings up to 2/acre. If production is unable to meet all quota requests, a maximum of 100,000 fry, 5,000 small fingerlings or 2,500 large fingerlings will be stocked per water.
Frequency – Fry or small fingerlings the first year, then large fingerlings for 4 years.
Evaluation - If natural reproduction is not reestablished after 10 years from the onset of stocking, discontinue stocking until action is taken to identify and correct the reason(s) for the poor natural recruitment.

2. Research: Stocking sizes and frequencies as needed to realistically meet the objectives of the approved evaluation project.

3. Remediation or Recreation: *Waters* - Based on evidence provided by Fields et al. (1997), we recommend that no stocking occur in waters with adequate natural reproduction, in order to minimize the potential negative impact of stocked fish on naturally reproducing populations in the receiving or connected waters (Goal I. C). No stocking quotas should be developed for Class A2 lakes less than 200 acres in size or for Class A1, B, or C lakes less than 500 acres in size.

Size of Fish – Either small fingerlings (4"-6") or large fingerlings (> 7"), depending upon abundance of existing predators.
Source of fish – Basin stock.
Stocking rate – Small fingerlings up to 5/acre; large fingerlings up to 2/acre. If production is unable to meet all quota requests, a maximum of 5,000 small fingerlings or 2,500 large fingerlings will be stocked per water.
Frequency – Small fingerlings or large fingerlings annually or in alternate years.
Evaluation - If the fishery objective (adult density, catch rate, etc.) is not met after 10 years, discontinue stocking until action is taken to identify the reason(s) for poor survival.

Summary of Stocking Practices, by Strategy.

Strategy	Priority	Life Stage	Size	Stocking Rate	Stocking Frequency	Maximum per waterbody
Rehabilitation (first year; choose one)	1	Fry	--	500/acre	First year of Rehabilitation	100,000
		Small Fingerling	4 to 6”	Up to 5/acre	First year of Rehabilitation	5,000
Rehabilitation (after year 1)	1	Large Fingerling	> 7”	Up to 2/acre	Annual, for up to 4 years	2,500
Research	2	As needed	As needed	As needed	As needed	Size-dependent
Remediation or Recreation	3	Small Fingerling	4 to 6”	Up to 5/acre	Alternate	5,000
		Large Fingerling	> 7”	Up to 2/acre	Alternate	2,500

Brood Stock Lakes – No stocking should occur in current or potential inland brood source lakes, except from the same waters in years when that lake is used as a brood stock. The following waters are currently identified as brood stocks, listed by basin stock:

Upper Chippewa River Basin – Chippewa Flowage, Grindstone, Lost Land/Teal, Lac Courte Oreilles, and Whitefish lakes, Sawyer County; Butternut Lake, Price County.

Upper Wisconsin River Basin – Moen Chain, Minocqua Chain, Pelican, and Squirrel Lakes, Oneida County; Big/Little Arbor Vitae, North/South Twin, and Plum Lakes, Vilas County.

Muskellunge Stocks available

Stock name	Suitable for the following inland basins	Suitable for Great Lakes/ outlying waters
Great Lakes Spotted ^ (currently unavailable)	Lake Winnebago System and downstream via the Fox River to Green Bay; Inland Brood Stock Development Waters	Green Bay, Lake Michigan and L. Superior
Upper Chippewa River	Chippewa R., St. Croix, L. Superior inland waters, Black River; Universal Receptors*	N/A
Upper Wisconsin River	Wisconsin River and L. Michigan inland basins; Universal Receptors*	N/A

^ The Fisheries Management Board will be examining basins where Great Lakes Spotted Muskellunge may be appropriately stocked.
* “Universal Receptors” are waters outside the native range of muskellunge that are dependent on stocking.
N/A = not appropriate.

No dramatic changes are recommended in the current recreational stocking practices because no compelling scientific evidence for change exists. However, this does not mean that inefficiencies do not exist or that improvements are not needed, just that we lack adequate information at this time.

Projected Demand for Muskellunge.- The demand for muskellunge has averaged about 140,000 fingerlings annually. This is essentially unchanged from the projections made in the 1999 report. We do not anticipate major changes in our stocking practices over the next 10 years, so no significant changes are anticipated in the demand for muskellunge fingerlings. We have observed a trend toward lower requests in recent years within the native range of muskellunge. Discussions with fisheries biologists suggest that fewer fish are requested because higher minimum length limits and increased voluntary release of legal-sized fish by anglers have reduced mortality and has resulted in better survival of adult muskellunge. Also, higher quality (larger) fingerlings from the hatcheries have had higher survival, which has reduced the numbers needed to improve fishing. However, the reductions in the native range appear to be offset by increased demand outside the native range, where some relatively large waters are dependent on stocking to sustain fishing. Therefore, we anticipate that demand for muskellunge fingerlings may remain stable or decline slightly regardless of changes in stocking policies. There are a few new introductions being planned, but any increased demand for fish in these waters will likely be offset by lower stocking in waters within the native range.

Summary of Projected Wisconsin Stocking Goals (2010-2019)

Fish Species (size)	Size	Stock/strain	Statewide Annual Stocking Goal (1999)	Statewide Annual Stocking Goal (2010)
Muskellunge	Large fingerlings	Great Lakes	0	65,000
Muskellunge	Large fingerlings	Upper Chippewa River	0	40,000
Muskellunge	Large fingerlings	Upper Wisconsin River	0	15,000
Muskellunge	Large fingerlings	Unspecified	140,000	85,000
		Total	140,000	205,000
Muskellunge	Yearlings	Great Lakes	0	3,000

Summary and Recommendations

Risks associated with projections.- The projections contained in this report are based on a combination of past stocking practices and best professional judgment. Historically, the demand for hatchery fish has been based partially on public expectations and perceptions and, to some degree, on available supply. Projections based on historic supply are constrained by past hatchery practices which, while untested, could be modified considerably to meet demand. This is the first contemporary attempt by DNR to estimate demand for hatchery fish, so there is some uncertainty associated with these projections. However, the approach taken in this report is viewed as a logical first step from which future refinements can be made.

Management Recommendations

Several recommendations were common across many of the species reviewed in this report. The most important ones are highlighted below.

Protection of existing natural reproduction. - This is a universal theme throughout this report. Populations sustained through natural reproduction provide the best fishing, and are therefore worthy of vigorous protection. Any actions we can take to reduce the risk of impacting naturally reproducing populations should be pursued, whether through the hatchery system, habitat protection, or harvest regulation.

Strain Development.- The department should fully evaluate the development and use of genetic strains. Broader use of this approach would ensure that the most appropriate stock or strain is used to most efficiently manage Wisconsin's fishery resources. Therefore, as a first step, basin-specific stocks should be used for most stocking in the state. This may initially result in some difficulties in the hatchery system, in terms of timing and location of appropriate feral stocks and keeping stocks separate in the hatchery system. However, it is believed that this approach will, in the long term, result in stocking a product that is better suited to the receiving waters and, ultimately, better fishing. In the future, requests for different strains will need to be evaluated through the quota system in order to accurately assess demand.

Define "Self-sustained". - Many of the recommendations in this use the term "self-sustained" to characterize fisheries supported by natural reproduction. We need to ensure that population characteristics indicative of self-sustained populations are identified and well defined.

Long-term quotas.- We recommend the establishment, where feasible, of stocking plans with long-term quota requests for individual waters. For the major stocked species, the demand for stocked fish is relatively constant from year to year. Development of a 5- or 10-year stocking plan for stocked waters will reduce annual planning workload and will provide the hatchery system, private fish hatcheries, and cooperators with a long-term demand. In cases where special needs arise, the system should be flexible enough to address these short-term demands from the hatcheries. Stocking plans for individual waters should clearly identify the desired outcome of the stocking regime and an evaluation of the success of the plan. Attainment of that outcome should be evaluated before renewal of another long-term commitment for fish from the hatcheries or private providers.

Per-Water-Maximums.- In general, the per-water-maximum numbers for stocking are eliminated in

deference to the best biological recommendation, regardless of limitations in production. However, due to the high variability in hatchery production from year to year, there will be inevitable shortfalls. We recommend addressing this problem by prioritizing stocking strategies statewide and, within those categories, requiring cuts in the waters that are stocked rather than spreading out fewer fish in all waters where fish were requested. This approach assumes that the likelihood for success is higher for a few waters that get adequate numbers of fish rather than for a few fish in a greater number of waters, assuming the quota requests are biologically-based.

Shortfalls in Hatchery Production.- The requested number of fish of any one species could likely be met by the hatchery system, but it would adversely affect the availability of other species from the hatcheries. For example, walleye and muskellunge are the primary species competing for space in the warm water hatcheries while Great lakes and inland salmonids compete for space in the cold water facilities. Demand for many of these species is currently not being met.

Examination of the need for stocked fish, coupled with instances where we are unable to meet that need through the state hatchery system suggests that there may be room for increased involvement from private fish hatcheries throughout the state, as suggested by WDNR (1997). Development of longer-term quotas would make it easier for private industry to plan for and provide fish for stocking. Development of more cooperative agreements would benefit both the state and private fish hatcheries.

Stocking Team.- A team of Department biologists and hatchery personnel should be formed to periodically evaluate the stocking program. This forum would provide an outlet for 1) presentations on in-state stocking evaluations; 2) review of current scientific literature related to stocking, propagation, and related issues; 3) increased communication between biologists and hatchery personnel; and 4) development of work planning guidance for future stocking evaluation projects. In short, the purpose of this team would be to maintain the state-of-the-art in our stocking program through a continuous improvement process.

Literature Cited

Beacham, T., C.B. Murray, and R.E. Withler. 1989. Age, morphology, and biochemical genetic variation of Yukon River chinook salmon. Transactions of the American Fisheries Society 118:46-63.

Fields, R.D., M.D.G. Desjardins, J.M. Hudson, T.W. Kassler, J.B. Ludden, J. V. Tranquilli, C.A. Toline, and D.P. Philipp. 1997. Genetic analyses of fish species in the upper midwest. Aquatic Ecology Technical Report 97/5. Illinois Natural History Survey. Champaign.

Gharrett, A.J., C. Smoot, and A.J. McGregor. 1988. Genetic relationships of even-year northwest Alaska pink salmon. Transactions of the American Fisheries Society 117:536-545.

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 G.E. Hall, Editor. Managing muskies. American Fisheries Society Special Publication 15, Bethesda.

Jennings, Martin. 1996. Genes make all the difference. Wisconsin Natural Resources, February.

Kampa, J.M. and M.J. Jennings. 1998. A review of walleye stocking evaluations and factors influencing stocking success. WDNR, Research Report.

Kapascinski, K.L., B.J. Belonger, S. Fajfer, T.J. Lychwick. 2007. Population dynamics of muskellunge in Wisconsin waters of Green Bay, Lake Michigan, 1989-2005. Environmental Biology of Fishes 79:27-36.

Keim, S. 1998. Expenditures of Great Lakes Salmon and Trout Stamp Revenues; Fiscal Years 1996-1999. WDNR, Bureau of Fisheries Management and Habitat Protection. Administrative Report 42.

Kerr, S.J. and six other authors. 1996. Walleye stocking as a management tool. Ontario Ministry of Natural Resources. Petersborough, Ontario.

Klingbiel, J. 1981. The status of bass management - an informational report to the natural resources board. WDNR, Bureau of Fish Management, Administrative Report 12.

Klingbiel, J. 1986. Population Data for Fisheries Management, Fish Management Reference Book. WDNR, Bureau of Fisheries Management. Madison.

Krueger, C.C., E.J. Marsden, H.L. Kincaid, B. May. 1989. Genetic differentiation among lake trout strains stocked into Lake Ontario. Transactions of the American Fisheries Society 118:317-330.

Li, J., Y. Cohen, D.H. Schupp and I.R. Adelman. 1996. Effects of walleye stocking on year-class strength. North American Journal of Fisheries Management 16:840-850.

Loomis, J. and P. Fix. 1998. Testing the importance of fish stocking as a determinant of the demand for fishing licenses and fishing effort in Colorado. Human Dimensions of Wildlife 3(3):46-61.

Margenau, T.L. 1992. Survival and cost-effectiveness of stocked fall fingerling and spring yearling muskellunge in WI. North American Journal of Fisheries Management 12:484-493.

Newburg, H. J. 1975. Review of selected literature on largemouth bass life history, ecology, and management. Minnesota Department of Natural Resources, Investigational Report 335.

Oehmcke, A.A. 1969. Muskellunge management in Wisconsin. WDNR Division of Fish, Game and Enforcement. Bureau of Fish Management Report 19.

Philipp, D.P. 1991. Genetic implications of introducing Florida largemouth bass *Micropterus salmoides floridanus*. Canadian Journal of Fisheries and Aquatic Science 48:58-65.

Philipp, D.P. 1991. Survival and growth of northern, Florida, and reciprocal F1 hybrid largemouth bass in central Illinois. Transactions of the American Fisheries Society 120:58-64.

Philipp, D.P., W.F. Childers and G.S. Whitt. 1981. Management implications for different genetic stocks of largemouth bass (*Micropterus salmoides*) in the United States. Canadian Journal of Fisheries and Aquatic Science 38:1715-1723.

Philipp, D.P. and J.E. Claussen. 1995. Fitness and performance differences between two stocks of largemouth bass from different river drainages within Illinois. American Fisheries Society Symposium 15:236-243.

Ryman, N. and F. Utter. 1987. Population genetics and fishery management. University of Washington Press, Seattle.

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 G.E. Hall, Editor. Managing muskies. American Fisheries Society Special Publication 15, Bethesda.

Szendrey, T.A., and D.H. Wahl. 1996. Size specific survival and growth of stocked muskellunge: effects of predation and prey availability. North American Journal of Fisheries Management 16:395-402.

Wahl, D.H., and R.A. Stein. 1989. Comparative vulnerablility of three esocids to largemouth bass (Micropterus salmoides) predation. Canadian Journal of Fisheries and Aquatic Sciences 46:2095-2103.

WDNR (Wisconsin Department of Natural Resources). 1998. Production capacities of the Wisconsin Department of Natural Resources' Fish Propagation Facilities. WDNR, Bureau of Fisheries Management and Habitat Protection, Madison.

WDNR (Wisconsin Department of Natural Resources). 1997. The role of private fish hatcheries in Wisconsin: in search of a clear direction. WDNR, Bureau of Fisheries Management and Habitat Protection, Madison.

WDNR (Wisconsin Department of Natural Resources). 1979. Fish and wildlife comprehensive plan. Part I - Management strategies 1979-1985. WDNR, Madison.

WLAB (Wisconsin Legislative Audit Bureau). 1997. An evaluation - Fish stocking activities – Department of Natural Resources. Report 97-9.

Appendix

Appendix Table A. Previous stocking guidelines for the sizes of warm water fish available from the hatchery system. Data are stocking rates per acre; maximum number per water).

Size	Muskellunge	Walleye	Northern pike	Black Bass	Lake Sturgeon
Fry	500/acre (100k)	1000/acre (500k)	1000/acre (200k)	100/acre (100k)	200/acre (250k)
Small fingerling	4-6" 5/acre (5k)	1.75"-2.25" 50/acre (100k)	3.5" -5.5" 5/acre (5k)	1.5"- 2" 50/acre (50k)	1 - 3" 50/acre (50k)
Large fingerling	> 7" 2/acre (2500)	2.5"-3.25" 25/acre (50k)	> 7" 2/acre (2500)	2.25"-2.75" 25/acre (25k)	> 3" 5/acre (5k)
Extended growth	--	> 5" 10/acre (10k)	--	> 4.5" 10/acre (10k)	--
Adults	--	--	--	--	50 (minimum)

Appendix Table B. Revised stocking guidelines and recommended sizes of fish needed from the hatchery system. Data are stocking rates per acre (maximum number per water, if production is limited).

Size	Musky	Walleye	Northern pike	Black bass	Lake Sturgeon
Fry	500/acre (100k)	1800/acre	1000/ habitat acre	--	--
Small fingerling	4-6" 5/acre (5k)	> 1" 100/acre	3.5" –5.5" 5/habitat acre	--	> 3" 80/mile or 0.5/acre
Large fingerling	> 7" up to 2/acre (2500)	> 4" 20/acre	> 5.5" 2/habitat acre	2"+ 25/acre	> 6" 40/mile or 0.25/acre
Adults	--	--	--	5/acre	50 (minimum)