Wisconsin Muskellunge Brood Stock Management Plan

Tim Simonson, Dr. Brian Sloss, Dr. Martin Jennings, and the
Muskellunge Management Team

Revised September 2011

Background:

One major objective of muskellunge management in Wisconsin is to manage the species as a trophy. Another key goal is to protect naturally reproducing populations. Concerns have been raised about the performance of stocked musky fisheries in Wisconsin. Some anglers believe that the source of muskellunge eggs for our hatchery system may be resulting in fewer than expected trophy muskellunge being caught by anglers. Further, many stocked lakes have not exhibited subsequent natural reproduction. While there is no conclusive evidence of this, past spawning practices may have contributed to poor performance of stocked fish. The most appropriate source of muskellunge for propagation and stocking into both native and non-native muskellunge waters in Wisconsin has been at the center of this discussion.

This plan is intended to improve the long term propagation of muskellunge in Wisconsin. While many of the fish handling and selection processes have generally been done in a sound manner, we have identified some areas for improvement based on genetic principles. In the short term, new brood stock lakes will need to be identified. In the long term, these practices will improve the fitness of fish stocked into Wisconsin waters and will ensure the species' survival in our waters.

Objectives: This document addresses 1) Best Management Practices for spawning operations related to muskellunge brood stock management in Wisconsin, and 2) outlines a field evaluation of muskellunge brood sources for lakes dependent upon stocking.

<u>1. Best Management Practices for Spawning Operations</u> (Originally excerpted from Sloss 2005; with revisions in 2011).

Introduction

We reviewed the current status of the musky propagation program, and few key elements stood out. First, the use of non-recruiting, supplemental stocked lakes as the sole sources of gametes for the program should be abandoned. This approach is prone to high risk of genetic impact on the propagated fish. In essence, this approach will result in a magnification of hatchery impacts experienced and in many cases unavoidable, within a supplementation program. Efforts should focus on identifying genetically 'healthy' and reproductively vigorous muskellunge populations that require no supplementation for consistent recruitment. Second, the selection of which fish to spawn needs refined and distinct guidelines for hatchery personnel should be outlined to allow for efficient gamete collections. Third, the number of fish selected for breeding each year will need to be increased. Efforts described later will focus on a strategy aimed at maximizing the effective number of breeders and overall effective population size across a putative muskellunge generation.

Until efforts to identify and test putative stock boundaries of muskellunge in Wisconsin waters is completed (see Chapter 2) a modification of the genetic management zones (GMZ) of Fields et al. 1997 should be employed and adhered to. The five muskellunge GMZ's within Wisconsin are Lake Superior watershed, Upper Mississippi watershed, Lower Mississippi watershed, Wisconsin River watershed, and Green Bay/Lake Michigan watershed. It is important to note that the data supporting these as distinct GMZ's fail to resolve the zones as distinct stocks. However, anecdotal data and trends in the data suggest these may be at a minimum a solid default approach.

Many of the questions surrounding muskellunge propagation are addressed below. These guidelines should be followed as long as fish are stocked into waters with existing natural reproduction. Further, following these guidelines may improve the chances of stocked fish becoming naturalized in current non-natural reproduction lakes.

Recommendations

1. *Brood stock lakes should be self-sustained, not sustained through stocking. Plant-back of fry should be discontinued, but stock-back of large fingerlings is permissible in years when eggs are collected from the given brood lake, if supplemental stocking is deemed necessary by the local fisheries biologist to maintain sufficient numbers of spawning adults. When feasible, PIT Tagging of fingerlings is recommended to evaluate survival and linage.*

Stocked populations should not be used as broodstock as long as NR lakes are available within the genetic management zone to meet production needs. Reliance on stocked lakes increases the probability of inbreeding and will result in a magnification of inadvertent selection (size, age at first spawning, run timing, etc.).

Selection of broodstock lakes should be based on various factors, including those outlined by Miller and Kapuscinski (2003):

a. Genetic lineage – Selected populations should be a naturally occurring spawning population with a known history of past stocking events. Ideally, past stockings did not cross default GMZ boundaries.

b. Life history patterns – Selected population should come from waters with habitat similar to recipient waters (e.g., riverene vesus lacustrine, etc.).

c. Ecology of source and receiving populations should be similar, in terms of food web dynamics and potential predators and competitors.

Locating NR populations with sufficient densities of spawning adults has proven to be difficult. Therefore, we will currently allow the stock-back of fingerlings into brood lakes in years that eggs are taken for production. The intent is to ensure good numbers of spawning adults in future years.

2. *Ultimately, each GMZ should have 5 brood stock lakes (and 5 backup lakes) identified, and egg take should rotate among lakes each year. An odd number of brood stock lakes should be selected to ensure different sources of fish in alternate-year stocked lakes*.

Our goal is to develop at least 3-5 brood source lakes and keep the crosses within a single source. This suggestion is based on a couple of factors. First, if we rely solely on one NR musky lake, we could potentially harm this source over an extended period of time by taking a significant proportion of its reproductive output. Second, a 3-5 lake rotation enables a satisfactory level of genetic diversity to be included in the program while not putting undue pressure on any one NR population. Further, the use of an odd number (3 or 5) of source populations will result in all populations receiving progeny from all brood source populations over a 6 or 10 year period of time, because most populations receive fish in alternating years.

A consistent rotation should be developed and adhered to. If numbers are unavailable for a given year, move to the identified back up lake. If numbers are still low, curtail stocking for that year. In the event this is not an option, crosses should be limited to within populations only, with no outcrossing.

This approach has the benefit of minimizing the impact on any given source NR population, it is not without challenges. The relevant information necessary to choose a brood source lake (see question 1) may increase the workload of hatchery and field personnel. It may also necessitate an increased load on fish health personnel. Nevertheless, this approach represents an acceptable risk while providing benefits to the long-term muskellunge propagation program as a whole.

3. *When collecting eggs, use a nested stratified, random design across spawning season and fish size. This is essential in order to avoid size, age, spawning time, sex ratio, weight, etc., discrimination in relation to selecting the individual fish for spawning. The most pressing of these issues in relation to muskellunge is time of spawning and size of fish. It is, however, permissible to avoid sick or deformed fish when selecting spawners*.

Choose 3-5 sample periods during the normal spawning season. An adaptive approach can be initially favored wherein over the near-future, the proportional collection of gametes will be consistent with the overall proportion of spawners in normal years. The initial efforts could concentrate on data we have on hand regarding the intensity of spawning through time. Within any given sampling effort, crews should attempt to randomly select fish in regards to length and weight. Care should be given to not spawn large fish just with large fish, small with small, etc. In this regard, the information I've reviewed suggests the state does a fair job of this. However, care should be taken to not simply collect until the quota is filled but to collect until the strata are represented. This approach will require monitoring and evaluation of the spawning grounds of NR lakes in order to consistently improve the accuracy of this design.

The ultimate goal is to avoid inadvertent selection of heritable traits (i.e., domestication) consistent with the goals laid out by Miller and Kapuscinski (2003). In addition, it is important not to use the same brood fish in successive years. Although the use of multiple brood lakes on a rotational basis will reduce the impacts of using the same breeders sequentially it is still recommended to avoid this if at all possible. To this end it is important to mark all fish being used as brood fish from each of the source populations. It is also preferred to take a small genetic sample (a fin clip would suffice) to allow for future evaluation of stocking efforts and efficiency. This would also allow more accurate measures of natural recruitment versus stocked fish in some of our unknown reproductive status systems.

This represents added effort on the part of the hatchery and field personnel responsible for gamete collections. I also recognize the added challenges to the rearing process in terms of having fish roughly the same size at the same time. However, the benefits, genetically, are necessary to ensure the propagation of diverse and healthy muskellunge populations. Time of spawning has been shown in many species to be heritable and thus, selectable by hatchery operations.

> 4*. Each facility should spawn 19 to 26 females (and 57 to 78 males) each year involving exactly 3 males per female, and families should be kept separate (don't spawn the males or the females with any other fish). Alternatively, spawning 25 to 36 pairs at 1 female to 1 male is also acceptable. Roughly the same number of eggs should be taken from each female. Efforts should be made to spawn the target number of females if at all possible. All spawned fish should be marked and sampled for genetic material.*

This is a critical issue in maintaining the diversity and viability of muskellunge populations affected by the propagation program in Wisconsin. The issues of minimum numbers and crossing strategies focus on the effective number of breeders in a given season (N_b) and the effective population size of the entire generation of muskellunge (N_e). With iteroparous fish such as muskellunge, the generation time can roughly be equated to the mean age of spawning fish. I have not been able to find an estimate on any of our populations currently being used for brood sources. Therefore, for the purpose of calculating N_e I figured two prospective generation times for muskellunge, five years and seven years. In general with walleye, we find the mean age of spawners to be roughly equivalent to the age when these fish first reach reproductive age. This is important because estimates of N_b can be summed to determined N_e.

The main challenge when determining numbers of brood fish for hatchery production lies in balancing the effort in collection, rearing, and overall production of a given number of individuals versus the increase in inbreeding and genetic drift (genetic sampling error) associated with the same number of individuals.

Despite the suggested use of multiple populations over time, the N_e will be calculated on the basis of a single generation of hatchery productions (5 years and 7 years). Our goal is to maintain the level of genetic diversity present in the source populations. In this situation, it is important to preserve rare alleles (alleles present in the population at a frequency of 5% or less). Long-term viability of populations relies on the preservation of this integral genetic variation. An effective population size of between 350 and 500 individuals/ generation provides a 95-99% probability of retaining rare alleles over this timeframe. In order to achieve this N_e the annual N_b needs to average 70-100 individuals for the 5-year generation estimate and 50-71.5 individuals for the 7-year generation.

Currently, the N_b with unequal sex ratios is:

$$N_b = 4N_f\, N_m / N_f + N_m$$

Where N_f = number of females and N_m = the number of males.

With this formula we can estimate the maximum N_b of the two hatchery programs (Governor Thompson and Art Oehmcke).

Thompson (assume 3 males/cross): $N_b = 4(18)(54)/18+54 = 54$ individuals/year

$$N_{e\text{-}5yr/gen} = 5 \times (N_b) = 270$$
$$N_{e\text{-}7yr/gen} = 7 \times (N_b) = 378$$

Oehmcke (assume 3 males/cross): $N_b = 4(8)(24)/8+24 = 24$ individuals/year

$$N_{e\text{-}5yr/gen} = 5 \times (N_b) = 120$$
$$N_{e\text{-}7yr/gen} = 7 \times (N_b) = 168$$

Both current strategies fail to reach the target range of 350-500 over a 5-year generation interval. However, the Thompson hatchery does make the minimum size if a 7-year generation is assumed. Additionally, factors influencing the reproductive variance among individuals adversely affect the final N_e measure. For example, if males suffer even a small percentage of infertility and/or differential success when milt is combined (i.e., sperm competition), it effectively reduces the numbers of males we can consider as contributors of genetic material.

Let's assume a low degree of male infertility coupled with a random (poisson distributed) probability of fertilization among the males combined to fertilize a female. Let's assume these combine to effectively make every one male used equivalent to ¾ of a male. This is not an unreasonable estimate as the same factors in salmonid studies have effectively reduced male contribution to as low as 0.60 that of a given female. Therefore, if we use three males to fertilize every female, we effectively are using 1 female and 2.25 males. Taking this into account in our equations would lower the N_b and N_e estimates of both systems. For the 5-year generation, Thompson N_b = 49.8 and N_e = 249.2 and Oehmcke N_b = 22.2 and N_e = 110.8. For the 7-year generation, the N_e estimates become 348 and 155.4 for Thompson and Oehmcke, respectively.

Ideally, we would cross in a 1:1 ratio with no mixing of gametes to eliminate the variability of fertilization and the possibility of male infertility. However, given the low milt production of muskellunge, it appears necessary to combine milt for fertilization. Nevertheless, the combination of eggs should be avoided throughout the propagation program. This introduces a level of variability that is unnecessary and will result in lowered effective size production compared to theoretical maximum numbers. Given that males are more numerous when collecting gametes, I would suggest the following approach: 1 female: 3 males. This should allow adequate milt for fertilization of all eggs. I use these numbers not entirely from a genetics perspective but the fact that both current hatchery protocols experience ~ 80% fertilization with this current approach suggesting a low variability among female family size.

Efforts should begin immediately to find a way to eliminate the combination of milt to maintain this 1:3 cross ratio. One approach that has been discussed is the use of sperm extenders. If and when this is possible, the approach should still be 1 female to 3 males. However, the approach should result in the eggs of a single female being divided equally (or as close as possible) into three batches and fertilized independently by the milt of a single male. Further, the males should only be used to fertilize a single female. As with other suggestions, all brood fish should be marked and sampled for genetic analysis. We can then begin efforts to investigate sperm viability and/or other factors related to mixing of milt. It is not unreasonable that this approach could result in the present method (combining milt) being cleared of potential detrimental effects and thus becoming the long-term standard protocol.

Using the logic we used earlier to estimate the effective number of males (0.75/male), each individual cross (1 female and 3 males or 4 fish total) would have a N_b = 2.77. Therefore, to reach our minimum target goal of 70/year (5-year generation), we would need 26 females/year. This gives us an N_b = 72 and a final N_e = 360. Given this number is only 8 more females than are used currently by the Governor Thompson hatchery, this should be an attainable goal without greatly increasing the man-hours and rearing space. This does represent slightly more than a three-fold increase in the number of females necessary for the Oehmcke hatchery. Hopefully, this would be possible out of the potential brood lakes. An alternative strategy could be a partial factorial crossing scheme. However, this would require a large effort in crossing design and in-field manipulations. The easier route would most likely be increasing the number of females sampled. Similar estimates for the 7-year generation would result in a minimum target goal of 19 females/year.

Taking this number of females will result in an excess of eggs under the current fecundity and egg-take scheme. My suggestion would be to raise less eggs/female to reach the production quota. Efforts should be made to produce roughly the same number of fry/female. Therefore, I am suggesting a minimum number of females used in any given year be 19 females with exactly 3 males/female being used. The males should only be used on a single female, no mixed crosses of males to multiple females. I would like to reiterate that no mixing of eggs should occur. Efforts should be made to make the target of 26 females to provide a more conservative approach toward generation time (5 years) and provide for N_e in excess of 350 individuals.

5. Ensure that all families contribute to the fish being stocked into any given water body in any given year.

A final factor is the rearing and stocking of muskellunge. Currently, several ponds are used to rear muskellunge with all production from a subset of females going into a given pond. When stocking time arrives, a given recipient population generally is stocked with fish from a single pond or only a few ponds. This raises concerns because the target goal of N_e = 350-500 will never be achieved, despite the best broodstock selection strategy, spawning strategy, and lake choices. My suggestion is that all stocking be from a combination of ponds. Alternatively, all ponds could be pooled into single rearing pond. However, issues with cannibalism may make the pooling of all families unfeasible. From a genetics perspective, it is important to ensure that all families contribute to the fish being stocked into any given water body in any given year. The more deviation from this, the more the N_b of the receiving water body's is negatively impacted. This strengthens the need to more accurately identify and, more importantly, quantify what constitutes a naturally recruiting muskellunge population. Avoiding stocking into these waters would minimize the long-term impact of low N_b hatchery issues on NR waters. New guidelines could be developed and, perhaps, modified approaches to ensure non-NR waters are stocked according to a genetically viable and sustainable approach within the boundaries of hatchery production logistics.

6. Brood stock lakes should be protected from selective angling harvest by establishing high minimum length limits?

To ensure consistent, adequate numbers of spawning adults, higher minimum lengths limits may be proposed for all brood stock lakes. The committee will work out the details (specific size limit) by February 2006 and as the list of brood stock lakes is developed, companion rule change proposals may be submitted for each lake that is not already protected with the appropriate regulation. We anticipate the first proposals will be presented at the 2007 Spring Fish and Wildlife Rules Hearings.

Conclusion

These guidelines are the best available recommendations. In many cases, however, the specific data and or experiments have not been conducted to most accurately formulate the correct approach. Further, year to year variation may result in some of the suggested targets being unattainable. In that case, effort should focus on coming as close as possible to the targets. The suggested numbers of fish to spawn and the rotation of lakes will allow some room for failure to meet target goals without increasing the risks to an intolerable level. Nevertheless, these guidelines represent the best scenario available to ensure the propagation of muskellunge in Wisconsin is producing a quality product representative of native, naturally-recruiting muskellunge populations.

Other important thoughts on the propagation program for muskellunge.

1. There is currently have no quantitative index of natural reproduction and subsequently, no effective means of objectively identifying self-sustained populations. As these are two specifically identified items of importance in the Muskellunge Management Update (Simonson 2004), future efforts and attention should be paid to resolving this question.

2. The goal of stocking muskellunge into specific Wisconsin waters is poorly defined compared to other state, regional, and national stocking programs being implemented throughout the country. Generally speaking, management actions such as supplemental stocking of a recruiting population are usually accompanied by a specific objective statement and evaluation/monitoring program to measure the success of the stocking. Further, it is alarming when a population is showing ‘inadequate’ recruitment, especially if the population was formerly a strong recruiting population. In these cases, stocking could result in a direct violation of Program Goal I.B. (protection of genetic integrity) while Program Goal I.A. ‘Identify and protect existing spawning and nursery habitat’, may help ameliorate the cause of the decline.

3. Private hatcheries and private interest stocking of muskellunge in Wisconsin should be monitored very closely. Private hatcheries should be required to meet similar effective population size limits and provide pedigree information for all broodstock prior to allowing release of these fish into Wisconsin waters. It is not uncommon for private hatcheries to use the appropriate number of brood fish thus appearing to be consistent with the genetic goals outlined earlier. What is seldom known is the ultimate source of these brood fish and the number of founder fish used to establish this source. This is another reason why all waters stocked in the state should be treated as a potential source for future generations.

Acknowledgements: The muskellunge management team reviewed and suggested revisions to an earlier draft of this document. We specifically thank Bruce Underwood and Gary Lindenberger for their assistance and openness in helping understand the current practices done and helping develop these suggested guidelines. Discussions with Dr. Martin Jennings, Tim Simonson, and Scott Stewart have helped me become more familiar with the history, present status, and importance of muskellunge propagation in Wisconsin. I would also like to thank all the private/public interests who have taken a supportive role in the muskellunge propagation program and the continued improvement of muskellunge propagation in Wisconsin. In particular, the comments of Tom Penniston, Secretary Capital City Chapter of Muskies, Inc. and a former State Hatchery Scientist for the Arkansas Game and Fish.

Literature Cited

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. Phillipp. 1997. Genetic analyses of fish species in the Upper Midwest: Final Report. INHS Aquatic Ecology Technical Report 97/5.

Hall, G.E. (editor). 1986. Managing Muskies: A Treatise on the Biology and Propagation of Muskellunge in North America. American Fisheries Society Special Publication 15.

Miller, L. and A.R. Kapuscinski. 2003. Genetic guidelines for hatchery supplementation programs. in E. Hallerman, editor. Population Genetics: Principles and Applications for Fisheries Scientists. American Fisheries Society, Bethesda, Maryland.

Simonson, T. 2004. Muskellunge Management Update. Publication FH-508-2004, Bureau of Fisheries Management and Habitat Protection. Wisconsin Department of Natural Resources. Madison, WI.

Sloss, B.L. 2005. FISH HANDLING/PROPAGATION OF MUSKELLUNGE ISSUES. Wisconsin Cooperative Fisheries Research Unit, U.S.Geological Survey, College of Natural Resources, University of Wisconsin-Stevens Point, Stevens Point, WI.

2. Field Evaluation of Selected Brood Sources in Lakes Dependent upon Stocking

The most appropriate source of muskellunge for propagation and stocking into non-native muskellunge waters in Wisconsin has been the subject of some debate. Part of WDNR response to stakeholder concerns was to compare Leech Lake and Chippewa Basin strain performance cooperatively with interested local Muskies, Inc., chapters.

Fish originating from Leech Lake, Minnesota are being compared in paired stockings with WI production muskellunge, starting in spring 2006. Evaluations will include 2 stocked waters, one in western and one in southern WI, outside the native range of muskellunge. The stocked waters are Lake Wissota, Chippewa County; and Lake Monona, Dane County.

All fish in both lakes will be fin clipped (Left ventral = Leech Lake; right ventral=WI fish). Also, a portion of each strain should be PIT tagged to evaluate growth of individual fish. The Leech Lake source fish will be provided by local Muskies, Inc., clubs via purchase from a private source.

			Number Stocked		
Lake	County	Acres	LL strain	WI strain	Years Stocked
Lake Wissota	Chippewa	6300	2500	2500	06,07,08,09
Lake Monona	Dane	3274	985	985	06,07,08,09

On each sampling rotation, we hope to be able to conduct a population estimate on the fish and collect age and growth data. In addition we can collect some data continuously during annual surveys and by using angler diaries provided to select anglers that catch a large number of fish each year.

We had also originally planned to evaluate Leech Lake source fish raised along with our production fish (to eliminate any bias associated with rearing and hauling) in seven other NW WI waters within the St. Croix drainage system, but we encountered difficulties obtaining and raising the fish, so the project was terminated.

Timeline:

Summer 2005 through 2007
Identification and selection of 10 self-sustained lakes for brood stock within each presumed Genetic Management Zone. Initially, we need to identify at least 3 interim self-sustained lakes for each facility (Winter 2005), which will be used over the next 3 years. Ultimately, 5 self-sustained lakes and 5 back-up lakes will be identified and used in a 5 year rotation for egg collection (Fall 2007).

Spring 2006
-Begin implementation of Best Management Practices for spawning operations.
-Continue identification and selection of self-sustained brood stock lakes.

Spring 2007
-Preliminary determination of Genetic Management Zones (interim report from Dr. Brian Sloss and students).
-Selection of additional interim brood stock lakes.

Spring 2009
-Final determination of Genetic Management Zones (final report from Dr. Brian Sloss and students).
-Selection of potential brood stock lakes based on final genetic survey.

Spring 2010
-Review and revise Best Management Practices, where needed, based on initial experiences.

Winter 2012
-Continue identification of appropriate inland brood stock lakes.