Virginia's Muskellunge Management Plan

2020 – 2025

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Introduction

Muskellunge (*Esox masquinongy*) have been stocked in many waters throughout Virginia and have developed into popular sport fisheries that provide anglers the opportunity to catch a trophy fish. Although native Muskellunge populations exist in the upper Tennessee River drainage, this historical distribution is not thought to include Virginia (Jenkins and Burkhead 1994). Therefore, the presence of Muskellunge in Virginia is considered to be solely the result of hatchery introductions, including waters within the Tennessee River, Big Sandy River, and New River drainages as well as waters throughout the remainder of the state. The purpose of this plan is to summarize the current status of Muskellunge management in Virginia and to provide goals, objectives, and strategies to manage Muskellunge populations into the future.

The Virginia Department of Wildlife Resources (VDWR), formerly the Virginia Department Game and Inland Fisheries, began stocking Muskellunge in various waters throughout the state in 1963. VDWR currently recognizes 19 waters as having existing muskellunge populations, which include 9 rivers and 10 impoundments (Table 1). These populations are maintained by annual stocking or through natural reproduction following previous introductions.

Wingate (1986) identified four primary goals that have historically been pursued in the management of Muskellunge in North America. These goals include 1) producing trophy fisheries, 2) providing diversity to angling opportunities, 3) providing top-down predator control of fish populations, and 4) protecting and restoring endemic Muskellunge populations. With the exception of the final goal listed, these are the same goals that have been, and continue to be, followed in the management of Muskellunge in Virginia.

Most naturalized populations of Muskellunge in Virginia exhibit low population density and are primarily managed as Class C fisheries with the goal of adding diversity to angling opportunities (Table 1). These waters do not receive annual stockings and are managed under relatively liberal length limits. The two exceptions to this are the James and New River populations both of which are self-sustaining and relatively dense in terms of Muskellunge abundance. Additionally, these waters exhibit great trophy potential and have become destination fisheries and as such are considered Class A Muskellunge waters. The Shenandoah River and the South Fork Shenandoah River are also considered Class A Muskellunge waters, but require stocking to maintain these fisheries. The remainder of stocked waters are considered Class B Muskellunge waters and are managed to provide diverse or trophy angling opportunities or, in the case of Rural Retreat Lake and Lake Shenandoah, for top-down predator control of a stunted Black Crappie (*Pomoxis nigromaculatus*) fishery.

Biology

Muskellunge inhabit both lakes and rivers where they prefer cover such as vegetation, woody debris, bars, and rock outcroppings. In rivers, Muskellunge prefer deep pools or other areas with slower-moving water. The optimal temperature range for Muskellunge is 62° - 77°F with reduced feeding occurring at temperatures above 84°F (Jenkins and Burkhead 1994).

Muskellunge typically reach sexual maturity at 3-4 years for males and 4-5 years for females. Spawning generally occurs in mid-April to early May, although pre-spawning movements may begin in late March (Younk et al. 1996). Spawning generally occurs at water temperatures of 55 – 62°F.

Muskellunge are top aquatic predators with diets composed primarily of other fish species. Although recently hatched fry will prey upon zooplankton and other invertebrates, they quickly switch to minnows and other small fish. As the Muskellunge grows it will switch to preying on larger and larger fish. Diets of adult Muskellunge may also include small birds, mammals, and amphibians. It is this aggressive, predatory nature that has often left other stakeholders with the perception that Muskellunge have a negative impact on native game fish species. Despite the popularity of Muskellunge fishing among many anglers, the development of these fisheries in Virginia has not been without similar conflict. In the case of the New River, as the Muskellunge fishery expanded anglers targeting Smallmouth Bass grew concerned that large Muskellunge were feeding heavily upon Smallmouth Bass and negatively impacting catch rates. To specifically address these concerns, VDWR contracted research aimed at assessing the potential impact of Muskellunge predation on Smallmouth Bass in the New River.

Brenden et al. (2004) found that, although Smallmouth Bass were found in the stomachs of New River Muskellunge, that Smallmouth Bass comprised just 4% (by weight) of Muskellunge diets overall. This study did find that Smallmouth Bass comprised a higher percentage (11% by weight) of the diet for larger Muskellunge (≥ 32 inches). However, this was still less than the percentages contributed by suckers (22%), minnows (24%), or sunfish (20%). These findings were consistent with other

Muskellunge diet evaluations (Deutsch 1986, Bozek et al. 1999) and, as a result, Brenden et al. (2004) concluded that predation by Muskellunge likely did not have a major impact on the New River Smallmouth Bass population. These authors did warn, however, that if VDWR altered their Muskellunge stocking protocols in a way that increased post-stocking survival of Muskellunge then the potential for a negative impact on Smallmouth Bass may be greater.

With changes to the management of Muskellunge in the New River (increased minimum length limit and increased stocking length) beginning in 2006 and a concurrent decline in New River Smallmouth Bass abundance, concerns over Muskellunge predation were raised again. Doss (2017) found that despite a fourfold increase in the abundance of adult Muskellunge since 2006, the contribution of Smallmouth Bass to Muskellunge diet was lower (3%) compared to that observed by Brenden et al. (2004). The importance of other species (suckers, minnows, sunfish) to the diet of Muskellunge was similar between the two studies.

Muskellunge growth can vary substantially among locations and is highly dependent on the availability of suitable prey (Cook and Solomon 1987). A strong sex-dependent difference in growth is apparent in Muskellunge with females growing faster and reaching a larger size than males. Growth estimates for Muskellunge in Virginia are limited to just two river systems, the Shenandoah River and the New River (Table 2). Brenden (2005) estimated that both male and female Muskellunge reached 30 inches by Age 3. At Age-6 the differences in growth became more apparent with males averaging 40 in and females averaging 43 in. By Age-8, females had reached a length exceeding 45 in while males averaged 41 in. Following the implementation of a 42-inch minimum length limit (MLL) in 2006, however, Doss (2017) observed reduced growth for Muskellunge in the New River. Both male and female Muskellunge were found to take an additional year to reach a particular length when compared the Brenden (2005) study. The author attributed this to increased intraspecific competition for forage resulting from higher Muskellunge density under the higher length limit.

In general, advanced age at maturity and low population density can make Muskellunge populations particularly vulnerable to exploitation and can limit the potential for trophy production (Casselman et al. 1996; Crane et al. 2015). Brenden (2005) estimated the annual exploitation rate of New River Muskellunge to be 14%, which was substantially lower than the rate (25%) suggested by Hanson (1986) as a maximum threshold for quality Muskellunge management. More recent investigations indicate that while angler utilization in terms of catch is high (defined as percentage of tagged fish caught; James River ≥ 50% and New River ≥40%), exploitation in terms of harvest is low (James River ≤ 5% and New River = 0%; VDGIF unpublished data).

Regulations

Nearly all Muskellunge fisheries in Virginia are managed under a 30-inch minimum length limit and a 2-fish daily creel limit. The only exceptions to this are regulations developed for the New River and Lake Shenandoah aimed at reducing harvest and increasing the abundance of large Muskellunge. The Muskellunge population in Lake Shenandoah is managed under a 40-inch MLL and 1 fish per day creel limit. In 2006, the MLL for the New River fishery was increased from 30 in to 42 in and the daily creel limit was reduced to 1 fish per day. Doss (2017) concluded that the 42-in MLL resulted in an increased abundance of larger (≥42 in) Muskellunge in the lower New River (Claytor Dam to the WV state line). Concurrent with the increase in large Muskellunge, however, was a reduction in growth and condition of fish between 35 and 40 in, likely due to stockpiling. As a result of this research, VDWR implemented a seasonal 40 to 48 in protected slot limit (PSL) in 2017 with the intent of reducing intraspecific competition for fish <40 in through harvest while at the same providing additional protection for larger fish. From June 1 through the last day of February, no Muskellunge between 40 and 48 inches may be harvested. During the spawning period (March 1 – May 31) the regulation switches to a 48-in MLL to protect more spawning adults. The 1 fish per day creel limit remains in effect year-round for Muskellunge on the lower New River. Muskellunge in the upper New River (Fields Dam downstream to, and including, Claytor Lake) are still managed under the 42-in MLL.

Monitoring

Differences among the various systems where Muskellunge are present make it difficult to establish standardized sampling protocols and none will be included in this plan. However, biologists managing waters that receive annual or periodic stockings of Muskellunge should make an effort to evaluate stocking efficacy. In particular, relative post-stocking survival and growth should be determined. Priority fisheries that are maintained through natural reproduction should be sampled annually to provide an indication of recruitment. Most creel surveys currently conducted by VDWR on Muskellunge waters do not accurately capture levels of directed effort, catch, or harvest for this species. Typically, creel surveys are conducted only during the peak springsummer fishing season. However, much of the targeted effort for Muskellunge occurs fall – spring.

Production & Stocking

Initially, VDWR obtained Muskellunge eggs or fry from a number of states (New York, Pennsylvania, Tennessee, and West Virginia) for introduction into Virginia waters. Over the years, the agency has shifted to collecting brood fish from Virginia waters for in-house production of Muskellunge fingerlings. Additional eggs or fingerlings have been periodically obtained from other states (New Jersey and North Carolina) in years in which in-house production was not sufficient to meet the requested allocation. With the implementation of more stringent biosecurity measures by VDWR, New Jersey and North Carolina are now the only states from which VDWR may obtain surplus Muskellunge.

The mean length of Muskellunge fingerlings produced for stocking was initially 4-6 in for all state resources. Standard stocking rates at this size were established at 1-3 fish/acre of surface area for impoundments and approximately 1-2 fish/acre of pool habitat for rivers. In 2007, the VDWR Aquaculture Science Team made the decision to switch to stocking advanced fingerings (8-12 in) with the goal of increasing survival and reducing strain on hatcheries. By switching to advanced fingerlings, hatchery staff could stock less fish and require less hatchery pond space in the process. As a result of this decision, river and impoundment stocking rates were reduced by half to account for improved survival (0.5-1.0 fish/acre of pool habitat for rivers and 0.5-1.5 fish/acre of surface area for impoundments).

The current number of advanced fingerlings needed for statewide stocking is approximately 1,780 fish annually. Despite the relatively low number of fingerlings needed, these fish can be incredibly challenging and costly to raise. Limited hatchery tank or pond space, the high cost of forage for fingerlings, and unpredictable environmental conditions and resulting variable survival of fingerlings in rearing ponds can greatly affect the final number of fingerlings produced as well as the cost per individual fish. Table 3 provides a general breakdown of costs associated with the production of advanced Muskellunge fingerlings by VDWR. Total annual production cost is estimated at just over $30,000 with the purchase of minnows for feeding the fingerlings after they are stocked into the rearing pond accounting for nearly 60% of the total cost. This value is based on a single 5-acre pond with a maximum fingerling production of about 1,500 fish. If the pond is successful and the maximum number of fingerlings are produced, the production cost is around $20.36/advanced fingerling. As pond success decreases the cost per fingerling increases and can be about $40.73/advanced fingerling if the pond only produces half of the maximum.

Biologists and hatchery staff work together to collect broodstock muskellunge in March and April with a target of three ripe females and about 2 to 3 males per female. The primary muskellunge brood source for VDWR is currently the James River, although alternate sources (e.g. New River, Rural Retreat Lake, and Hungry Mother Lake) have been used historically and are still available if needed. Brood fish are transported directly to Vic Thomas Fish Hatchery (VTFH) due to its nearness to the James River and the availability of large holding tanks at VTFH. The availability of the large holding tanks allows for Muskellunge to be held and periodically checked for ripeness. Fertilized eggs (typically 150,000–200,000) are transported to Buller Fish Hatchery (BFH) for hatching and grow-out. The transfer to BFH is necessary because rearing Muskellunge at VTFH would conflict with Striped Bass (*Morone saxatilis*) production at that facility. The need to strip and fertilize eggs at VTFH is necessary because holding space for adult fish is limited at BFH. Currently, just one 5-acre pond is allocated for Muskellunge production at BFH with a maximum production capacity of approximately 1,500 advanced fingerlings. As a result, current VDWR production capacity for advanced Muskellunge fingerlings is insufficient to cover annual stocking requests for existing waters and prohibits the development of new Muskellunge fisheries.

Given the potential for insufficient hatchery production, it is imperative that VDWR establishes stocking priorities each year prior to the Muskellunge production season. These priorities will be established by the Muskellunge working group within the VDWR Warmwater Streams Committee and will be maintained in a "living" spreadsheet that will accompany this plan. The working group includes both hatchery personnel and field biologists. Class A waters (lower New River, James River, Shenandoah River, and South Fork Shenandoah River) will be assigned the highest stocking priorities each year based on the popularity of these fisheries. However, with the self-sustaining nature of the lower New River and James River fisheries, stocking will only be necessary when problems with recruitment become apparent through annual monitoring. If stocking is not necessary in the New River or James River, then the remaining Class A waters will receive the highest stocking priority followed by Class B waters. Whether or not a particular Class B water received Muskellunge fingerlings the previous year as well as the proximity of a particular water to a population center will be the primary criteria used to establish annual stocking priorities within the Class B management category. Logistic constraints associated with the harvest and transport of fingerlings can be used to adjust priorities annually as needed.

Program Justification

Given the challenges and costs associated with maintaining Virginia's Muskellunge fisheries, it is imperative that these efforts are in line with, and contribute to, VDWR's overall mission. More specifically, it is important to consider how Muskellunge fisheries contribute to the agency's efforts aimed at recruiting, retaining, and reactivating (R3) participation in outdoor recreation.

Muskellunge are a challenging and exciting species for anglers to target, but fishing for them is not for everyone. Known as "the fish of 10,000 casts", it takes dedication, research, and some specialized equipment and techniques for anglers to be successful. Costly, complex, and extreme types of fishing are generally considered barriers to recruitment of new anglers to fishing (Aquatic Resource Education Association 2016). For new anglers, the opportunity for relaxation is a strong driver for participation and as a result may not be attracted to the challenges associated with Muskellunge angling (American Sportfishing Association 2012a; Recreational Boating and Fishing Foundation and the Outdoor Foundation 2015). However, more experienced or avid anglers generally seek greater excitement and challenge and may become more specialized in their angling activity. Additionally, Muskellunge are one of the few sport fish in Virginia that are actively feeding during the winter months and most dedicated

Muskellunge anglers believe that this is the best time of year to target these fish. The additional wintertime angling opportunities provided by Virginia's Muskellunge fisheries have the potential to increase angler retention and reduce churn rate by increasing the number of days per year a person fishes (Aquatic Resource Education Association 2016).

Therefore, while VDWR's Muskellunge program may not serve as a primary option for recruiting new anglers, this program has tremendous potential to advance the other two components of R3, retention of existing anglers and reactivation of lapsed anglers. While VDWR focuses substantial effort toward recruiting new anglers through events like free fishing weekends and kids fishing days, there are few programs solely devoted to retaining and reactivating anglers. The Muskellunge program could function as one of the tools used to prevent angler lapse and serve as a blueprint for other programs ill-suited for recruitment. By marketing the program to current and lapsed anglers, we have the opportunity to reduce churn rate (the annual level of anglers that lapse in the activity) and reactivate disinterested anglers.

Evaluation

The Muskellunge working group will meet regularly to evaluate the effectiveness of current Muskellunge management practices. If evaluations of specific waterbodies yield poor results a change of the classification of a given fishery will be considered. The working group may make recommendations to increase sampling effort or change stocking rates in an effort to improve an ailing population. Hatchery production will also be routinely evaluated and fine-tuned to improve yields. If yields improve, efforts will be made to increase muskellunge fishing opportunities.

The committee will critically evaluate success in meeting stakeholder related goals as well as the success or failures of outreach efforts related to R3. Changes will be discussed and enacted as deemed appropriate by the Muskellunge working group.

Goals

Goal 1: Maintain and enhance recreational fishing opportunities for Muskellunge with consideration of associated fish assemblages and aquatic communities.

Objective 1. - Maintain and protect existing self-sustaining Class A Muskellunge fisheries.

Strategies

- Closely monitor populations to detect potential problems with recruitment, growth, or mortality.
- If problems with recruitment are detected, divert hatchery production of advanced fingerlings to these fisheries in accordance with the prioritized stocking list outlined in this plan.
- Implement regulations as needed to maintain a sustainable level of exploitation (≤25%).

Objective 2. – Maintain and protect existing self-sustaining Class B Muskellunge fisheries.

Strategies

- Adhere to the prioritized stocking list outlined in this plan to most effectively utilize hatchery production of fingerlings.
- Implement regulations as needed to maintain a sustainable level of exploitation (≤25%).

Objective 3. - Insure sufficient hatchery production of advanced Muskellunge fingerlings sufficient to maintain stocked fisheries.

Strategies

- Adhere to the prioritized stocking list and stocking rates outlined in this plan to most effectively utilize hatchery production of fingerlings.
- Explore potential for tank rearing of advanced fingerlings as a means to reduce variability in annual hatchery production and reduce costs.
- Work with VDWR Veterinarian to identify additional states that may serve as a source for Muskellunge fingerlings.
- Review existing Muskellunge stocking rates to insure optimal utilization of annual hatchery production.
- Support overall efforts to improve VDWR's statewide hatchery production capacity.

Objective 4. – Increase Muskellunge fishing opportunities statewide through development of new waters or enhancement of existing Muskellunge fisheries.

Strategies

- Evaluate the potential of more restrictive regulations such as higher minimum length limits to increase Muskellunge density in existing self-sustaining Class C waters.
- Create list of potential new Muskellunge waters that could be created if hatchery surplus is available. These waters would only be stocked after all other existing waters are stocked.

Goal 2: Use science-based management for Virginia's Muskellunge fisheries.

Objective 1. – Establish a standing Muskellunge working group to assist the Fisheries Chief in addressing management issues. This group will be a sub-committee under the Warmwater Streams Committee.

Strategies

- Conduct a review of Muskellunge stocking rates currently employed by VDWR.
- Evaluate the feasibility of implementing an angler diary program for estimating Muskellunge catch rates and size structure on particular waters or statewide.
- Develop a list of research and information needs for maintaining Virginia's Muskellunge fisheries.

Objective 2. – Improve current monitoring efforts directed at existing Muskellunge fisheries.

Strategies

- Design future creel surveys conducted on major Muskellunge fisheries to cover the important fall-winter period to allow for improved estimation of directed effort as well as catch and harvest rates.
- If feasible, implement an angler diary program for estimating Muskellunge catch rates and size structure.
- Monitor exploitation rates on major Muskellunge waters through tagging studies.
- Conduct directed annual sampling on Class A Muskellunge fisheries, especially those that are sustained through natural reproduction.
- Collaborate with Muskies Inc. Chapter 76 (Virginia) to assist with monitoring and research efforts.
- Develop and maintain a list of fishing guides targeting Muskellunge in Virginia. This list could serve as an important source of

information such as catch and usage, economic impact, and other issues related to these fisheries.

Goal 3: Foster improved communication to promote the recreational value of Virginia's Muskellunge fisheries and minimize conflict among stakeholder groups.

Objective 1. – Improve communication efforts relating to Muskellunge fisheries in Virginia.

Strategies

- Maintain most current Muskellunge information on VDWR website. https://www.dgif.virginia.gov/wildlife/fish/muskellunge/
- Promote Muskellunge webpage and "Musky 101" video through social media and email campaigns.
- Collaborate with Muskies Inc. Chapter 76 (Virginia) to assist with communication efforts.

Objective 2. – Promote Virginia's Muskellunge fisheries as a means to maximize utilization of these resources.

Strategies

- Market the Muskellunge program to anglers as a way to extend their fishing season.
- Utilize targeted marketing in population centers with nearby Muskellunge fisheries to inform the public about trophy fishing opportunities available to them.
- Promote the Muskellunge webpage and "Musky 101" video through social media and email campaigns as a means to attract anglers to the sport of Musky fishing.
- Collaborate with neighboring states to create a "Southern Musky Trail" and market to northern anglers to fish southern waters in the winter when their resources are iced over or in spring when they are closed to fishing.

Objective 3. – Utilize Muskellunge fishing as an integral part of VDWR's efforts to retain current anglers and re-activate lapsed anglers.

Strategies

- Market the Muskellunge program to current anglers as a way to extend their fishing season.
- Promote the Muskellunge webpage and "Musky 101" video through social media and email campaigns as a means to attract anglers to the sport of Musky fishing.
- Collaborate with neighboring states to create a "Southern Musky Trail" and market to northern anglers to fish southern waters in the winter when their resources are iced over or in spring when they are closed to fishing.

- Email link to VDWR’s Muskellunge webpage directly to lapsed anglers in an effort to reactivate them by offering a new angling challenge.
- Collaborate with Muskies Inc. Chapter 76 (Virginia) to assist with recruiting new anglers, educating the public, and participating in ongoing research.

Table 1. – List of existing Muskellunge waters in Virginia. Class A waters are considered trophy Muskellunge destination waters. Class B waters provide good fishing opportunities for Muskellunge, although catch rates and trophy potential is generally lower than Class A waters. Class C waters support fishable Muskellunge populations, although they do not contribute a significant part to the overall fishery.

	Area (acres)	**Stocked/ naturalized**	**Management classification**	**Stocking allocation**	**Regulations**
Rivers					
Clinch River	790	naturalized	C	**	statewide
Cowpasture River	**	stocked	C	**	statewide
Jackson River	**	stocked	C	**	statewide
James River	1,644	naturalized	A	822-1,644	statewide
New River	3,064	naturalized	A	1,202-2,403	special
Powell River	**	naturalized	C	**	statewide
SF Shenandoah River	828	stocked	A	414-828	statewide
NF Shenandoah River	196	stocked	B	98-196	statewide
Shenandoah River	384	stocked	A	192-384	statewide
Impoundments					
Burke Lake	218	stocked	B	109-327	statewide
Claytor Lake	4,475	naturalized	C	**	statewide
Flannagan Reservoir	1,143	naturalized	C	**	statewide
Hungry Mother Lake	108	stocked	B	54-162	statewide
Lake Shenandoah	36	stocked	B	18-54	special
North Fork Pound Lake	154	naturalized	C	**	statewide
Ragged Mountain Reservoir	170	stocked	B	85-255	statewide
Rural Retreat Lake	90	stocked	B	45-135	statewide
Smith Mountain Lake	20,600	naturalized	C	**	statewide
South Holston Reservoir	1,600	naturalized	C	**	statewide

Table 2. – Mean length-at-age (inches) for Muskellunge from two Virginia rivers. Populations in the New River (2000-2003) and Shenandoah (2014) were managed under a 30-inch minimum length limit (MLL) at the time of data collection while the New River (2013-2016) population was managed under a 42-inch MLL.

	New River[1] (2000-2003)		New River[2] (2013-2016)		Shenandoah River[3] (2014)
Age	**Female**	**Male**	**Female**	**Male**	**Combined**
2	27	29	20	23	25
3	33	34	27	28	30
4	38	37	32	32	34
5	41	39	37	35	37
6	43	40	40	37	40
7	44	41	43	39	42
8	45	41	45	40	43

[1] from Brenden (2005)
[2] from Doss (2017)
[3] VDWR (unpublished data)

Table 3. – General costs of producing and stocking advanced Muskellunge fingerlings by VDWR. Values given are based on a single 5-acre pond with a maximum fingerling production capacity of 1,500 fish.

Category	**Cost**
Labor (416 hours @ $20/hour)	$8,320
Supplies	$3,078
Forage (minnows)	$17,900
Transportation	$1,248
Total	$30,546

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Appendix 1 – Detailed Muskellunge Egg Collection & Fertilization Procedures

1) **Collecting Brood Fish**

   a) Collect three females 35 to 45 inches in total length when river temperature reaches about 55°F, preferably during a warming trend.

   b) If a ripe female is found skip to step 6.

   c) Unripe fish will be injected with Common Carp Pituitary Gland powder (CCP).

2) **CCP Preparation**

   a) Remove cap from specimen cup and place it on the table face up (outside of lid touching table). Weigh out 0.15g (150mg) CCP powder using sterile spoon to scoop CCP powder directly into sterile specimen container. Replace cap and label specimen cup. Store at room temperature and avoid light.

3) **Reconstitution of CCP**

   a) Attach an 18 gauge (green) needle to a 35ml syringe. Fill syringe with 20ml sterile water. Remove cap from specimen cup and place it face up (outside of lid touching table). Add sterile water to specimen cup with CCP powder. Put the needle in sharps container. Replace specimen cup lid and shake. Use within one hour of reconstitution. Discard remainder of reconstituted CCP in the regular trash.

4) **Intracoelomic (IC) Injection**

   a) Use anesthesia gloves to control females during injection.

   b) Weigh the fish you plan to inject

   c) Use 12ml syringe with 20 gauge needle (Pink) for fish injections. Fill syringe with amount of CCP solution based upon the injection chart (Column C). Place fish on dorsum. Insert needle at 45 degree angle just off the midline anywhere between the following landmarks: halfway between the pelvic and anal fins but proximal to the anal pore. (Inject in the pocket behind the pelvic fin). Plunger should be easy to depress if the needle is in the body cavity. If difficult to depress, re-insert the needle to find the body cavity. Discard needle in sharps container.

   d) Place fish into musky holding pen. Check ripeness in 3 days.

5) **Collecting Milt**

   a) Collect 3 males 35-40" for each female in holding.

   b) Use anesthesia gloves to control fish

   c) Disinfect the fish's vent with a 1:100 (10ml per liter) iodophor solution and wipe the vent surface dry with a clean paper towel.

d) Express male and collect milt using sterilized plastic syringe. Deposit milt in sterile vial. Avoid collecting urine in sample.

6) General Procedure for Fertilization and Egg Disinfection

a) For spawning use three people, one to control the head, one to anesthetize the fish, and the other to strip the female.

b) Disinfect the fish’s vent with a 1:100 iodophor solution (10ml per liter) and wipe the vent surface dry with a clean paper towel. Spawn eggs into a clean, dry pan and add milt from 2-3 males to fertilize the eggs. Gently stir the eggs with a clean turkey feather to ensure full distribution of the milt throughout the mass of eggs. Add de-chlorinated distilled water and mix to ensure milt activation (1-2 minutes). Keep eggs in an ice bath to keep eggs cool (15 degrees C).

c) Rinse excess milt and any blood or feces off the eggs with a large amount of de-chlorinated distilled water.

d) If the eggs are adhesive and require use of a de-adhesive agent (i.e., walleye), add tannic acid or Fullers earth from a stock solution and mix gently, but thoroughly. Stir for approximately 2 minutes. Caution: Fuller’s earth and tannic acid have been commonly used as an anti-clumping agent for cool water species. Published research suggests that when tannic acid is combined with iodophor, tannic acid destroys the ability of either compound to effectively inhibit VHS, Type IVB. Thorough rinsing of both de-adhesive agents is required to ensure that it does not interfere with the disinfectant properties of iodophor. We typically do not use Fullers Earth or Tannic Acid in the spawning process, clumping has not been a huge issue

e) Gently pour off the solution and gently rinse eggs with clean, de-chlorinated distilled water.

f) Immediately but gently add the prepared solution of 50 ppm iodophor (5ml per liter of distilled water) and gently mix to ensure even distribution of iodine to the egg mass. Disinfect for 30 minutes out of light. Keep eggs in an ice bath to keep eggs cool – match the temperature of the water used to hold brood fish (typically 15 C).

g) Gently rinse eggs with de-chlorinated distilled water into waste bin. Place eggs into de-chlorinated distilled water to complete water-hardening. Pour into transport bag and add air for shipping. Ship in dry cooler with a few cubes of ice to hatchery.

h) Clean, disinfect and dry all potentially contaminated equipment used in the disinfection process.

7) Equipment Disinfection

a) Remove organic debris from equipment using tap water, detergent, and scrubber or sponge.

b) Fill plastic container with desired amount of water. Add enough Chlorhexadine to turn water sky blue color.

c) Let equipment sit for 10 minutes, then rinse and dry.

Equipment Checklist

- Plastic syringes for milt extraction
- Syringes for CPP injection
- 3 egg pans
- Musky holding pen, 4 weights, 8 ropes, 4 floats. Sign.
- Anesthesia Gloves
- Musky Socks / Musky Nets
- Measuring Cups
- Feathers
- Premeasured CPP
- Distilled water
- Iodophor
- Timers
- Oxygen Tank, Banding Tool, Bands, Egg Bags, Large Cooler
- Biohazard Container

Appendix 2 – Detailed Muskellunge Hatchery Rearing Procedures

Egg Transfer and Acclimation

Musky are strip spawned at Vic Thomas Fish Hatchery. Fertilized eggs are then placed in plastic bags with water and compressed oxygen and sealed with rubber bands. Eggs water harden during the 3 hours it takes to transport them to Buller Fish Hatchery. Once eggs are received they are poured into plastic containers to start the water temperature acclimation process. Well water at 54F is poured into each plastic container gradually to slowly cool down eggs. Temperature is monitored as well water is added to each container. The acclimation process takes approximately 30 minutes to get the water temperature down to 54F.

Egg Incubation, Enumeration, Treatment, and Hatch

Once acclimation is complete musky eggs are poured into McDonald jars and are separated by spawning batches. Initial volume of eggs in each jar is recorded after eggs settle to the bottom of the jars. Water flow is then adjusted for each jar until the eggs are rolling properly. Water flow is usually set between 1gpm and 1.5gpm depending on the amount of water needed to roll eggs. Eggs are continuously monitored throughout the incubation process to make sure they are moving appropriately in each jar.

The next day eggs are sampled from each jar to determine an estimation of the number of eggs per ounce. Eggs are collected by using a siphon tube with a bulb on the end, they are then transferred to a Von Bayer trough where 3 inches of eggs are placed in a line and counted. Three inches is then divided by the number of eggs in the count, this will give a diameter or measurement of each egg. For example, if you have 35 eggs within 3 inches in the trough, the egg diameter is .085. This number is then used to look up how many eggs you have per ounce using the Von Bayer egg chart. Musky eggs generally range between 1900-2100 per ounce depending on the size of the female. To get the total estimation of eggs per jar, the number of eggs per ounce is multiplied by the total ounces in each jar. Fertilization estimates are also taken 4 days post fertilization by counting good eggs and the total number of eggs in a clear tube and a percentage of viable eggs is calculated.

Treatment of eggs is initiated two days after they are received. Hydrogen peroxide is used at 500ppm to reduce or eliminate saprolegnia fungus that will cover eggs if left untreated. Eggs are treated every other day for 15 minutes using a flow through treatment. Treatment is calculated by using the following formula [water flow (gpm) X treatment duration (min) X treatment concentration (mg/L) / % Active Ingredient x Correction factor/ specific gravity]. For example, treatment of musky eggs, water flow 1 gpm for 15 minutes at 500 ppm [1gpm x 15 x 500ppm/ .35 AI x .003785 CF / 1.132 SG]

= 72 ml hydrogen peroxide. Dead eggs are siphoned from jars daily throughout the incubation period to help reduce fungus.

A few Eggs will begin to hatch at 8 to 9 days at 54F post fertilization. Once hatch is observed egg treatment is discontinued and eggs are transferred to wire mesh trays placed in 300 gallon rectangular tanks. Hatching will continue for up to 15 days or 342 temperature units. The water temperature in the rectangular tanks is the same temperature 54F. Any fungus clumps or unfertilized eggs should be removed from the screen tray platform to help reduce the spread of fungus to sac fry. Sac fry that hatch on the wire mesh tray are fanned using a turkey feather to encourage them to swim off the screen tray. Once the majority of live sac fry have swam off the platform the platform trays are removed.

Fry Tank Production

Fry generally take 7-10 days to absorb their yolk sac and swim up. During this time frame, and throughout the fry tank production period, musky are treated prophylactically every other day with a formalin static bath at 150 ppm. This is done to reduce fungus. Temperature is gradually increased via inline heater to 68F. Water flow is set between 1 and 3 GPM in each tank.

Once fry are observed swimming, brine shrimp are cultured. Brine shrimp are hatched using six 15 gallon culture units. Artificial light is left on 24 hours per day. A space heater in the brine shrimp room heats water to 84F and salinity is adjusted to 28 ppt. Brine shrimp will hatch, and are harvested, 24 hours after setup. Only one 15 gallon brine shrimp cone is used per 24 hour hatch period. Water is always filled 24 hours before eggs and salt are added to allow time for the water to heat.

Musky are hand fed Brine shrimp 7 to 8 times per day per tank. Otohime feed is mixed with brine shrimp at each feeding. Musky are fed for the last time in the evening around 9 pm, belt feeders are setup to feed otohime feed overnight. Each tank has a 4 foot led shop light left on 24 hours per day to help with visual feeding. Fry are fed otohime and brine shrimp for 14 days post swim up.

Tanks are cleaned twice per day once in the morning and once in the afternoon. Cleaning tanks is labor intensive and requires patience. Tanks are swept with a broom to concentrate leftover feed to one end of the tank, unfortunately musky are also swept with the leftover feed. When the waste is siphoned so are musky fingerlings and they have to be picked out with a net. Water exchanges should also be done once a week. The sides and bottoms of the tanks should also be wiped daily with a wash cloth to remove fungus and slime. The standpipe area of the tank should also be siphoned and wiped twice a week.

Fry are fed for approximately two weeks before they are sampled and transferred to a 5 acre production pond. If fry are held longer than two weeks in tanks, cannibalism causes major fry loss. Fry are acclimated to pond water and are spread out in different locations throughout the pond. The pond should be stocked with 5,000 musky fry per acre.

Pond Production and Fertilization

Pond #2 (5 acres) is filled around the 1st week in March. Brood minnows are ordered (500lbs.) and delivery is scheduled for the last week in March or the 1st week in April. Brood minnows are fed 3 times per week with small trout feed pellets. Two weeks prior to stocking musky fry, the pond is fertilized with 50lbs. of soybean meal, 50lbs of Alfalfa meal and 8 lbs. of granular pond fertilizer per acre. Fertilization is done to provide a zooplankton bloom to fathead minnow fry and musky fry. The fertilization regimen should continue once a week through the end of June, then should be switched to 5lbs of granular pond fertilizer per acre until harvest in September.

The second shipment of fathead minnows should be delivered around the 3rd week in June. The minnows should be small in size (700lbs.). The third shipment of fathead minnows should be delivered during the third week in July. The minnows should be pond run (700lbs.). The fourth shipment of minnows supplied by King and Queen Fish Hatchery should be delivered by the third week in August (300lbs.).

Harvest

Musky are generally harvested during the second or third week in September. The 5 acre production pond takes 7-8 days to drain, heavy boards are pulled one at a time. Water flow is decreased but maintained throughout draining. Musky are drained into two concrete spillways with screens placed in the back slots of each spillway. Boards are placed in slots behind the screens to maintain water level in the spillway. Many musky have to be picked up by hand in the pond because they get stuck in aquatic vegetation and don't make it to the drain channels. Musky that have been picked up by hand are placed in 5 gallon buckets with bait aerators and then transferred to a fish hauling truck. Harvesting musky is very labor intensive and requires a crew of 10-12 staff. Harvested musky are counted from the hauling truck to the hatchery building and are separated by stocking locations. Musky are allowed to rest overnight in the hatchery building before being sampled and shipped to stocking locations throughout the state.

Cost Analysis of Musky Production

LABOR ESTIMATE

Collection and Spawning= 48 hours

Transport of eggs= 10 hours

Tempering and setting eggs= 3 hours

Egg Treatment= 6 hours

Egg checks, fertilization rates etc. = 4 hours

Tank Setup heater, pumps and screens= 4 hours

Treatment of Musky Fry= 4 hours

Cleaning and feeding @3weeks =110 hours

Pond prep, setup and draining= 40 hours

Pond fertilization and feeding minnows= 32 hours

Administrative, planning, ordering minnows, data etc. = 10 hours

Harvesting Musky= 105 hours

Stocking Musky= 40 hours

Total Hours= 416 @ $20 per hour Average labor rate without benefits.

Total Labor Cost= $ 8,320

FORAGE COST

Brood Fathead Minnows- 500 lbs. $8.50/lb. = $4,250

Small Fathead Minnows- 700 lbs. $11.00/lb. = $7,700

Pond Run Fathead Minnows- 700 lbs. $8.50/lb. = $5,950

Total Forage Cost= $17,900

TRANSPORTATION COST

Hauling trips

Trip #1- Shenandoah Lake, SF Shenandoah, NF Shenandoah, Main Stem Shenandoah. Round Trip (Verona-Buller-stops-Verona) 576 miles

Trip #2- Ragged Mountain Res, Burke Lake. Round Trip (Front Royal-Buller-stops-Front Royal) 660 miles

Trip #3- Hungry Mother, Rural Retreat Lake. Round Trip (Buller-HM-RR-Buller) 54 miles

Egg transfer- VTFH to Buller, 2 trips 374 miles

Total Mileage= 1664 miles @ $.75 per mile = $1248

SUPPLY COST

Soybean meal- 1500 lbs. @ $.217 lb. = $325.50

Alfalfa meal- 1500 lbs. @ $.319 lb. = $478.50

Pond Max- 640 lbs. @ $1.60 lb. = $1,024

Minnow Feed- 500 lbs. = $300

Chemicals hormones, formalin etc. = $250

INAD= $700

Total Supply Cost= $ 3,078

TOTAL COST MUSKY PRODUCTION 5 ACRES (1500 MAX PRODUCTION) = $30,546

1,000 fish- cost per fish= $30.55

1,250 fish- cost per fish= $24.44

1,500 fish- cost per fish= $20.36

TOTAL COST MUSKY PRODUCTION 10 ACRES (3000 MAX PRODUCTION) = $ 54,114

Extra Cost to add 5 acres of production

Minnows=$17,900

Labor 177 HRS (pond setup, draining, harvesting, and fertilizing) = $3,540

Fertilizer and Feed= $2,128

2,000 fish- cost per fish= $27.05

2,500 fish- cost per fish= $21.64

3,000 fish- cost per fish= $18.04