Plan for Management of Muskellunge* in Pennsylvania

***-Includes tiger muskellunge management wherever mentioned.**

Pennsylvania Fish and Boat Commission
Division of Fisheries Management

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Executive Summary

The Pennsylvania Fish and Boat Commission (PFBC) intensively manages muskellunge (*Esox masquinongy* Mitchell) and tiger muskellunge (*Esox lucius x E. masquinongy*) in numerous lakes and rivers across the Commonwealth. This management effort is dependent both on hatchery stocking and harvest restrictions to sustain density and protect vestige wild stocks. This document reviews survey data, describes regulation and management changes implemented in 2007, proposes a plan to evaluate these changes, and identifies goals, objectives and strategies that will guide muskellunge fishing to its optimum potential in Pennsylvania.

Trap net catch data from 1977 to 2007 was used to establish a benchmark for retention in any lake or reservoir in the stocking program. For both purebred muskellunge and tiger muskellunge, this benchmark was established as a median catch rate in lakes of 0.01 per hour in spring, using Pennsylvania trap nets. In flowing waters however, historical information on muskellunge is sparse, so no benchmark has been established. So, surveys targeting this species in flowing waters should be directed to fill this data gap. Identification and evaluation of waters with natural reproduction should guide future survey objectives and strategies should be implemented to further protect and enhance these wild populations.

Proposed management recommendations for muskellunge populations will be evaluated using a method developed in 2007 which involves multi-year data collection on the catch-rate and size-structure of muskellunge and tiger muskellunge. For initial evaluation, we are proposing sampling on eight waters; one from each of the inland fisheries management areas. To allow the best opportunity for detecting significant change in the muskellunge population within a reasonable period, it will be necessary to gather five years of historical muskellunge catch data and five years of post-treatment data for these waters. The recommended gear for lakes in this evaluation is the Pennsylvania trap net, fished during the spring spawning period. In addition to pre- and post- Catch Per Unit Effort (CPUE) information for evaluating density, length-frequency, growth and condition will also be evaluated.

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I. Introduction

Pennsylvania has a long history of managing and culturing muskellunge. Native to the Ohio River and Lake Erie basins in Pennsylvania, muskellunge were historically common in Presque Isle Bay, the Allegheny River and the natural lakes of the northwest part of the Commonwealth (Hoopes and Cooper 1984). Within their native range, overfishing and widespread habitat loss drastically reduced natural recruitment in Pennsylvania (Graff 1986).

The primary goal of the muskellunge management program in Pennsylvania is to support a trophy fishery (Selcher and Cooper 1976; Hoopes and Cooper 1984). However, the loss of natural reproduction in its historical range, combined with the desire to expand muskellunge fishing outside its native range and the proliferation of new artificial impoundments across the Commonwealth, have contributed to the increased demand for stocking of fingerlings to maintain and expand the fishery, particularly through stocking tiger muskellunge.

In Pennsylvania's lake and rivers (Figure 1), muskellunge are found at relatively low densities and anglers catch them at low rates compared to other important game fish such as black bass, trout and walleye. Nevertheless, when caught, they can generate tremendous interest because of their large size and tendency towards trophy status. Catches of legal size (historically ≥ 30 inches) and trophy size (≥ 50 inches) muskellunge are often mentioned by local media which brings added attention to the fishery. Over the years, recreational angling for muskellunge has shifted towards more specialized anglers (Crossman 1986). These organized anglers fish for muskellunge frequently and are highly involved in their fishery (Margenau and Petchenik 2004). They are willing to travel long distances and spend more money than the average angler on their sport. The highly specialized muskellunge anglers often have different opinions regarding the fishery, compared to the general angling community (Margenau and Petchenik 2004). Specialized muskellunge anglers tend to advocate and practice catch-and-release, whereas anglers not targeting muskellunge may wish to keep a larger fish due to the uncommon experience. Consequently, muskellunge harvest management is an important component in the overall fisheries management of Pennsylvania's waters.

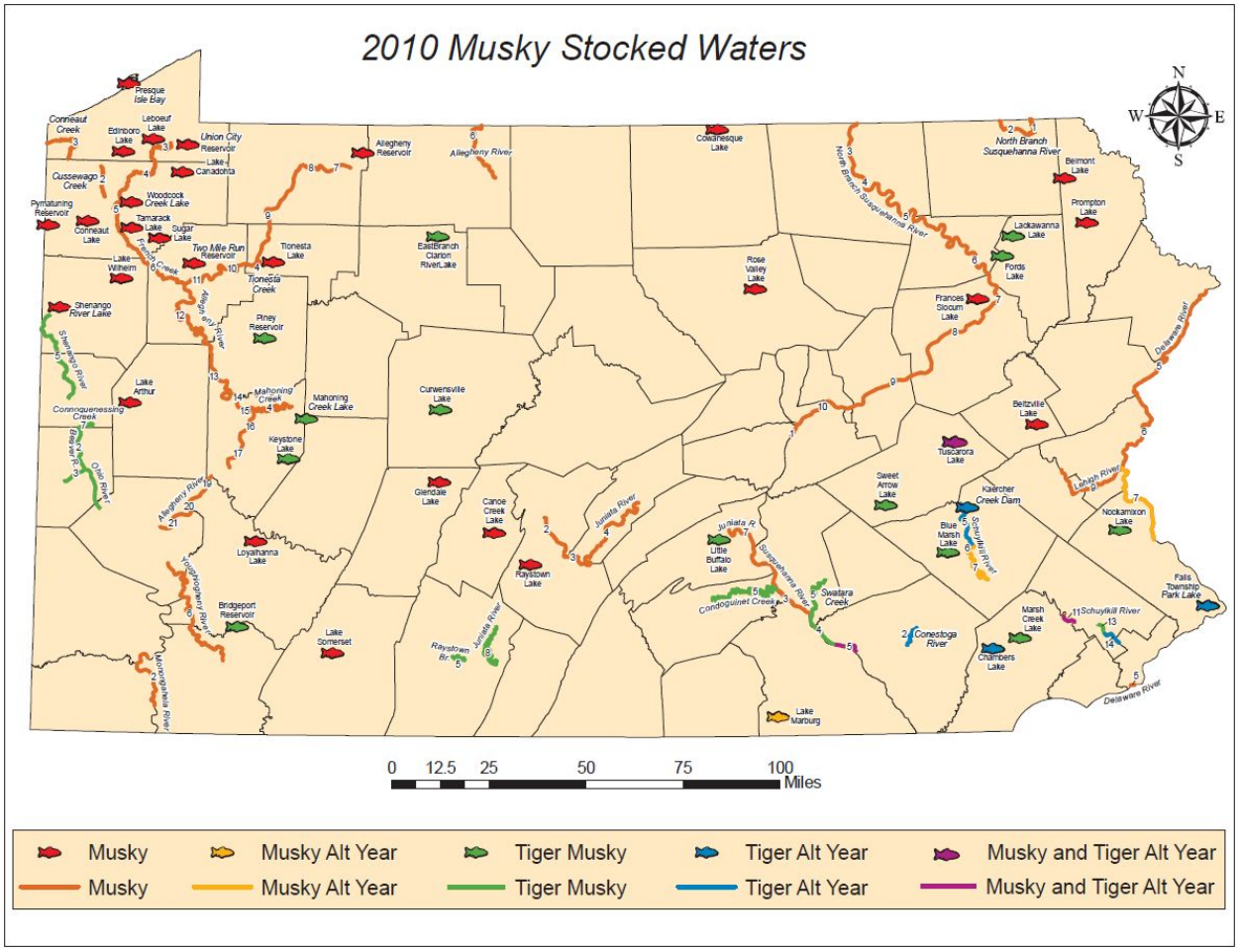

Figure 1. Pennsylvania waters currently stocked and managed for muskellunge and tiger muskellunge.

Goal of the Plan for Muskellunge Management in Pennsylvania

The goal of the muskellunge management program is to identify and rehabilitate where practical, natural reproducing populations of muskellunge in Pennsylvania and, through the efficient and effective use of hatchery culture techniques, stocking practices, regulations, and angler involvement, provide high quality angling opportunities for these popular sportfish.

Purpose of the Plan for Muskellunge Management in Pennsylvania

Unlike other important game fish in Pennsylvania, a management plan specifically for muskellunge and tiger muskellunge has not been previously written, but management goals and objectives were presented in the Warmwater Rationale (Selcher and Cooper 1976), the Strategic Plan for Pennsylvania's Warmwater/Coolwater Fishes (Hoopes and Cooper 1984), and on the PFBC website (Lorantas and Kristine 2005). This Muskellunge Management Plan is intended to

formally review historical catch information, formulate goals and management strategies, and provide the structure to evaluate recent management changes intended to enhance muskellunge fishing in Pennsylvania.

II. Natural Reproduction and Life History

As with other fish species, muskellunge should be managed through natural reproduction whenever possible. This is desirable both from an economic and ecological perspective. Economically, fostering natural reproduction would be expected to reduce the number of stocked muskellunge necessary to meet angler expectations, resulting in an overall savings to the Pennsylvania Fish and Boat Commission. Ecologically, a muskellunge population maintained by natural reproduction, especially in the historic natural range, would be indicative of a healthier aquatic community. Identifying and enhancing natural reproduction of muskellunge also incorporates the "Resource First" philosophy into management of muskellunge, fulfilling an agency policy requirement of this plan.

Muskellunge Life History

To understand proposed management strategies, it is important to recognize the critical factors involved in natural reproduction of muskellunge. Additional information on natural reproduction of muskellunge can be found in Scott and Crossman (1973) and Lorantas *et al*. (2005). Muskellunge spawn in spring and begin spawning behavior when water temperatures reach 42° F and males begin to appear on the spawning areas. Females begin to appear at 46 ^{o} F (Buss 1960). Spawning usually occurs in late April to early May when water temperatures are 49-59° F (Scott and Crossman 1973). Muskellunge typically seek shallow water with aquatic vegetation for spawning. Nests are not built. The fish pair–off and swim together side by side over several hundred yards of shoreline releasing small amounts of sperm and eggs simultaneously. The fertilized eggs are scattered randomly (Scott and Crossman 1973) and no parental care is given to eggs or hatchlings. Fecundity of muskellunge is high, which fits this reproductive strategy of random spawning with no parental care. Females can deposit up to 265,000 eggs with the usual number around 120,000 (Scott and Crossman 1973). The eggs tend to sink to the bottom or onto vegetation (Scott and Crossman 1973) although muskellunge eggs are non–adhesive. Under natural conditions, the percentage of fertile, deposited eggs is low (34%), and hatching occurs in

8-14 days at water temperatures of 53 to 63 ^{o} F (Scott and Crossman 1973). Adequate dissolved oxygen at the substrate level is critical for successful egg survival (Rust *et al*. 2002). In hatcheries, 60% to 95% of eggs are fertile and egg survival is very high where environmental conditions are carefully controlled.

Identification, protection and enhancement of suitable spawning habitat are vital for a self-sustaining, naturally reproducing muskellunge population. Among the constraints on habitat use, excessive sediment can affect the quality and availability of preferred habitat for reproduction. Excessive sediment within the spawning area can smother eggs that have been broadcast onto the substrate or reduce dissolved oxygen at the substrate-egg interface. As a result of the non-adhesive nature of muskellunge eggs, when broadcast over vegetation, the eggs often roll off the vegetation and settle to the substrate. This close association with the substrate has been found to contribute to reproductive failure in muskellunge as a result of low dissolved oxygen levels at the substrate water interface which were attributed to the decay of organic material by bacteria (Dombeck *et al*. 1984; and Rust *et al*. 2002).

Upon hatching, the young are 9.5-10.3 mm in length and remain dormant until the yolk is consumed, which takes about 10 days. At this time they become active and begin to feed exogenously. Juvenile muskellunge feed on aquatic invertebrates for 7 to 10 days after yolk sac absorption and then switch to aquatic insects and then to fish (Scott and Crossman (1973). Growth is rapid in the first year with fish reaching 254-305 mm by the end of the growing season. In Pennsylvania, muskellunge reach maturity in about three to four years. Rate of increase in length is rapid for the first few years and then slows at sexual maturity, however increases in weight continue throughout the life of the fish (Scott and Crossman 1973).

Adult muskellunge are opportunistic and have been documented feeding on a wide variety of prey including fish, small ducks, muskrats and frogs, yet most diet studies indicate a large percentage of their diet is fish (Scott and Crossman 1973). Muskellunge are “ambush predators” that generally seek larger fish as prey. Growth and survival of larger muskellunge is often impaired when prey of adequate size is not available (Scott and Crossman 1973). They tend to feed on these large fish then remain quiescent for a period of time before resuming feeding

activity. Various sucker species, along with common carp, have been found to be the most often consumed prey of muskellunge in the Susquehanna River (Deutsch 1986). Suckers, yellow perch and other panfish species were found in the diet of muskellunge in lakes (Bozek *et al*. 1999). Although preyed upon, game fish such as black bass and walleye generally do not comprise a large percentage of the muskellunge diet nor do they tend to be consumed in relation to their overall abundance in a waterbody. Since suckers and panfish are usually much more densely populated compared to game fish, they are eaten more frequently by muskellunge.

While muskellunge have a reputation as a ferocious and voracious predator (Crossman 1986), they are much less effective at controlling overabundant panfish compared to other large predators such as black bass and walleye. This is due to the relatively low density of muskellunge and their style of preying on larger fish then remaining inactive for long periods before resuming feeding activity, when compared to these other predators.

Dombeck (1986) and Rust *et al*. (2002) identified the following as features that relate to healthy muskellunge populations in lakes:

- limited northern pike abundance,
- rising spring water levels,
- high alkalinity,
- woody debris, and,
- aquatic vegetation in spawning areas.

Development of shoreline areas adjacent to spawning areas was identified as a negative factor affecting reproduction (Rust *et al*. 2002).

Like most esocids, muskellunge are attracted to aquatic vegetation and benefit from its effects on the aquatic community. Aquatic vegetation provides attachment sites for invertebrates and generally enhances productivity of littoral (near-shore) areas of lakes. This attracts small fish which provide forage for a variety of age classes of muskellunge. For young muskellunge, aquatic vegetation serves as cover from predators, and for adults also provides camouflage and ambush cover when preying on forage species. It is important for nursery areas to have mixed aquatic vegetation that approaches the surface of the water (Farrell *et al*. 2003). Studies in the

St. Lawrence River found wild celery (*Vallisneria*) in 95% of nursery areas followed by coontail (*Ceratophyllum*), bulrush (*Scirpus*), and water milfoil (*Myriophyllum*) (Farrell *et al*. 2003). Other aquatic plants associated with muskellunge nursery areas are muskgrass (*Chara*) and common water weed (*Elodea*).

Incorporation of Natural Reproduction into Muskellunge Management in Pennsylvania

Currently, with the exception of Section 6 of the West Branch Susquehanna River, the PFBC muskellunge management strategy assumes that all waters managed for muskellunge need to be systematically stocked to provide high-quality fishing. However, we have not consistently attempted to quantify natural reproduction within Commonwealth waters or whether fish recruited through natural reproduction have a higher likelihood of surviving to adulthood as compared to stocked fish. The Muskellunge Management Work Group expressed a strong interest in identifying waters that might support natural recruitment (Lorantas *et al*. 2005). Within the historic natural range of this fish, the PFBC should develop improved information on the current level of natural reproduction, and especially the survival to adulthood of wild fish compared to hatchery reared fish. If a high percentage of *wild* muskellunge were recruited to the adult population, then a relatively low level of reproduction may have the potential to supply the same number of adult fish as a higher number of stocked fingerlings. This could reduce the need for stocking fish.

These data needs could be answered by a method of reliably and permanently marking stocked muskellunge. This would allow for the quick and easy differentiation of naturally reproduced muskellunge from hatchery stock. Currently, the PFBC is studying the feasibility of using Coded Wire Tags (CWT) for marking stocked muskellunge fingerlings to differentiate the survival of fall-stocked fingerlings compared to spring-stocked yearlings. A secondary goal of this study is to observe the success of long-term CWT retention of muskellunge into adulthood. If proven reliable, use of CWT may be recommended for all muskellunge stocked within their native range to assess natural reproduction. The tagging portion of the fall fingerling versus spring yearling study is scheduled to conclude in 2015.

A second method for marking muskellunge is use of Passive Integrated Transponders (PIT) tags. This method involves the injection of the tag into the peritoneal cavity or musculature of the fish and is currently being used at the Linesville hatchery to track broodstock (L. Hines, PFBC, personal communication). These adult muskellunge have been tagged and released into the Pymatuning sanctuary lake. Subsequently, many of these fish have been recaptured in the main lake at Pymatuning indicating substantial movement. PIT tags allow identification of individual fish and more accurate measurement of growth between capture events. This feature would decrease the problems associated with using scales to age muskellunge and could also be used to validate information gained when scales are used for aging fish. Extensive research on these techniques is underway (Appendix A).

For a robust management plan, improved accuracy and quantification of natural reproduction is necessary, even when muskellunge are not the primary target species. As an example, backpack electrofishing surveys have observed Young-Of-Year (YOY) muskellunge on rivers and warmwater streams during YOY smallmouth bass surveys. These muskellunge are often sampled prior to hatchery stockings in these waters and can be presumed to be wild fish. Because smallmouth bass have been the primary target of these surveys, it has been difficult to consistently sample for muskellunge. As a result of these observations, additional backpack electrofishing should target YOY muskellunge in heavily vegetated areas where YOY muskellunge may be more abundant. To begin addressing this concern, preliminary sampling was initiated in August 2011 at three sites on the Allegheny River using both backpack and daytime boat electrofishing (B. Ventorini, PFBC, personal communications 2011).

III. Stocking History and Description

Muskellunge Stocking History in Pennsylvania

In the 1890's, muskellunge were stocked in the Commonwealth; however, as a result of complications with propagation, stocking was discontinued. With improvements to propagation methods, by 1953, the PFBC returned to raising muskellunge in Commission-owned hatcheries (Graff 1986) and continues to propagate these fish. The PFBC currently propagates and stocks the Ohio strain muskellunge throughout the Commonwealth, which originated from broodstock obtained from Chautauqua Lake, New York (Buss and Miller 1967). The PFBC has been

engaged in culturing the hybrid tiger muskellunge, which is the genetic cross between the purebred muskellunge and northern pike (*Esox lucius* Linnaeus), since the early 1960's (Buss and Miller 1967). The relative ease of propagating tiger muskellunge (Hoopes and Cooper 1984) using these intensive methods allowed the stocking program to expand greatly in the latter half of the 1960's and 1970's. Hybrid muskellunge are functionally sterile and resource managers have greater management control in areas where natural reproduction may not be desired. Due to limited earthen pond space and a lack of minnow forage, the PFBC raises most of their muskellunge and tiger muskellunge intensively in tanks and raceways, and on an artificial diet (Bender and Graff 1986). However, in recent years new artificial feeds and culture techniques have greatly improved the ability of PFBC hatcheries to raise purebred muskellunge and this is now allowing culture of greater numbers of purebreds (L. Hines, PFBC, personal communication 2011). There are several waters in the Commonwealth receiving both purebred and tiger muskellunge. In these waters where habitat characteristics favor both types of muskellunge, the goal is often to provide improved muskellunge densities for increased angler success. This is accomplished by using tiger muskellunge coupled with a lower density population of purebred muskellunge, which typically reaches the desired trophy lengths. Tiger muskellunge are also frequently stocked in reservoirs outside of the native range of muskellunge in Pennsylvania.

For about 40 years (*circa* 1970's), the PFBC has experimented with stockings of muskellunge and tiger muskellunge in several lakes and flowing waters. At that time, the management philosophy was to diversify the fishery along with adding a trophy component, but not necessarily to create a directed muskellunge fishery. Subsequent sampling on many waters found that the stocking results often did not yield survival sufficient to warrant continuation of stocking, especially on many smaller waters. This was especially evident in the early history of the statewide program when fry-sized muskellunge and tiger muskellunge were often stocked. However, in the early 1980's, poor fry survival compared to fingerlings, led to the discontinuation of stocking fry (Table 1), and in recent years, yearling-sized fish have been stocked. Spring-stocked yearling muskellunge have been experimentally stocked in three lakes since 2002. In 2011, a total of 206,017 muskellunge (125,363 purebred muskellunge and 80,654 tiger muskellunge) were stocked into the waters of the Commonwealth.

Table 1. Stocking history of purebred muskellunge and tiger muskellunge in Pennsylvania from 1953 to present (2011).

	Muskellunge				Tiger Muskellunge				
Year	Fry	Fingerling	Yearling	Total	Fry	Fingerling	Yearling	Total	Cumulative Total
1953	5000	249	0	5251	0	0	0	0	5251
1954	10000	591	0	10666	0	0	0	0	10666
1955	20000	537	0	20599	0	0	0	0	20599
1956	0	3970	0	3992	0	0	0	0	3992
1957	0	3860	0	3869	0	0	0	0	3869
1958	10000	7565	0	17595	0	0	0	0	17595
1959	0	13619	0	13647	0	0	0	0	13647
1960	0	19904	0	19927	0	0	0	0	19927
1961	0	10770	0	10770	0	0	0	0	10770
1962	10000	23199	0	33214	0	0	0	0	33214
1963	341000	31012	0	372014	0	0	0	0	372014
1964	495000	65361	0	560361	0	0	0	0	560361
1965	454500	83600	0	538100	0	10512	0	10512	548612
1966	351500	59481	0	410981	0	10000	0	10000	420981
1967	465000	3776	0	468776	0	71	0	71	468847
1968	1057000	35418	0	1089594	0	10042	0	10042	1099636
1969	3800	48082	0	44029	0	6580	0	6580	50609
1970	310000	49300	0	358362	22000	1450	0	23450	381812
1971	635000	57362	0	692371	316000	800	0	316800	1009171
1972	477000	80764	0	557764	0	3988	0	3988	561752
1973	516000	55390	0	571396	181500	13795	0	195295	766691
1974	499000	90428	0	589428	523000	81264	0	604264	1193692
1975	365500	47480	0	412980	71000	92507	0	163507	576487
1976	0	45611	0	45611	0	63110	0	63110	108721
1977	0	28089	0	28089	0	105346	0	105346	133435
1978	0	112015	0	112015	0	162392	0	162392	274407
1979	0	98237	0	98237	0	93835	0	93842	192079
1980	0	73228	0	73228	410000	80870	0	490874	564102
1981	210000	44477	0	254477	0	108875	0	108875	363352
1982	58700	77392	0	136092	0	61340	0	61340	197432
1983	0	57000	0	57000	0	103951	0	103954	160954
1984	0	83950	0	83950	0	116128	0	116128	200078
1985	0	64375	0	64375	0	141950	0	141950	206325
1986	0	91271	0	91271	0	112115	0	112115	203386
1987	0	69563	0	69563	0	94505	0	94505	164068
1988	0	101058	0	101058	0	85376	0	85376	186434
1989	0	89460	0	89460	0	121270	0	121270	210730
1990	0	89117	0	89117	0	98190	0	98190	187307
1991	0	52171	0	52171	0	96002	0	96002	148173
1992	0	151382	0	151382	0	150209	0	150209	301591
1993	0	139403	0	139403	0	98175	0	98185	237588
1994	0	137985	0	137985	0	129105	0	129105	267090
1995	0	163901	0	163901	0	157204	0	157204	321105
1996	0	122905	0	122905	0	97550	0	97550	220455
1997	0	88045	0	88045	0	81775	0	81775	169820
1998	0	108670	0	108670	0	141500	0	141500	250170
1999	0	164043	0	164043	0	76525	0	76525	240568
2000	0	127130	0	127167	0	63455	0	63455	190622
2001	0	111938	0	111938	0	84275	0	84275	196213
2002	0	122938	1308	124246	0	73475	0	73475	197721
2003	0	78719	1465	80184	0	87513	0	87513	167697
2004	0	122392	1603	123995	0	80476	0	80476	204471
2005	0	99878	2062	101940	0	79369	0	79369	181309

2006	0	111379	2865	114244	0	91993	0	91993	206237
2007	0	104247	2525	106772	0	95374	7400	102774	209546
2008	0	144377	1665	146042	0	108711	0	108711	254753
2009	0	107756	3505	111261	0	110621	0	110621	221882
2010	0	149348	1518	150866	0	66621	5200	71821	222687
2011	54000	69728	1635	125363	0	80654	0	80654	206017

Propagation costs can also play a role in stocking rates and strategies. In 2010, the average cost per stocked esocid fingerling was calculated at $4.76 (C. Vargason, PFBC, personal communication 2012). This gives an estimated production cost for the esocid program in 2011 of at least $723,601. These costs represent a substantial investment in the muskellunge program and require close evaluation to ensure judicious support of angler needs statewide.

Current Muskellunge Resources

In 2010 and 2011, a total of 46 lakes and impoundments totaling 25,890 ha (63,948 acres) were stocked with purebred muskellunge and/or tiger muskellunge (Figure 1). Some waters were stocked with one species; some annually with both species; and some on alternate years with both species. Some 31 waters were stocked with muskellunge (Table 2) and 24 waters stocked with tiger muskellunge (Table 3). The areas of stocked muskellunge and/or tiger muskellunge, grouped by resource category (i.e., impoundment size), includes 24,220 ha (59,823 acres) in large reservoirs (≥202 ha; ≥500 acres); 1,647 ha (4,068 acres) in medium reservoirs (≥20 ha - <202 ha; ≥50 - <500 acres) and 23 ha (57 acres) in small reservoirs (<20ha; <50 acres; Table 2 and Table 3). Purebred muskellunge and/or tiger muskellunge were stocked in 1,633 km (1,012 miles) of flowing water. Some waters were stocked with one species; some on alternate years with both species or annually with both. Fish were allocated to some 10 major rivers (41 sections), 13 small rivers (20 sections) and tiger muskellunge were stocked into 16 sections of 10 rivers (Tables 4 & 5). For muskellunge, 36 major river sections, 12 small river sections, and two warmwater stream sections were stocked (Table 4). For tiger muskellunge, 7 major river sections and 11 small river sections were stocked (Table 5). Grouped by resource category (i.e., drainage area) for flowing waters, purebred and/or tiger muskellunge were stocked in 1,077 km (668 mi) of major rivers (drainage ≥579 sq km; ≥1500 square miles), 506 km (314 mi) in small rivers (drainage <579 - ≥96.5 sq km; <1500 - ≥250 square mile) and 50 km (31 mi) in warmwater streams (drainage <96.5 sq km; <250 square miles). Muskellunge and tiger

muskellunge are managed almost exclusively in the medium-to-large waters, whether standing or flowing and this strategy is consistent with the habitat needs of these species.

Since 2006 change has characterized the stocking program to meet new program goals as described herein. This goal change has led to removal of some waters historically stocked and increased stocking rates on waters or water sections where such change could be accommodated. In addition, stocked fish condition has been elevated in conjunction with new diets (C. Vargason, 2012 personal communication). In all, some 48 waters or water sections have been removed from the program, and fingerling stocking rate has increased significantly (+17.5%) on the most popular resource category of large reservoirs. Changes in stocking rates in other resource category may occur to meet new program goal criteria set forth in this plan.

Table 2. Lakes managed and stocked with purebred muskellunge as of 2010 with resource category.

Area	Lake Name	SubSub basin[1]	Area (ha)	Resource Category	Notes
2	Allegheny Reservoir	16B	4,891	Large	Steep sided reservoir, cannot trap net effectively
5	Belmont Lake	1B	70	Medium	Broodstock Lake
5	Beltzville Lake	2B	383	Large	
7	Canoe Creek Lake	11A	63	Medium	
2	Conneaut Lake	16D	376	Large	Broodstock Lake
4	Cowanesque Lake	4A	441	Large	Stocked with purebreds and tigers
2	Edinboro Lake	16A	97	Medium	Fall fingerling vs. spring yearling water, Broodstock Lake
4	Francis Slocum Lake	5B	67	Medium	
3	Glendale Lake	8C	648	Large	
6	Kaercher Creek Dam	3B	13	Small	Stocked with purebreds and tigers
1	Lake Arthur	20C	1,305	Large	
2	Lake Canadohta	16E	69	Medium	Fall fingerling vs. spring yearling water, Broodstock Lake
6	Lake Marburg	7H	516	Large	Purebreds first stocked in 1996
8	Lake Somerset	19F	102	Medium	Alternate year stockings of purebred and tigers
2	Lake Wilhelm	16G	704	Large	
2	Leboeuf Lake	16A	28	Medium	Broodstock Lake
8	Loyalhanna Lake	18C	194	Medium	Stocked with purebreds and tigers
6	Marsh Creek Lake	3H	217	Large	Collaborative Musky Club fish source; PFBC approved source
1	Presque Isle Bay	15A	1,337	Large	
5	Prompton Lake	1B	113	Medium	Purebreds first stocked in 1992
1	Pymatuning Reservoir	20A	5,636	Large	
7	Raystown Lake	11D	3,359	Large	Stocked with purebreds and tigers
3	Rose Valley Lake	10B	157	Medium	Stocking discontinued in 2012
1	Shenango River Lake	20A	1,441	Large	
2	Sugar Lake	16D	36	Medium	Broodstock Lake
2	Tamarack Lake	16D	228	Large	Broodstock Lake
2	Tionesta Lake	16F	231	Large	Fall fingerling vs. spring yearling water
6	Tuscarora Lake	3A	39	Medium	Stocked with purebreds and tigers
2	Two Mile Run Reservoir	16E	58	Medium	Alternate year stocking of purebreds and tigers
2	Union City Reservoir	16A	10	Small	Broodstock Lake
2	Woodcock Creek Lake	16A	132	Medium	Broodstock Lake

[1] See Figure 2 for Sub-Sub basin location detail

Table 3. Lakes managed and stocked with tiger muskellunge as of 2010 with resource category.

Area	Lake Name	Subsub basin[1]	Area (ha)	Resource Category	Notes
6	Blue Marsh Lake	3C	466	Large	
8	Bridgeport Reservoir	19D	28	Medium	
6	Chambers Lake	3H	36	Medium	
4	Cowanesque Lake	4A	441	Large	Tigers and purebreds stocked
3	Curwensville Lake	8B	320	Large	
2	East Branch Clarion River Lake	17A	470	Large	Steep sided reservoir, cannot trap net effectively
6	Falls Township Park Lake	2E	27	Medium	
4	Ford Lake	4G	30	Medium	
6	Kaercher Creek Dam	3B	13	Small	Tigers and purebreds stocked
2	Keystone Lake	17E	385	Large	
8	Keystone Lake	18C	32	Medium	
4	Lackawanna Lake	4F	80	Medium	
6	Lake Marburg	7H	516	Large	Tigers and purebreds stocked
8	Lake Somerset	19F	102	Medium	Tigers and purebreds stocked alternate years
7	Little Buffalo Lake	12B	36	Medium	
8	Loyalhanna Lake	18C	194	Medium	Tigers and purebreds stocked
2	Mahoning Creek Lake	17D	113	Medium	Steep sided reservoir, cannot trap net effectively
6	Marsh Creek Lake	3H	217	Large	
6	Nockamixon Lake	2D	587	Large	
2	Piney Reservoir	17B	279	Large	Tigers first stocked 1995, cannot trap net effectively
7	Raystown Lake	11D	3,359	Large	Tiger and purebreds stocked alternate years
7	Sweet Arrow Lake	7D	40	Medium	
6	Tuscarora Lake	3A	39	Medium	Tigers and purebreds stocked
2	Two Mile Run Reservoir	16E	58	Medium	Tiger and purebreds stocked alternate years

[1] See Figure 2 for Sub-Sub basin location detail

Table 4. Flowing waters managed and stocked with purebred muskellunge as of 2010 with resource category.

Area	Stream Name	Sec	Subsub basin[1]	Length (Km)	Resource Category	Notes
2	Allegheny River	6	16C	39.7	Small River	
2	Allegheny River	7	16B	14.1	Major River	
2	Allegheny River	8	16B	12.0	Major River	
2	Allegheny River	9	16F	47.3	Major River	
2	Allegheny River	10	16E	33.0	Major River	
2	Allegheny River	11	16E	12.0	Major River	
2	Allegheny River	12	16G	53.5	Major River	
2	Allegheny River	13	17C	31.5	Major River	
2	Allegheny River	14	17C	11.7	Major River	
2	Allegheny River	15	17D	15.4	Major River	
2	Allegheny River	16	17E	11.0	Major River	
2	Allegheny River	17	17E	15.07	Major River	
8	Allegheny River	19	18A	10.1	Major River	
8	Allegheny River	20	18A	15.6	Major River	
8	Allegheny River	21	18A	12.5	Major River	
1	Conneaut Creek	3	15A	31.6	Lake Erie Trib	Would fit the WW Stream Resource Class
2	Cussewago Creek	2	16D	18.1	WW Stream	
5	Delaware River	5	1D	65.21	Major River	
5	Delaware River	6	1F	41.6	Major River	
6	Delaware River	7	2D	42.7	Major River	
2	French Creek	3	16A	12.6	Small River	
2	French Creek	4	16A	45.6	Small River	
2	French Creek	5	16D	10.4	Small River	
2	French Creek	6	16D	49.9	Small River	
7	Juniata River	2	11B	11.7	Major River	
7	Juniata River	3	12C	19.64	Major River	
7	Juniata River	4	12A	52.33	Major River	
7	Juniata River	7	12B	13.2	Major River	
5	Lehigh River	9	2C	38.6	Small River	

[1] See Figure 2 for Sub-Sub basin location detail

Table 4 (continued). Flowing waters managed and stocked with purebred muskellunge as of 2010 with resource category.

Area	Stream Name	Sec	Subsub basin[1]	Length (km)	Resource Category	Notes
2	Mahoning Creek	4	17D	29.9	Small River	
8	Monongahela River	2	19C	33.5	Major River	
4	North Branch Susquehanna River	1	4E	7.86	Major River	
4	North Branch Susquehanna River	2	4E	17.23	Major River	
4	North Branch Susquehanna River	3	4B	26.73	Major River	
4	North Branch Susquehanna River	4	4C	7.08	Major River	
4	North Branch Susquehanna River	5	4D	59.6	Major River	
4	North Branch Susquehanna River	6	4G	58.2	Major River	
4	North Branch Susquehanna River	7	5A	3.4	Major River	
4	North Branch Susquehanna River	8	5B	47.5	Major River	
4	North Branch Susquehanna River	9	5D	31.0	Major River	
4	North Branch Susquehanna River	10	5E	35.3	Major River	
6	Schuylkill River (Auburn Dam pool)	2	3F	4.0	Small River	Collaborative Musky Club fish source; PFBC approved source
6	Schuylkill River	6	3F	8.2	Small River	
6	Schuylkill River	7	3C	21.3	Small River	
6	Schuylkill River	11	3F	6.8	Small River	
7	Susquehanna River	1	6B	2.1	Major River	
7	Susquehanna River	3	7C	39.6	Major River	
7	Susquehanna River	5	7G	23.0	Major River	
2	Tionesta Creek	4	16F	1.4	Small River	
8	Youghiogheny River	6	19E	74.4	Major River	

[1] See Figure 2 for Sub-Sub basin location detail

Table 5. Flowing waters managed and stocked with tiger muskellunge as of 2010 with resource category.

Area	Stream Name	Sec	Subsub basin[1]	Length (km)	Resource Category	Notes
1	Beaver River	2	20B	20.3	Major River	
6	Conestoga River	2	7J	14.6	Small River	
1	Connoquenessing Creek	7	20C	8.6	Small River	
7	Conodoguinet Creek	5	7B	60.6	Small River	
8	Monongahela River	2	19C	33.5	Major River	
6	Ohio River	3	20G	29.6	Major River	
7	Raystown Branch Juniata River	5	11C	9.77	Small River	
7	Raystown Branch Juniata River	8	11D	43.21	Small River	
6	Schuylkill River	5	3F	21.5	Small River	
6	Schuylkill River	6	3F	8.2	Small River	
6	Schuylkill River	7	3C	21.3	Small River	
6	Schuylkill River	11	3F	6.8	Small River	
6	Schuylkill River	13	3F	5.3	Major River	
6	Schuylkill River	14	3F	7.9	Major River	
1	Shenango River	5	20A	54.4	Small River	
7	Susquehanna River	4	7D	6.1	Major River	
6	Susquehanna River	5	7G	23	Major River	
7	Swatara Creek	5	7D	25.2	Small River	

[1] See Figure 2 for Sub-Sub basin location detail

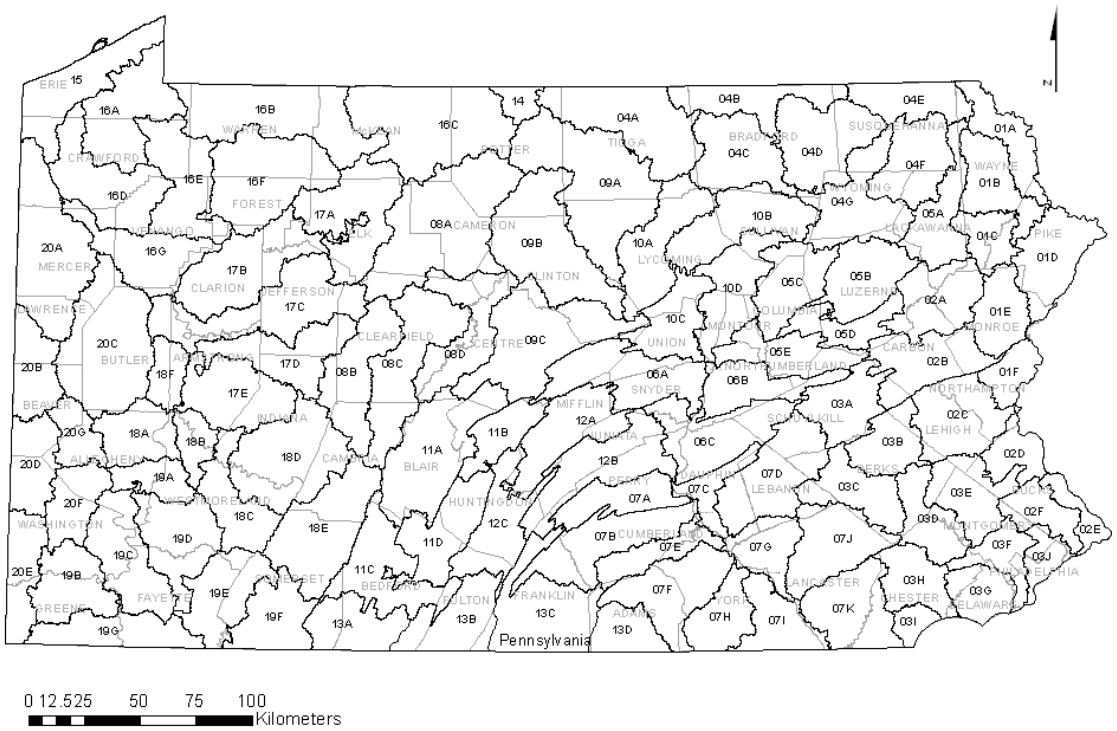

Figure 2. Map depicting sub sub basin watershed locations listed in management and stocking tables 2 through 5 above.

Within its native range, the greatest number of waters managed for muskellunge are in northwest Pennsylvania. Currently, the only water in Pennsylvania managed for muskellunge solely through natural reproduction, outside of the native range, is Section 06 of the West Branch Susquehanna River (J. Detar, PFBC, personal communication 2011). Other waters within the native range of muskellunge in Pennsylvania yield naturally produced young; however, natural production in those waters has been determined to be insufficient to sustain fishing. Precise quantification of natural muskellunge recruitment has only recently been undertaken, and identification of naturally produced young may broaden as survey work broadens through this plan. Generally, opportunity for incidental capture of naturally produced young through existing sampling programs in Pennsylvania is only fair. In naturally sustained populations outside of Pennsylvania, recruitment levels have been related to biotic and abiotic habitat characteristics (Rust et al. 2002). However muskellunge habitat use and requirements have been primarily or exclusively studied in lakes (reviewed by Rust et al. 2002), and broad application of known important characteristics to other waters (reservoirs and rivers), sufficient to guide effective habitat restoration or identification and sustainable recruitment, is limited. Habitat needs or habitat identification should be quantified to guide restoration or preserve its availability. Such quantification is best addressed through water-specific management plans, with stocking or restoration goals set based upon habitat availability and opportunity to restore or rehabilitate essential habitats.

Muskellunge tend to congregate in the tailwaters of stocked impoundments and occasionally stray from the waters where they are stocked, thus providing fishing opportunities in adjacent unstocked waters. This is evidenced from catches of muskellunge in surveys of these waters and from anecdotal reports of catches from anglers. Success in catching muskellunge in these tailwater areas can be attributable to confinement of fish to a smaller area compared to the adjoining lake. Often, muskellunge will travel upstream out of impoundments and provide fishing opportunities if these upstream waters are larger, warmwater creeks and rivers. Documenting spawning or natural recruitment in these upstream habitats may be important to protecting available natural spawning and nursery areas.

Muskellunge Stocking Rates and Procedures

For purebred muskellunge, the current base stocking rate is one per acre for most waters, with up to four supplemental stockings of one per acre. Broodstock waters have a base stocking rate of 10 per acre (Lorantas 2010). The recommended base stocking rate for tiger muskellunge is five per acre with supplemental stockings of two per acre, up to a maximum of 10 per acre. Substantial flexibility in formulating stocking rates have been afforded to managers to meet management goals identified in individual water specific management plans. The stocking rates in these plans should be tailored to available habitats. Supplemental stockings are conducted after all statewide waters have been stocked with their base request. The objective in stocking is to achieve a population density of 0.5 – 1.0 fish per acre of adult fish (>30 inches) after four years (Lorantas 2010).

Historically, many muskellunge waters were stocked on an alternate year schedule (Hoopes and Cooper 1984), but beginning in 2005, most waters have been stocked on an annual basis to provide more consistent recruitment. Also, in recent years, the availability of stocked muskellunge fingerlings from PFBC hatcheries has improved, allowing for annual stockings of all muskellunge-managed waters. Waters are prioritized to assure those waters most in need of stocking will have the highest likelihood of receiving fish if a shortfall in production occurs.

Survival of Stocked Muskellunge Fingerlings

The size of stocked fingerlings has been identified as a primary factor in survival following stocking (Stein *et al*. 1981; Hanson *et al*. 1986; Johnson and Margenau 1993; McKeown *et al*. 1999; Szendrey and Wahl 1996; Wahl 1999) and predation is a common source of mortality in stocked muskellunge (Kerr and Lasenby 2001). Fingerlings are more likely to survive predation in the first 7-to-30 days following stocking if they are at least 200 mm (Wahl 1999). Szendrey and Wahl (1996) reported that fingerlings stocked at 250 mm were two-to-three times more likely to survive compared to fingerlings stocked at 200 mm. However, Serns and Andrews (1986) reported that smaller fingerlings can contribute to the sport fishery when stocked in waters with low predator densities. In Pennsylvania, muskellunge are stocked primarily as fall fingerlings (Lorantas *et al*. 2005) and the length of fish at time of stocking depends upon the rearing conditions at each of the hatcheries. Historically, the length of stocked purebred

muskellunge fall fingerlings ranges from 150-200 mm (6 to 8 inches) and efforts are being made to grow and stock larger fingerlings.

Experimental stocking of spring yearlings versus fall fingerlings is currently being evaluated in three lakes in northwestern Pennsylvania. Spring yearlings are bigger at the time of stocking and it is hypothesized that their survival would be greater compared to fall fingerlings in presence of a dense predator population based upon the previously presented literature review. Spring yearlings are raised in the same manner as fall fingerlings and then are placed in outside earthen ponds or concrete raceways with sufficient minnow forage to overwinter, for subsequent stocking in spring. A vital feature for evaluating temporal components to stocking, such as differentiating spring yearlings from fall fingerlings, is developing a reliable method for marking and distinguishing fish. Fin clipping stocked fingerlings and yearlings has proven ineffective due to regeneration of fins several years after stocking. Thus, by the time fish become vulnerable to trap net sampling, the fin clips are difficult to identify. McNeil and Crossman (1979) also reported muskellunge regenerated clipped fins in multi-year studies and recommended they not be used in studies lasting more than one year. The reliability of coded wire tagging is now being evaluated as a method for differentiating fall fingerlings from spring yearlings. (See Appendix A for a further description of this experiment.)

IV. Regulation History and Recent Changes

Regulation History and Rationale

For the latter half of the 20th century and into the 21st century, the Commonwealth Inland Waters regulations for muskellunge consisted of a 30-inch minimum size limit, two-per-day creel limit, and a closed season during the spawning season from April 1 until the first Saturday in May. Historically, minimum size regulations have been used to protect juvenile fish up to maturity (Kohler and Hubert 1993). This was based on the management approach of maximum sustained yield where regulations were to provide the largest allowable average catch that the environment would sustain without diminishing the fishery (Ricker 1975). Based on the life-history of muskellunge, the 30-inch minimum size that has been part of the Commonwealth regulations would theoretically allow at least one year of spawning before the species would became vulnerable to harvest.

In addition to using the size of fish to control populations, creel limits are intended to equitably divide the harvest among anglers (Kohler and Hubert 1993). The creel limit of two-per-day for muskellunge allowed a liberal harvest of this low-density top predator. However, for many years during this period, the perceived difficulty in catching muskellunge lead fisheries managers to assume harvest was not shaping population size structure or abundance.

Through the 1980's and 1990's perceptions of both anglers and fisheries managers began to change about the concept of a quality muskellunge fishing experience. The angler's idea of what constituted a trophy size muskellunge evolved to a larger size fish (Margenau and Petchenik 2004). Anglers specifically targeting and specializing in fishing for muskellunge were no longer satisfied with low catch rates that had previously been the norm. Additionally, gear and tactics were becoming more refined and anglers were becoming more successful in exploiting muskellunge fisheries. Responding to these changing perceptions and trends in catch and harvest success, a growing percentage of muskellunge anglers were moving toward voluntary catch-and-release practices with the expectation of sustaining and improving muskellunge fishing. Fisheries managers were also recognizing that harvest by anglers, not necessarily specialists, was affecting both abundance and size structure of muskellunge populations.

Changing Management Strategies and Regulations in 2005-2006

In 2005, the PFBC began a review of regulations, both through internal discussions and by involving the muskellunge angling community. The feedback from anglers came from two sources, a muskellunge angler website survey and the Muskellunge Management Work Group (Lorantas *et al*. 2005). The website survey asked anglers to rate the quality of muskellunge fisheries in individual waters and the potential to improve these fisheries. The Muskellunge Management Work Group was made up of concerned anglers from several sportsmen groups including Muskies Inc., Pennsylvania Federation of Sportsmen's Clubs, Unified Sportsmen of Pennsylvania, Pennsylvania Bass Federation and PFBC staff. This mix of participants was intended to provide a diverse perspective among avid musky anglers, avid bass anglers, and more generalized Pennsylvania anglers. The work group met twice in the fall of 2005 with the goal of strategically enhancing muskellunge fishing through advanced fish culture methods, education,

and harvest management in the context of habitat potential (Lorantas *et al*. 2005). Results of these interactions, coupled with simulation work using a dynamic pool model, provided options for the Commission to consider for possible changes in management and regulations (Lorantas *et al*. 2005).

From these efforts, in 2006, the PFBC modified 58 Pa. Code §61.1, Commonwealth Inland Waters seasons, sizes and creel limit regulations for muskellunge. Regulations governing harvest became more restrictive with an increase in the minimum length limit from 30 to 40 inches and a reduction in the daily creel limit from two to one fish per day. However, regulations governing seasons were liberalized to allow for year-round fishing of muskellunge with no closed season, except for broodstock lakes where muskellunge continued to be protected from April 1 until May 31 under catch-and-release only regulations. The decision to allow for year-round fishing was based on use of stocked fish, rather than natural reproduction, to build the populations and support the muskellunge fishery in these managed waters. Consequently, there was no biological reason to close the season during the spawning period. These changes in regulations became effective in January, 2007. After implementation of these regulations, avid muskellunge anglers reported limited success during the spawning period, suggesting angling impact on spawning fish may be negligible. The higher size limit enhances opportunity for natural recruitment regardless of relaxed seasonal restrictions.

Additionally, under 58 Pa. Code §65.16 special regulations, the Commission created a special regulation called the Enhanced Muskellunge Program. This program allows for a minimum size limit of 45 inches and a one fish per day creel limit on select muskellunge managed waters. Waters managed in this program must have the potential to support increased muskellunge abundance and an improved size distribution, without a reduction in growth rates. At this time, no waters have been recommended for inclusion in this program pending an assessment of the recent increase in the minimum size limit from 30 to 40 inches.

The Muskellunge Management Work Group also recommended that the PFBC change its philosophical approach to muskellunge management. Specifically, it was recommended that the PFBC muskellunge management move towards creating high-quality fisheries where anglers

wishing to target muskellunge can expect a reasonable opportunity to catch muskellunge and move away from developing low-density populations that create an opportunity for a "once in a lifetime" catch. This philosophy requires fisheries managers to remove waters not suitable to this management objective from the stocking program (Lorantas *et al*. 2005). Subsequently, the hatchery-reared muskellunge previously placed in these less suitable waters would be available to increase stocking rates on waters, where increased survival and density could be safely increased.

A full account and results of the Muskellunge Management Work Group meetings and the results from the online web site questionnaire are provided by Lorantas *et al*. (2005).

V. Review and Analysis of Historical Muskellunge Catch Data

To document the condition of the fisheries, and to develop sound fisheries management plans, the Fisheries Management Division periodically surveys lakes and rivers (Hoopes 1989). Muskellunge populations are routinely assessed during these inventories and the data collected are entered into the agency resource database. This statewide muskellunge management plan relied upon a 30-year (1977 to 2007) biological assessment dataset for muskellunge and/or tiger muskellunge. Data retrieved from the agency resource database included: catch per unit effort, length frequency, age, growth, relative weight and other parameters and included catches from all gear types used on these waters. Data were used from sites where muskellunge were consistently recorded when caught, even if they were not the primary target of the survey. A zero catch was only included in the analysis when a sampling gear was deployed and muskellunge were a target species, but none were captured during that sampling event.

Several authors have emphasized that adult muskellunge occur at naturally low densities in most waters, confounding sampling and biological interpretation of results (Hanson 1986; Graff 1986; Cornelius and Margenau 1999; Bozek *et al*. 1999; Casselman *et al*. 1999; Margenau and AveLallemant 2000). In Pennsylvania, a review of historical catch data is congruent with these other findings and highlights the rarity of catching muskellunge, as well as the difficulty of sampling this naturally low-density top predator. For example, of approximately[1] 3,778 trap net sites sampled on lakes from 1977 to 2007, a total of 2,956 (78%) reported a zero catch for

muskellunge illustrating the low probability of capturing these fish. When including only lakes where muskellunge are currently managed and surveys were conducted during March, April and May, the number of trap net sites with zero catch was reduced slightly to 73%. ([1]-The number of sites sampled is considered approximate because data for the first few years of trap net data were entered as a single combined catch for several sites sampled lake wide).

Catch by Habitat, Gear Type and Gear Selectivity

Catch-by- Habitat: It is important to emphasize the rarity of collecting muskellunge. A low overall number (4,670) of muskellunge were collected during the 30-year period encompassed by this dataset (Table 6). By comparison, for example, during a similar period over 98,000 walleye were collected (T. Wilson, PFBC, personal communication 2011). These numbers also demonstrate distinct differences in the number of fish collected within major habitats (Table 6) with only 7% of the total catch of purebred muskellunge and 14% of the total catch of tiger muskellunge derived from flowing waters. These figures highlight the paucity of muskellunge catch data from flowing waters and point to a need for future sampling of flowing waters to improve our understanding of muskellunge populations in these habitats.

Table 6. Distribution of Pure and Tiger Muskellunge, by major habitat type, collected from 1977-2007.

	Lakes	**Rivers**	**Total**
Purebred Muskellunge	2685	196	2881
Tiger Muskellunge	1542	247	1789
Total	4227	443	4670

Catch-by-gear type: Similarly, a review of catch-by-gear type revealed that purebred muskellunge (Table 7) were predominantly collected with a smaller range of gear types than tiger muskellunge (Table 8). For purebred muskellunge, Pennsylvania (PA) trap nets were the most effective method accounting for 89% of the total catch. The next highest catch-by-gear type of purebred muskellunge in lakes was observed using nighttime boat electrofishing, which accounted for 5% of the total catch. All gillnets combined, accounted for 4% of the purebred muskellunge catch in lakes (Table 7). By comparison, for tiger muskellunge, PA trap net

accounted for only 37% of the catch whereas boat electrofishing accounted for a total of 43% of the tiger muskellunge catch (nighttime boat electrofishing 25% and daytime boat electrofishing 18%). Gillnets accounted for 19% of the tiger muskellunge catch in lakes, while seining accounted for 2% (Table 7). This difference in catch-by-gear may be influenced more by the differences in types of impoundments where purebred and tiger muskellunge are stocked rather than vulnerability to a specific gear type. For example, tiger muskellunge are often placed into steep-sided impoundments that lack the shallow water habitat that PA trap nets require to effectively sample the fishery. Trap nets are the gear type most commonly used to sample muskellunge fisheries in Pennsylvania lakes and also represent the primary gear used in many out-of-state studies Haas (1978), Hanson (1986), Hoff and Serns (1986) and Siler and Beyerle (1986).

Table 7. Purebred muskellunge total catch in lakes by gear type for the period 1977 to 2007.

Pure Musky catch	Day Boat EF	Night Boat EF	PA Trap Net	Seine	Exp Gill Net 6 Panel	Exp Gill Net 5 Panel	Constant Mesh Gillnet Floating	Constant Mesh Gillnet Sinking	Rod & Reel	Gill Net	Exp Gillnet 6 Panel Floating	Total Catch
Total measured	33	144	2319	20	45	14	5	14	1	24	1	2620
Unmeasured		1	60	5								66
Grand Total	33	145	2379	25	45	14	5	14	1	24	1	2686
% of Total	1.2	5.4	88.6	0.9	1.7	0.5	0.2	0.5	0.04	0.9	0.04	
See **Appendix B** for a dataset listing of catch by length group by gear.												

Table 8. Tiger muskellunge total catch in lakes by gear type for the period 1977 to 2007.

Tiger musky catch	Day Boat EF	Night Boat EF	Back Pack EF	PA Trap Net	Conn Trap Net	Seine	Exp Gill Net 6 Panel	Exp Gill Net 5 Panel	Constant Mesh Gillnet Floating	Constant Mesh Gillnet Sinking	Gill Net	Total Catch
Total measured	277	378	4	564	3	24	126	19	63	52	30	1540
Unmeasured		3		1								4
Grand Total	277	381	4	565	3	24	126	19	63	52	30	1544
% of Total	17.9	24.7	0.26	36.6	0.19	1.6	8.2	1.2	4.1	3.4	1.9	
See **Appendix B** for a dataset listing of catch by length group by gear.												

In the size-groups most often caught, length-frequency of the total catch revealed an interesting disparity between purebred muskellunge (Figure 2) and tiger muskellunge (Figure 3). PFBC

sampling techniques appear to be less effective at capturing small, purebred muskellunge compared to tiger muskellunge. This may be due to size selectivity of the gear types used to sample muskellunge and the catchability of sampling gear in waters stocked with purebred muskellunge and tiger muskellunge, as discussed earlier. Surveys found 77% of the purebred muskellunge caught by nighttime boat electrofishing in lakes were <650 mm in total length (TL) and characterized as immature, but in PA trap nets only 4% of the catch was <650 mm TL. It is obvious that PA trap nets were the most efficient gear for sampling mature of legal size purebred muskellunge in lakes.

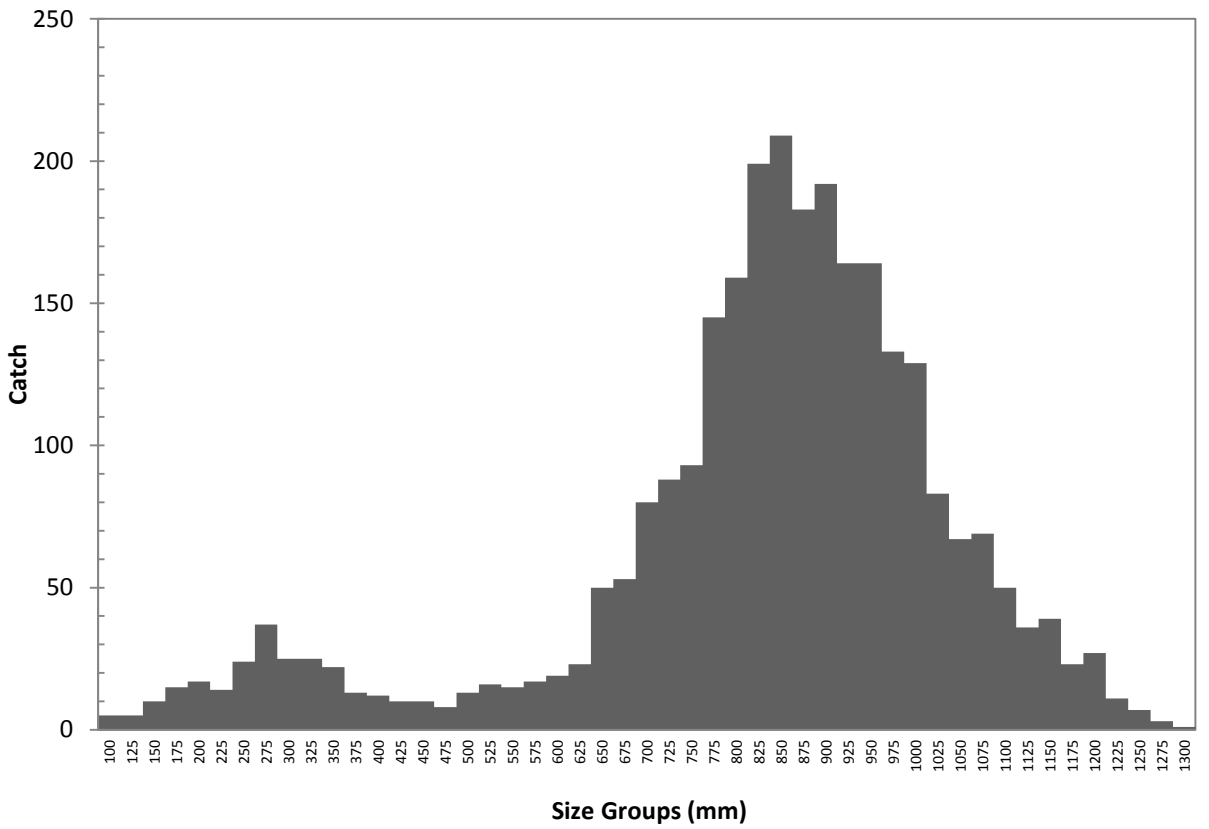

Figure 3. Catch of purebred muskellunge from spring trapnets in currently managed lakes 1977-2007.

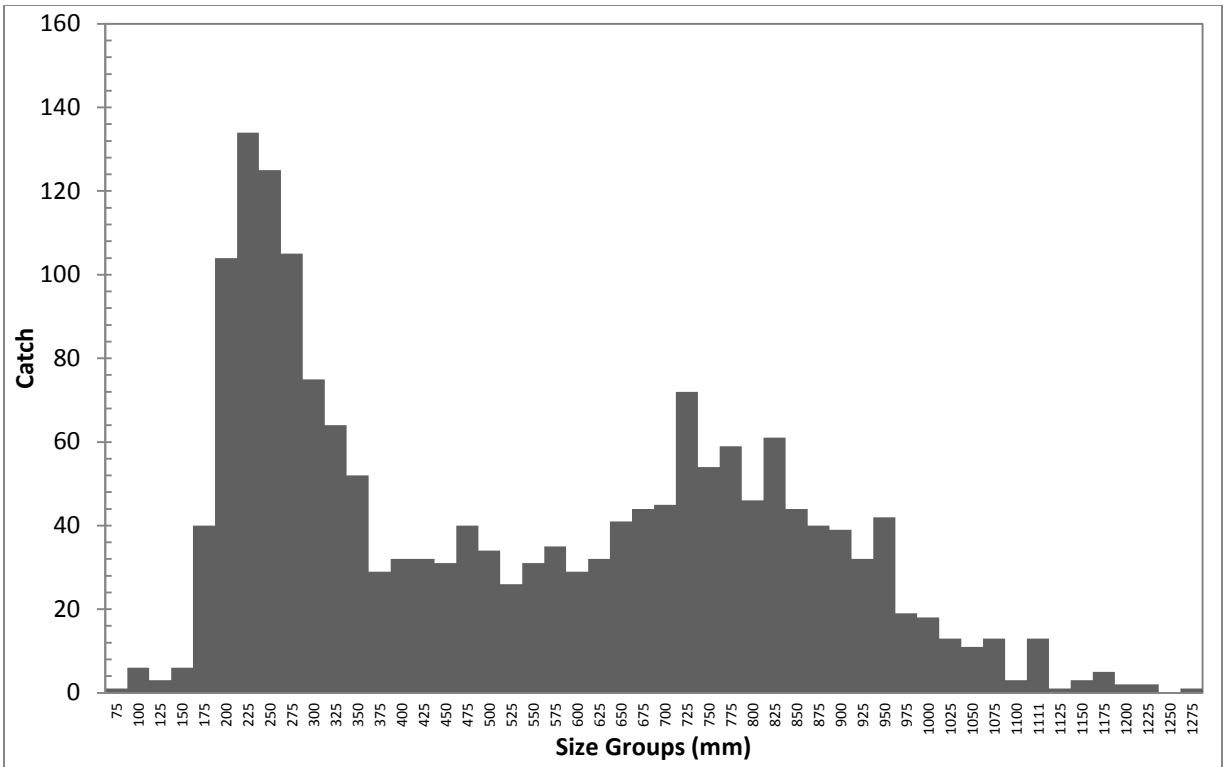

Figure 4. Length frequency of tiger muskellunge caught in all waters using all gear types from 1977 to 2007.

Gear size selectivity for tiger muskellunge was much less apparent. Nighttime boat electrofishing continued to be skewed toward immature tiger muskellunge with 86% of the catch <650 mm TL. However, PA trap nets sampled a much broader size spectrum of the tiger muskellunge population with 40% of the catch being <650 mm TL. Nevertheless, PA trap nets appear to be the logical gear for sampling mature tiger muskellunge in lakes where shallow water habitat is present. In steep-sided impoundments where PA trap nets would be ineffective, an alternate gear should be considered. When compared to PA trap nets, gillnets were the most effective gear for tiger muskellunge, but considerable mortality would be expected using this gear. Mortality of muskellunge captured in gill nets can be significantly reduced if the nets are closely monitored and not left unattended for more than a few hours before processing the catch.

Catch Per Unit Effort

Changes in regulation and stocking could contribute to increased total muskellunge abundance, especially on waters where stocking increases have occurred or harvest is common. This increase in total abundance would be expected to be reflected in Catch Per Unit Effort (CPUE); a

measure to compare relative abundance both among and within waters, and among years. CPUE may often be expressed as the "number of fish per unit of time".

For purebred muskellunge, the data for spring trap net catch-per-hour in lakes currently managed for muskellunge show a wide range of catch rates among lakes (Figure 4). The values represent the mean of all surveys conducted in each lake for which there was a reasonable expectation of capturing muskellunge. Some currently managed waters were not stocked with muskellunge until the 1990's so surveys conducted prior to that time were excluded. Also, spring trap net sampling was defined as occurring from March 1 through May 31.

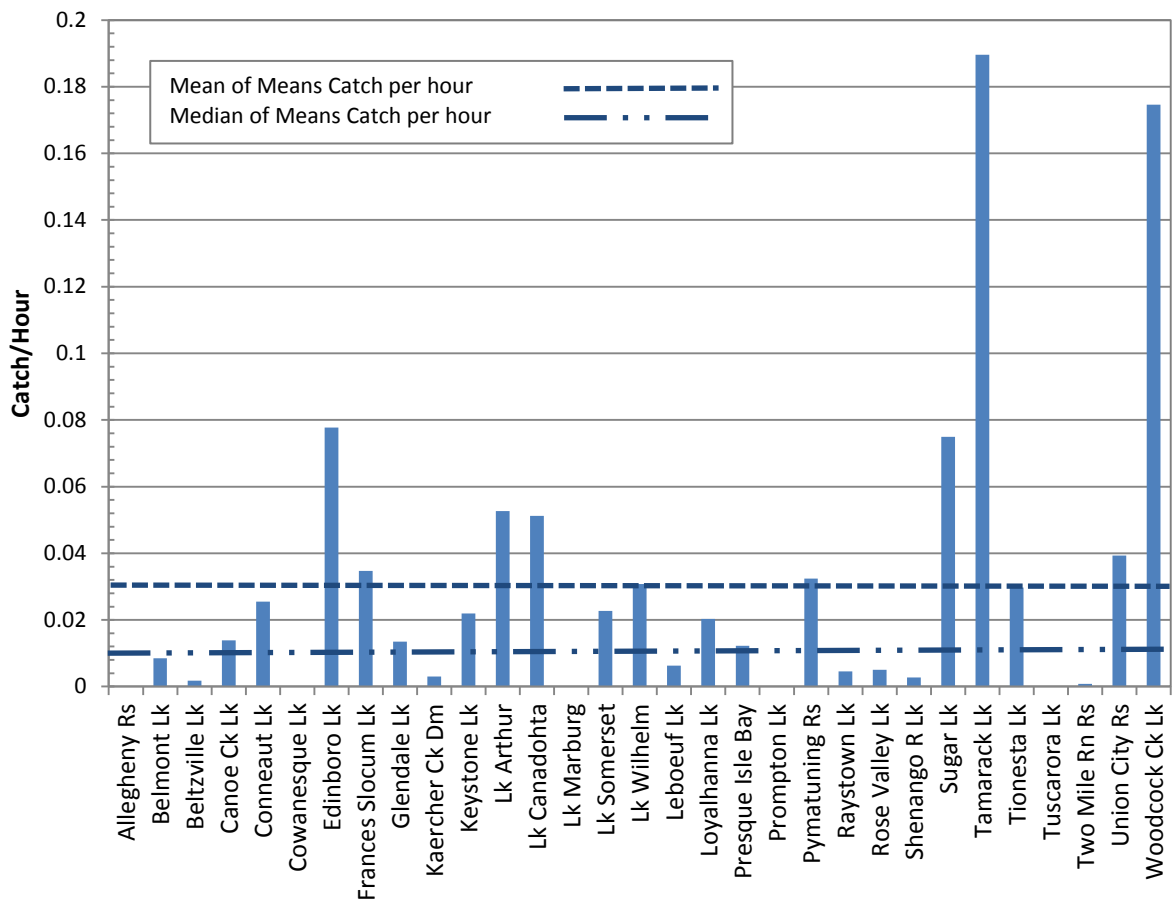

Figure 5. Mean catch-per-hour of purebred muskellunge from spring trapnets in currently managed lakes 1977-2007.

The mean of all the survey means for purebred muskellunge in lakes was 0.03066/hour or approximately three muskellunge caught for every (four) 24-hour trap net set. This mean value was inflated by the very high CPUE's obtained on Tamarack Lake and Woodcock Creek Lake (Figure 4). As a result, it was felt that the median value was more representative of the dataset. The median of the survey means was 0.01387/hour, or approximately one muskellunge captured for every four 24 hour trap net set. In reviewing the purebred muskellunge lakes sampled by PA trap nets, it is notable that some lakes with very low trap net CPUE rates were not well-suited for sampling by trap nets because of their steep-sided contour that lacked shallow water habitat. For these waters, alternative effective gear types were not employed, or the time to closely monitor gillnets was not available. The management philosophy of the time likely played into the lack of extensively focused sampling as muskellunge management targeted creating a low-density population and the opportunity to catch a fish of a lifetime. As such, concisely documenting population abundance was not a high priority.

Tiger muskellunge CPUE for spring trap nets in lakes had a much narrower range of mean catch per hour values (Figure 5). The mean catch was 0.01232/hour or one tiger muskellunge for every (four) 24-hour trap nets sites. Unlike the mean CPUE for purebred muskellunge, the mean and the median values were quite similar for tiger muskellunge with median CPUE of 0.01211/hour. Once again, it is noteworthy that several lakes with zero or very low CPUE values were not effectively sampled with trap nets.

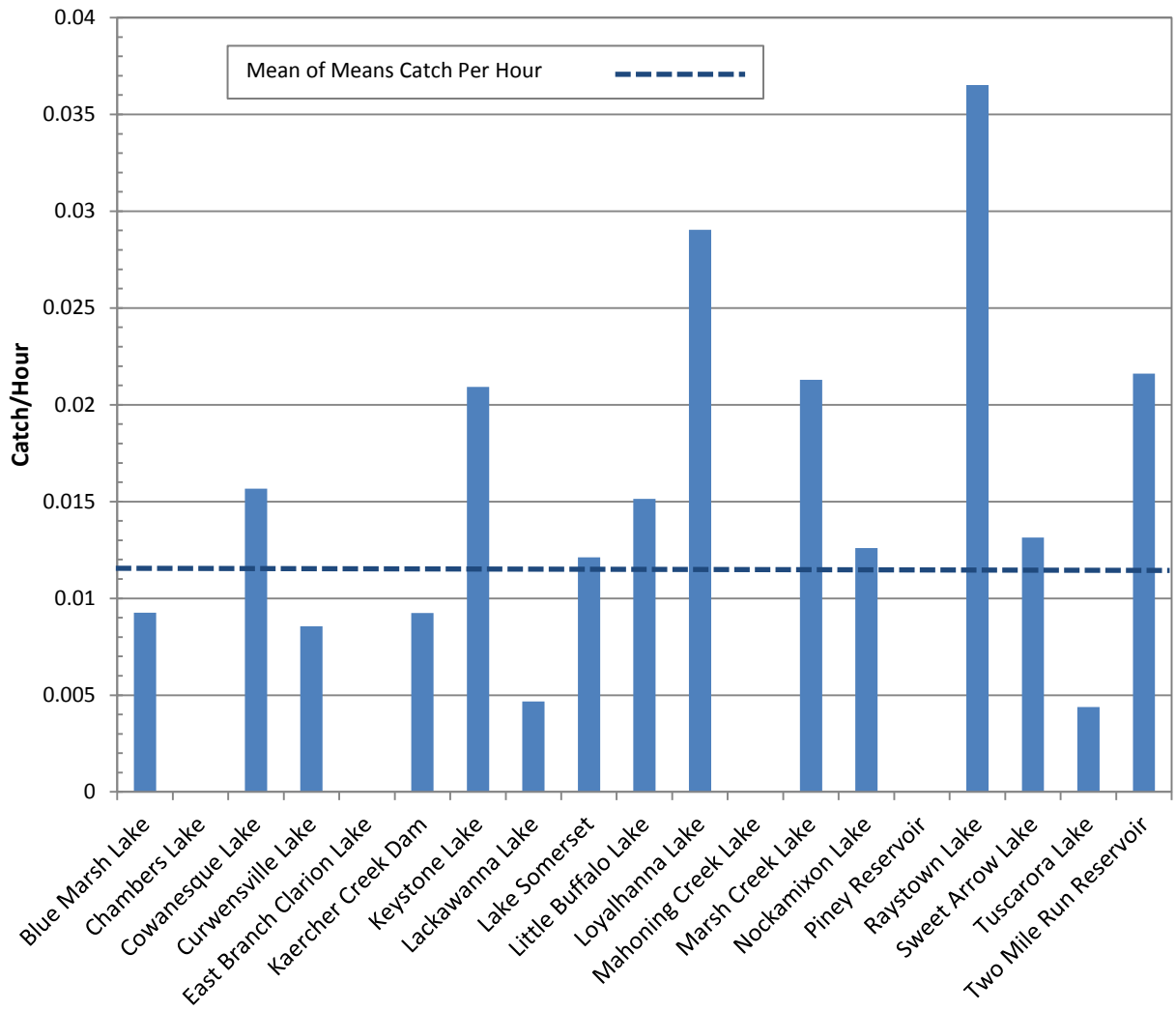

Figure 6. Mean catch-per-hour of tiger muskellunge from spring trapnets in currently managed lakes, 1977-2007.

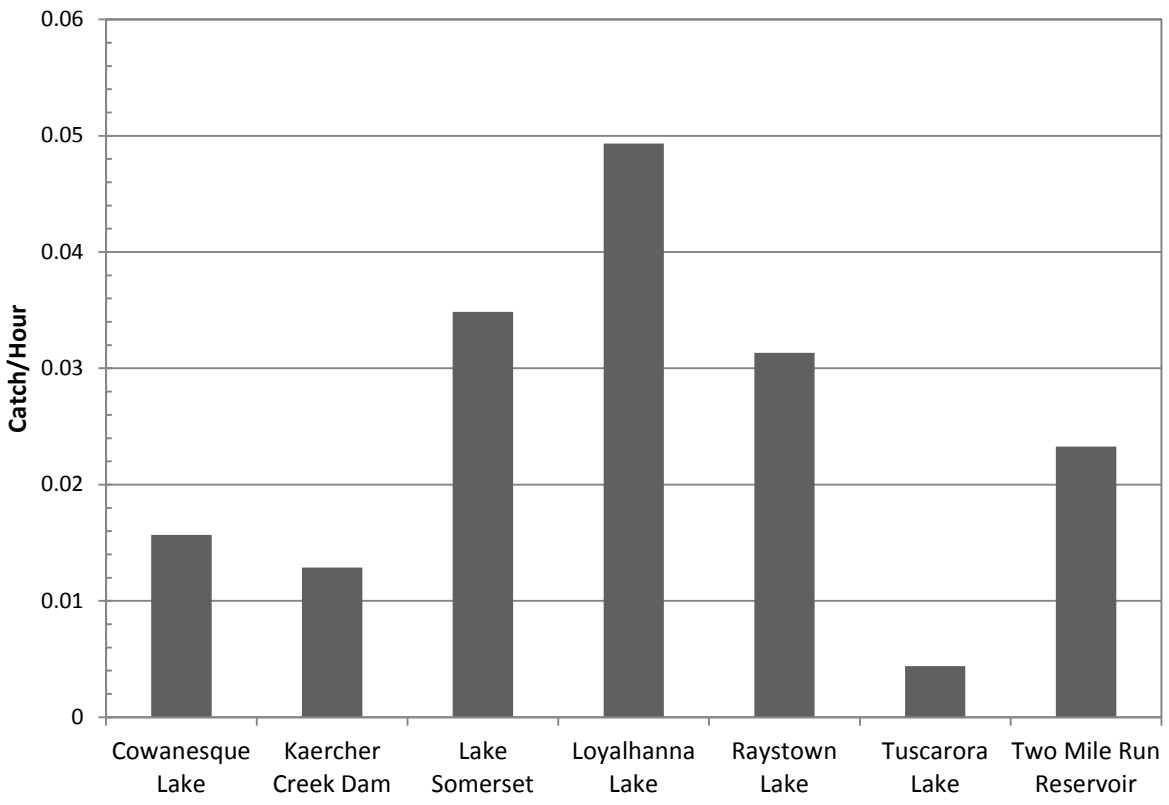

Figure 7. Mean catch-per-hour combined purebred and tiger muskellunge from spring trapnets in lakes stocked with both 1977-2007.

The median catch value of 0.01 muskellunge (purebred or tiger) per trap net hour is recommended as the minimum benchmark to maintain the listing of a lake in the stocking program. For example, in lakes with both purebred and tiger muskellunge, historical data indicate several lakes with rates above the minimum benchmark (Figure 6). In lakes where trap net gear is not effective, gillnets may be substituted. There is evidence to suggest that 5-inch stretch constant mesh floating gillnets are an effective method of capturing tiger muskellunge and work better than the sinking experimental gillnets, which are generally used for this sampling (M. Kaufmann, PFBC personal communication). If a lake fails to meet the minimum CPUE benchmark, but the Area Fisheries Manager suspects that poor sampling conditions may have been a factor, angler catch can be considered as additional criteria to continue the lake in the muskellunge program. In this situation, an angler log book program, catch reporting card or other method of reporting angler catch should be used. Angler catch rate benchmarks based upon on-line, club catch report statistics or paper log book require development and are an

objective of this plan. A benchmark angler catch-rate of 0.001/hr is recommended based on past angler catch information generated from angler use and harvest information.

The mean PA trap net catch value of 0.03 per hour for purebred muskellunge is recommended as the benchmark for a "high quality" muskellunge fishery and is the ultimate target catch rate when managing muskellunge as a directed fishery. In addition to serving as the mean CPUE value for all currently managed lakes, this figure closely approximates the long-term mean for Pymatuning Reservoir, which is generally considered a high-quality muskellunge fishery by anglers. The dataset for spring trap netting on Pymatuning Reservoir is quite extensive (1,461 sites) with sampling occurring annually since 1989, with the exception of 1993.

A lack of extensive historical catch information on flowing waters precludes inferring a benchmark for maintaining a stocking program. The low number of muskellunge sampled, coupled with the lack of a clear record that muskellunge were targeted, or at least consistently sampled during surveys, argues against using historical data to establish guidelines. A concerted effort to sample muskellunge-managed flowing waters should be a high priority in future sampling plans in the Division of Fisheries Management.

With 90% of the historical muskellunge catch taken using daytime or nighttime boat electrofishing, this gear is proposed as the preferred sampling method in flowing waters. Daytime boat electrofishing has been used by Axon and Kornman (1986) to evaluate muskellunge populations in Kentucky streams and Wahl (1999) reported using nighttime boat electrofishing both in the fall and spring to obtain CPUE and Schnabel population estimates. Although nighttime boat electrofishing is preferable to daytime boat electrofishing, on many flowing waters nighttime electrofishing may not be practical for safety reasons, thus restricting use to daytime boat electrofishing. The recent construction of the mini-boom electrofishing boats should enhance sampling efficiency of small rivers managed for muskellunge.

Age, Growth, Condition and Mortality

Age: Muskellunge have been reported up to 30 years old (Casselman *et al*. 1999), and although this is the extreme of the life-expectancy, muskellunge can regularly reach ages in excess of 20

years. This longevity is important because recent changes in the regulation and management of muskellunge may affect size and age structure of populations, growth rates, fish condition and mortality rates. Muskellunge age and growth information is routinely collected during most survey work, but accurate aging of muskellunge to obtain age structure, growth rates and mortality rates can be problematic due to the long life of muskellunge, declining rate of increase in the length of older fish, inaccuracy of the scale aging method and the strong sexual dimorphism in muskellunge growth. The slower growth rates of older fish can make annual growth increments small and difficult to identify on scales.

For fish collected from 1977-2007, the PFBC primarily used scales to determine the age of fish. It has been widely accepted that aging muskellunge older than 10 years of age using scales is highly inaccurate (Casselman and Crossman 1986) however, Fitzgerald *et al*. (1997) found that even aging muskellunge between three and eight years old could be unreliable when using scales. This was attributed primarily due to loss of outer annuli at the scale edge through resorption or erosion, or by formation of pseudoannuli within scale circuli (Fitzgerald *et al*. 1997). Use of other structures for aging, such as the cleithrum or otolith, has been found to be much more accurate, but require sacrificing the fish. Methods requiring the sacrificing of fish should not be considered for multi-year studies given the low density of adult muskellunge generally present in most waters.

An alternative approach for obtaining growth information would be tagging adult muskellunge to identify individual fish, and then following them through several years of growth. This method could also be used to validate age obtained from scales or other body parts. Linesville hatchery staff and PFBC Fish Production Services have been evaluating use of Passive Integrated Transponders (PIT) tags to follow brood stock movements and recapture rates (L. Hines, PFBC, personal communication). This method could be valuable for tagging adult muskellunge captured during a multiple year survey, both to monitor growth rates of individual fish and for marking captured muskellunge in multi–year, mark-and-recapture population estimates.

Growth: Growth rates in muskellunge are strongly sexually dimorphic (Casselman and Crossman 1986) with male muskellunge growing more slowly and generally shorter-lived than

females. For the 1977-2007 dataset, the sex of many sampled muskellunge was inconsistently recorded, consequently accurate analysis of the growth data is difficult. When the sex of aged muskellunge was recorded, data indicate greater mean length-at-age for females compared to males for ages four to nine, and a trend of increasing percentage of females in age classes starting at age six (Figure 7).

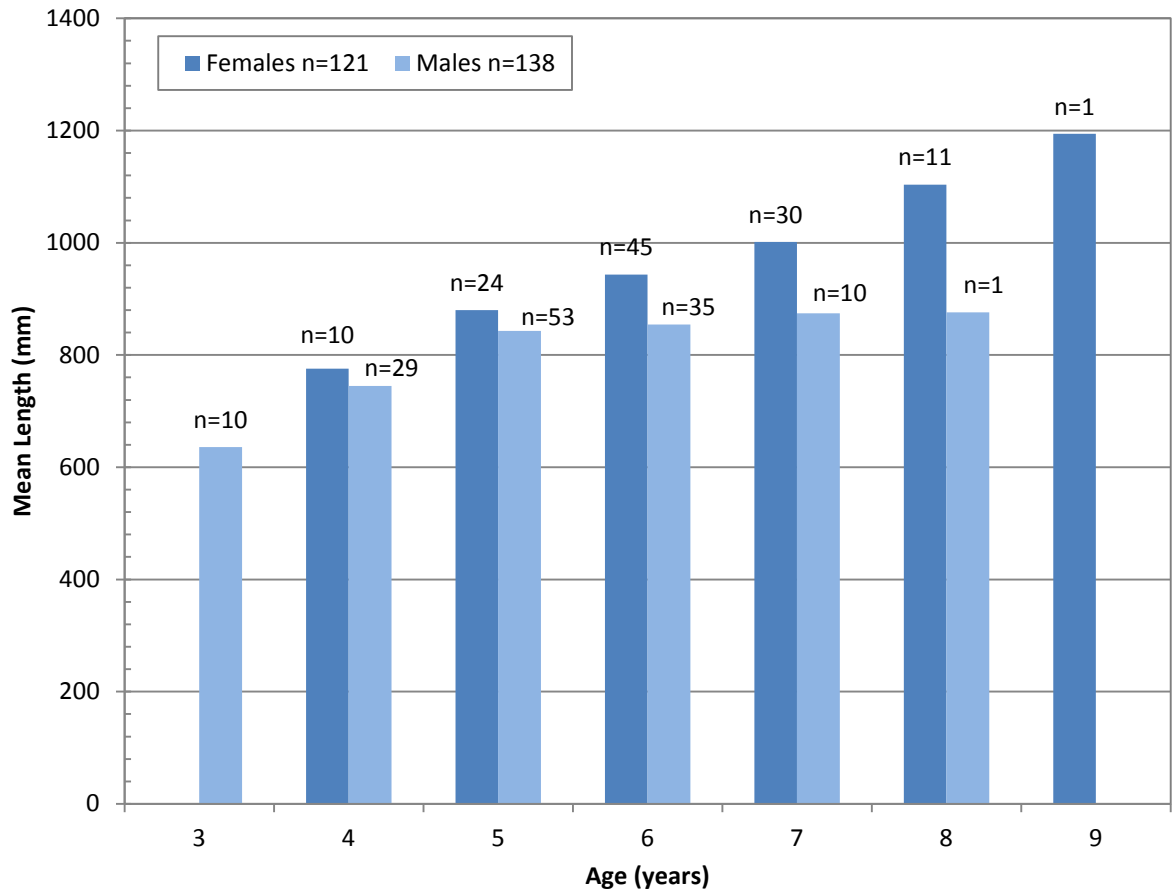

Figure 8. Mean length-at-age for male and female purebred muskellunge collected from 1977-2010 using all gear in currently stocked lakes.

For assessing growth rates in any future study, it will be necessary to consistently identify the sex of all sexually mature muskellunge sampled (≥650 mm). The method of sexing muskellunge based on shape of the urogenital pore (Lebeau and Pageau 1989) should provide an appropriate method, even when gametes cannot be extruded. Every effort should be made to determine muskellunge gender when collected.

Ongoing assessment should evaluate growth rates and fish condition, which may be affected through the added protection afforded by implementation of the 2007 regulations. Following the introduction of elevated minimum size limits, Cornelius and Margenau (1999) reported a decline in relative weights and an increase in the density of larger muskellunge. Thus, a sufficient increase in the number of adult muskellunge could contribute to increased intraspecific competition for food. Under the new PFBC regulations, if slow growth rates result in fewer fish less than 40 inches in length, then the positive effects of the additional protection for the population could be negated and potentially contribute to a reduced quality fishery.

Even at average growth rates, muskellunge take considerable time to grow from 30 to 40 inches (762 to 1016 mm). However, within the more southerly range of the muskellunge, growth rates in Pennsylvania may benefit from a longer growing season. On average, muskellunge in Pennsylvania reach 30 inches between ages thee and four, and reach 40 inches at around age 8 (Figure 8). The growth potential and the anticipated maximum size of muskellunge may vary among waters due to the productivity of the water, abundance and size of available prey, and even size of the water (Casselman 2007). This growth potential is an important consideration when determining minimum length limits for muskellunge and can help inform anglers about the potential size of trophy fish in a particular body of water. The previously discussed factors of lake size, lower productivity and limited forage base may lessen the ability of some currently managed waters to produce trophy length muskellunge (i.e., in the 50+ inch range). Nevertheless, according to the statewide growth curve, muskellunge in most waters currently managed for this species can reach the new 40-inch minimum length.

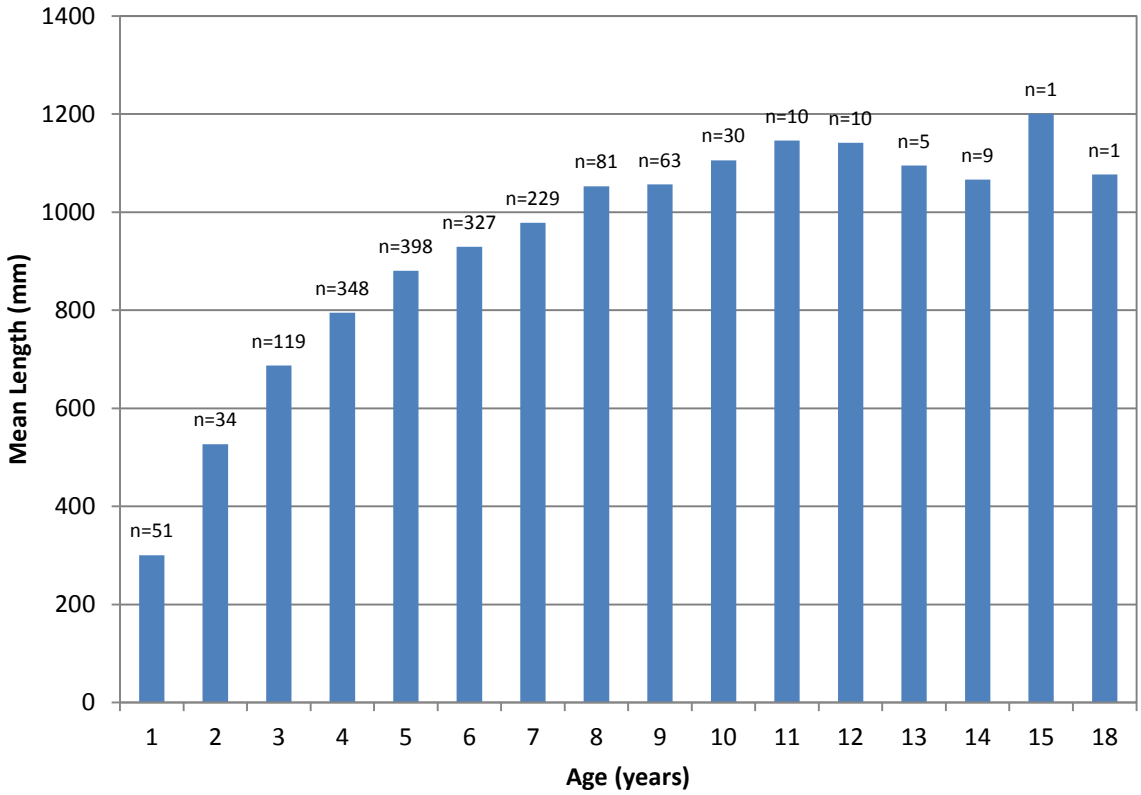

Figure 9. Statewide mean length-at-age for purebred muskellunge for all aged fish 1978-2010.

The difference in mean length-at-age between purebred muskellunge and tiger muskellunge is relatively small, with tiger muskellunge showing slightly lower growth rates (Figure 9). Because of the gap in age between 30-inch and 40-inch muskellunge, it will take several years for a shift in length and age structure to become noticeable, even with an anticipated drop in harvest by anglers as a result of the new regulations (Margenau and AveLallemant 2000).

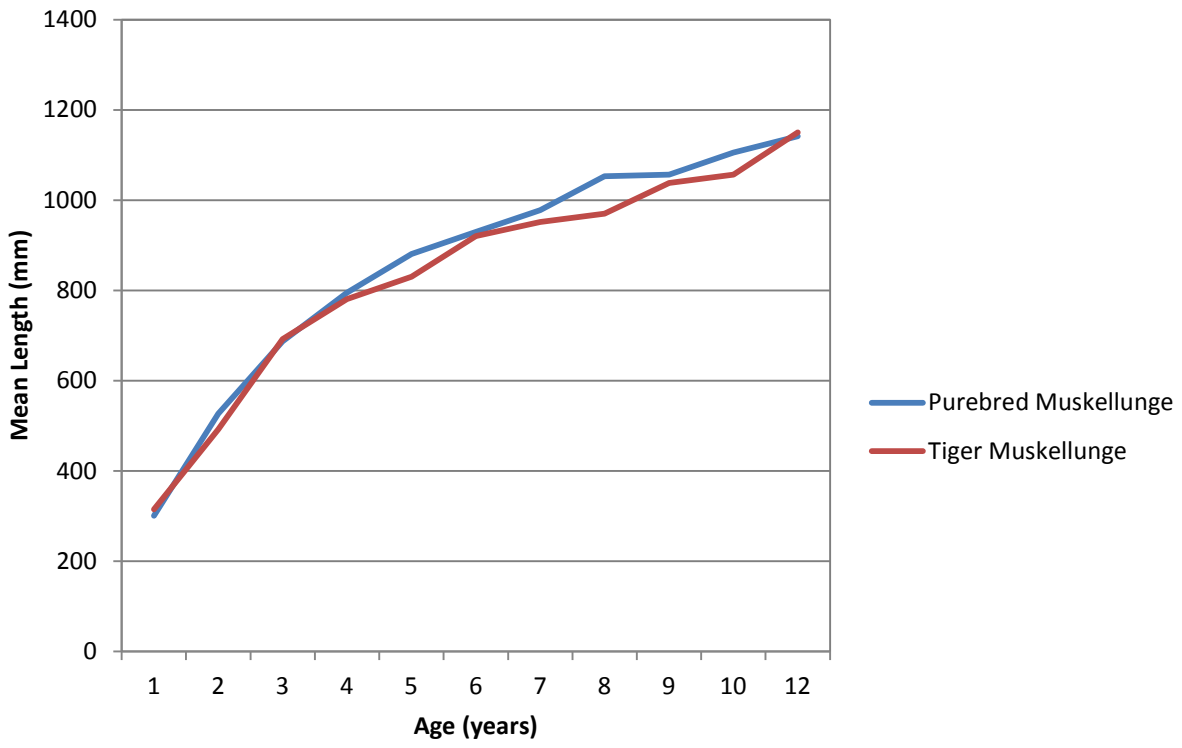

Figure 10. Comparison of mean length-at-age of purebred muskellunge and tiger muskellunge from all gear in all stocked waters 1978-2010.

Mean length-at-age data for purebred muskellunge in currently managed lakes (with age data available) show several waters with very low numbers of fish from which age data were collected (Figure 10). Consequently, these findings may not accurately represent the age and growth characteristics for those populations.

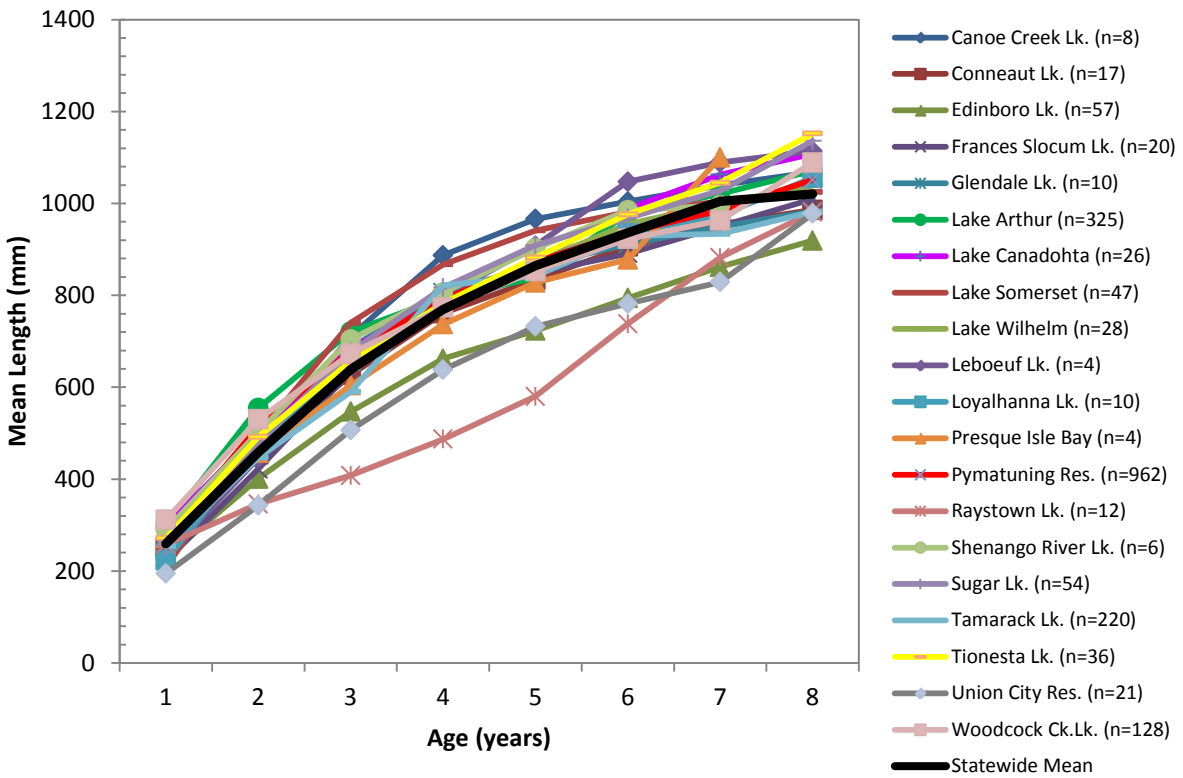

Figure 11. Mean length-at-age for purebred muskellunge from spring trapnets in currently managed lakes 1977-2010.

Lakes with a minimum of 45 aged muskellunge (i.e., Pymatuning Reservoir, Lake Arthur, Lake Somerset and Sugar Lake) show most age classes above the statewide mean (Figure 11). By comparison, Tamarack Lake and Woodcock Creek Lake exceed the statewide mean length-at-age for ages one through four fish, and then fall below the mean for older age groups. The high density of muskellunge in both Tamarack Lake and Woodcock Creek Lake may explain this drop in growth and suggests there may be a potential tradeoff between higher abundances of older larger fish and reduced length-at-age.

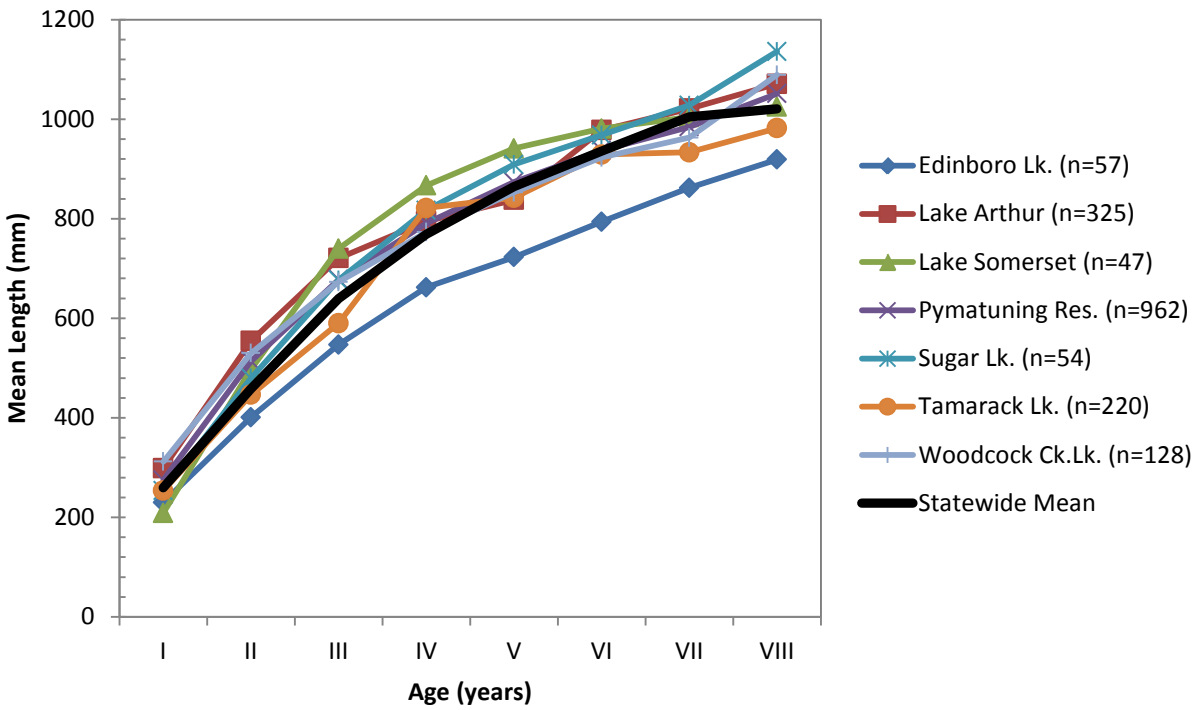

Figure 12. Mean length-at-age of purebred muskellunge in lakes with greater than 45 muskellunge aged.

For tiger muskellunge, length-at-age data in all currently managed lakes closely approximates the statewide mean. In reservoirs, tiger muskellunge length-at-age is more consistent among waters compared to purebred muskellunge waters (Figure 12). Nockamixon and Blue Marsh Lakes appear to have growth rates greater than statewide average for all age classes.

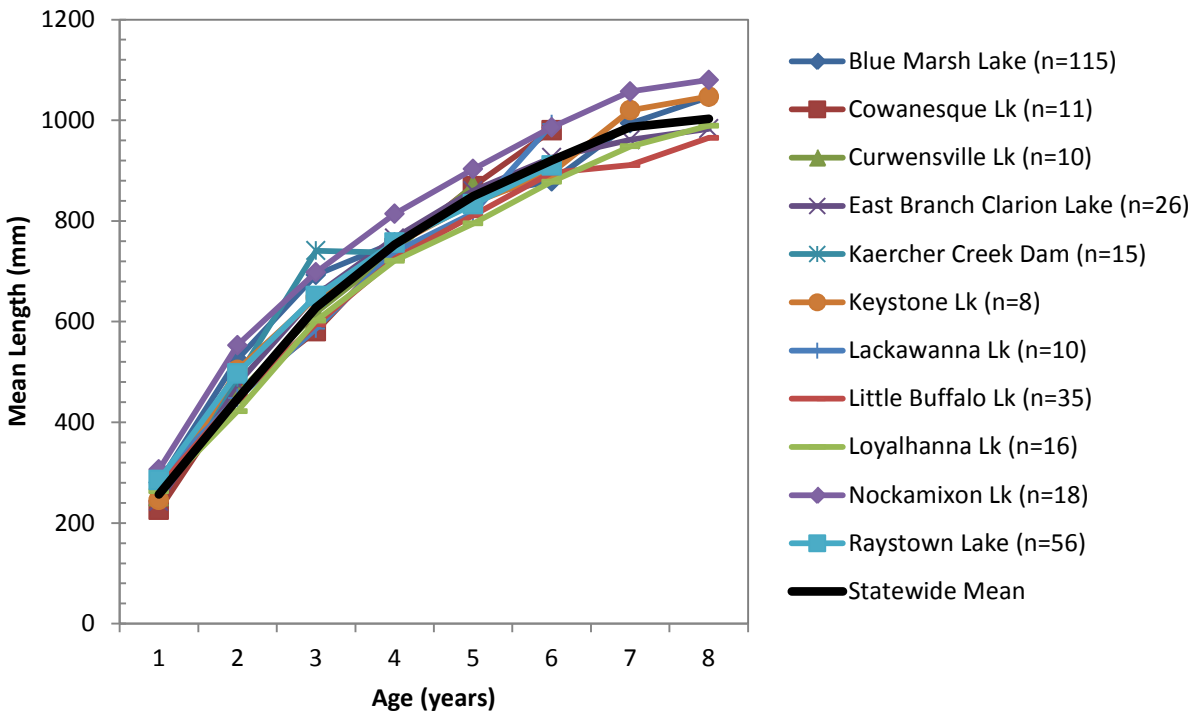

Figure 13. Mean length-at-age for tiger muskellunge in currently managed lakes 1977-2010.

In flowing waters, the small number of sampled and aged muskellunge confounds any valid conclusions regarding this segment of the fishery. Once again, more sampling is needed on flowing waters.

Condition: Growth rates are just one measure of fish health. Measures of well-being based on weight-to-length information can be an indicator of environmental conditions and prey availability (Blackwell *et al*. 2000). Plump fish can suggest favorable environmental conditions and plentiful forage, whereas thin fish may indicate a lack of forage or strong intraspecific competition for resources. One measure of fish condition is relative weight (W_r) which compares the weight/length relationship of a specific fish or sample of fish, to a standard weight for that given length of fish. We calculated the relative weights (W_r) for all currently managed purebred muskellunge lakes and compared them to the 100% or standard weight value considered the optimum weight–to-length relationship (Figure 13). Relative weights (W_r) for purebred muskellunge were calculated using the standard weight equation developed by Neumann and Willis (1994). The mean statewide average relative weight (W_r) was calculated at

95% indicating many muskellunge waters in Pennsylvania are below the optimum condition suggested by this relationship (Figure 13). However, in some waters (e.g., Pymatuning Reservoir and Lake Arthur), relative weights (W_r) exceeded the optimum (i.e., 100% level). The condition of these fish may reflect the characteristics of these waters which are large and productive, with excellent forage and habitat characteristics. Two lakes known to have dense populations of muskellunge based on CPUE information, Tamarack Lake and Woodcock Creek Lake, have relative weights below the 95% mean relative weight for Pennsylvania muskellunge lakes. As with the slower growth information highlighted above, the condition of muskellunge may be negatively affected by the high density of muskellunge in these waters. Closely monitoring condition factors should allow managers to determine if changes in management brought about by the 2007 regulations contribute to "stockpiling" of muskellunge and an increase in intraspecific competition for food. If condition factors decrease significantly, when compared to historic data, management decisions such as a reduction in the muskellunge stocking density, an increased daily creel limit, or reduced size limit, may be required to maintain a healthy population.

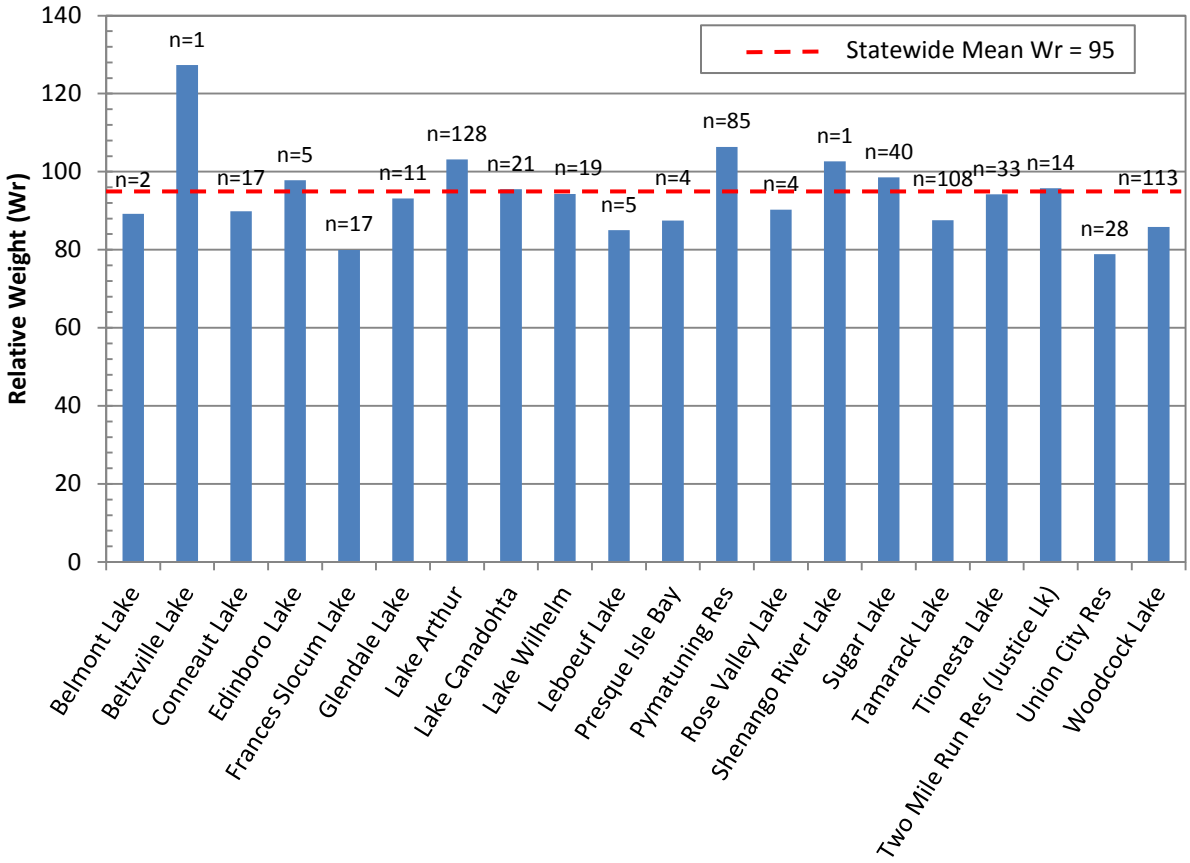

Figure 14. Mean relative weights (W_r) of purebred muskellunge >380 mm in length caught from all gear in currently managed lakes 1978-2010.

Relative weights (W_r) were determined for tiger muskellunge in lakes, using the equation for standard weights given by Rogers and Koupal (1997) (Figure 14). The statewide mean relative weight (W_r) was 93% for tiger muskellunge. This suggests a slightly lower condition for tiger muskellunge compared to purebred muskellunge.

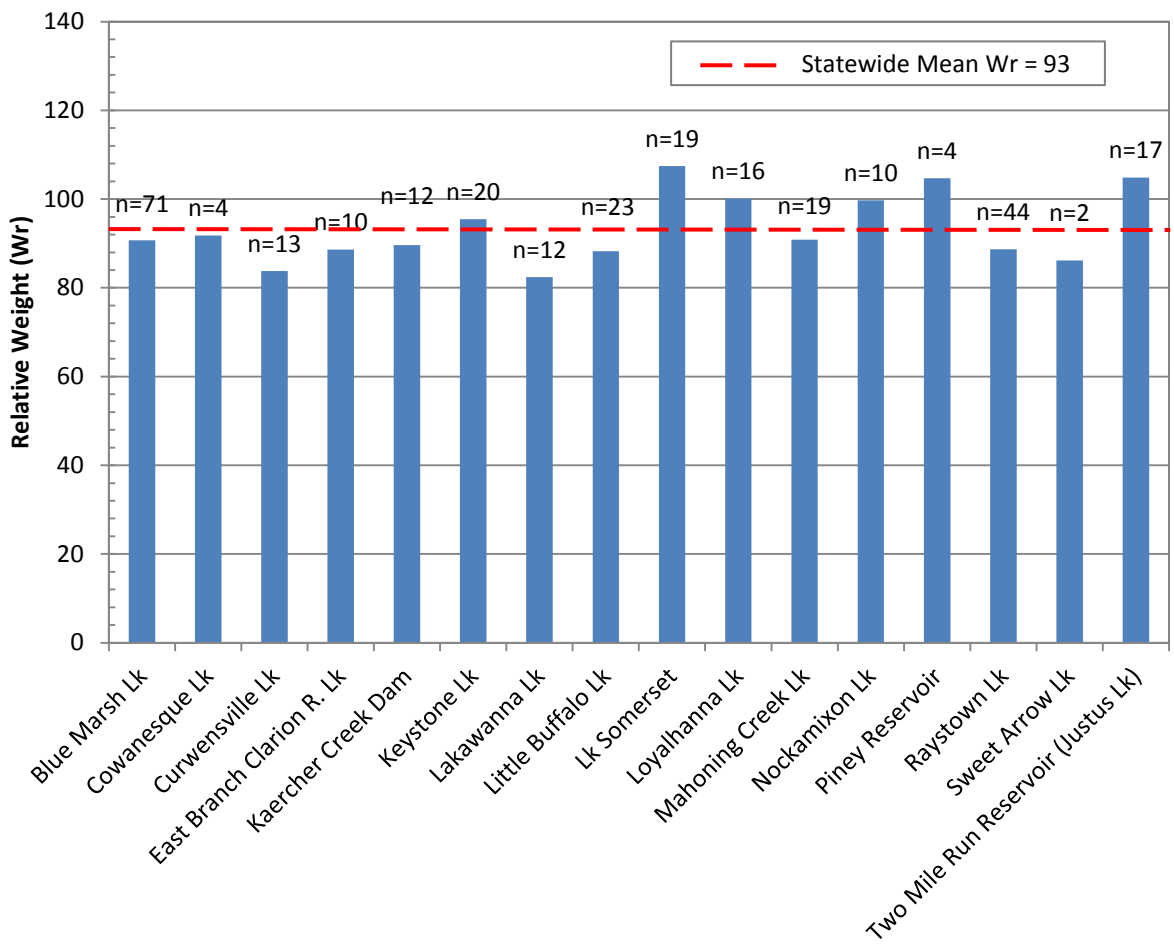

Figure 15. Mean relative weights (W_r) of tiger muskellunge >240 mm in length caught from all gear in currently managed lakes 1978-2010.

As mentioned above, the length-weight data are incomplete for the period 1977 to 2007. For example, length and scale sample were collected for tiger muskellunge, but weight was not recorded. This may have happened when tiger muskellunge were not the primary target species sampled, yet were captured during a survey. It is conjectured that because of their large size no device may have been available that would have been capable of weighing these often very heavy fish.

<u>Mortality:</u> Muskellunge mortality rates may also be affected by the 2007 regulation changes. For example, an increase in natural mortality due to stress from intraspecific competition or other factors could negate any decreases in fishing mortality accomplished through the added

protection afforded by the regulation changes. Total annual mortality of 41% was calculated for purebred muskellunge ages 4 through 14 (Table 9) and 34% for tiger muskellunge ages 3 through 10 (Table 10). Annual mortality of female purebred muskellunge was 41% compared to 32% for males (Table 11) and indicates possible higher fishing mortality for females because of their ability to live longer and grow to longer lengths. On select waters with high numbers of aged muskellunge, total annual mortality was 39% for Pymatuning Reservoir and 38% for Lake Arthur. On Blue Marsh Lake, a tiger muskellunge stocked water, yielded a total annual mortality of 37%. These mortality estimates are derived from estimated age structure over all years, with an age-length key applied to size distributions over all years.

Table 9. Total annual mortality statewide of purebred muskellunge from ages 4 to 14 in currently stocked lakes.

Lake	Ages	N	z	A
Statewide Mean	4-15	1489	0.5240	0.41(41%)

Table 10. Total annual mortality of tiger muskellunge from ages 3 to 10 caught in all gear from various lakes.

Lake	Ages	N	z	A
Statewide Mean	3-10	379	0.4181	0.34(34%)

Table 11. Total annual mortality of purebred muskellunge by sex caught in all gear from various lakes.

Lake	Sex	Ages	N	z	A
Statewide Mean	M	6-13	161	0.3929	0.32(32%)
	F	5-10	220	0.5308	0.41(41%)

Human Component to the Fishery

According to the 2006 National Survey of Fishing, Hunting and Wildlife Associated Recreation, in 2006, approximately 81,000 anglers (9%) of all Pennsylvania anglers directed their fishing towards muskellunge, muskellunge hybrids, northern pike or pickerel. An estimated 1,944,000 days (13%) of all the days fished in Pennsylvania were directed towards this group of fish. PFBC muskellunge and/or tiger muskellunge trip estimates from agency creel surveys expanded to all muskellunge and tiger muskellunge waters within the resource categories specified in tables 2 through 5 yield much lower use estimates, however. Using this method, we coarsely estimate some 104,000 trips are conducted annually. The creel estimates employed in our expansion span in excess of two decades. These disparate estimates indicate the need to refine our understanding of angler use specific to muskellunge as well as the economic value of this fishery. An estimated $723,601 propagation and distribution costs are incurred by the PFBC Bureau of Hatcheries to create fishing opportunities for muskellunge. An accurate and precise economic analysis is needed to concisely assess economic impact and economic contribution derived from these stocking efforts.

Adjustments to muskellunge regulations have implications for both the fisheries resource and humans. The human factors potentially impacted by changes in regulations include;

- angler effort directed toward muskellunge fisheries,
- angler catch,
- angler harvest and satisfaction.

Angler Effort: One anticipated outcome of the 2007 regulation changes was an increase in the amount of directed muskellunge fishing in Pennsylvania, which was the primary purpose for allowing year-round muskellunge fishing. Hoopes and Cooper (1986) stated that one reason for a closed season during the spawning period was to protect these fish when they are vulnerable to higher catch rates. Since most muskellunge populations are supported through stocking, the need to maintain a closed season on these waters during the spawning period was deemed less critical.

Angler Catch: Findings from creel surveys conducted on waters managed for muskellunge were varied. Waters with reputations for high-quality muskellunge fisheries generally had good angler catch numbers. Of waters reporting angler catch-per-hour of muskellunge, the 2009 survey of Cowanesque Lake (Soderberg 2009) reported the highest catch at 0.034/hr. and the 1989 survey of Tamarack Lake reported the second highest catch-rate at 0.016/hr. A 1987 ice fishing survey on Lake Ontelaunee was third at 0.0086/hr, a 1986 survey of Blue Marsh Lake fourth at 0.0076/hr, and a 1990 survey of Blue Marsh Lake, fifth at 0.006/hr. Both Lake Ontelaunee and Blue Marsh Lake are stocked with tiger muskellunge. Historically, tiger muskellunge were thought to be more vulnerable to anglers (Hesser 1978). Of the creel surveys reporting angler catch-per-hour of muskellunge, the mean value was 0.0019/hr and the median value was 0.0010/hr. As stated above, 0.001 fish/hour is recommended as a minimum catch-rate needed to continue muskellunge stockings.

Angler Harvest & Satisfaction: Generally, a small percentage of the total reported catch was also reported as harvested. Additionally, there appears to be a temporal trend of declining harvest. For example, harvest of muskellunge at Pymatuning Reservoir in the 1980's and early 1990's was between 24 and 36% of the catch. In Blue Marsh Lake anglers harvested 10% of the muskellunge caught in 1986 and 7% in 1990, while in Lake Arthur anglers harvested 10% of their muskellunge catch in 1986 and 13% in 1987. Muskellunge harvest from Tamarack Lake was 5.5% of the catch in 1989. In 2009, at Cowanesque Lake, anglers did not harvest any of the estimated nine purebred and 328 tiger muskellunge they caught. Fayram (2003) reported increased release rates of muskellunge in Wisconsin over time.

Input from the muskellunge fishing community suggested that more conservative regulations would tend to increase interest in fishing for muskellunge (Lorantas *et al*. 2005). Another expectation of the new regulations was an increase in the total angler catch rate of muskellunge and in the quality of the length of fish caught. Angler harvest is expected to decline with implementation of the more conservative regulations.

Angler satisfaction can be evaluated using a variety of methods as reviewed in Pollock et al. (1994). Those that have promise with respect to musky angler surveys include:

1. On-the-water,
2. Mail,
3. Voluntary angler reporting,
4. Pennsylvania Licensing System (PALS), and
5. Telephone & web-based surveys.

On-the-water angler: On-the-water angler surveys can be expensive and labor intensive, but they produce accurate and reliable water specific data on angler trips, anglers hours fished, muskellunge caught and released, number and sizes of muskellunge harvested, and other pertinent information. Drawbacks to on-the-water surveys are magnified by the low density of muskellunge in most waters, the rarity of catch by anglers, the negative factors related to on-water-angler surveys such as avidity bias, and many survey hours that would be needed to record relatively few catches by anglers. If on-the-water surveys for muskellunge catch are needed, they should be bundled into a more comprehensive survey dealing with the entire fishery.

Mail survey: Mail surveys are slightly less costly but can suffer from low return rates and recall bias. The low proportion of anglers targeting musky may yield high mailing cost without a concise musky angler sampling frame. The memorable component of a musky catch may make recall bias less of an issue for musky angler surveys.

Voluntary angler reporting: Voluntary angler reporting can be accomplished through an angler log book, fishing dairy, report card, fishing club report, or by using some type of web-based form for entering angler use and catch data. Compared to on-the-water creel surveys, the information gained from these methods may be less reliable, depending upon reporting compliance. However, this method would be less costly in any survey of all muskellunge managed waters. Compliance rate would have to be pursued as an objective to assess angler catch rate benchmarks detailed in this plan.

Pennsylvania Licensing System (PALS): The PFBC now has the ability to ask questions of their license buyers through the computerized Pennsylvania Licensing System (PALS). With this system, license buyers can provide information about their fishing interests and satisfaction.

These findings may enhance the efficiency of any species-specific telephone or mail survey by focusing on muskellunge anglers as well as the general angling population. Such surveys could assess angler catch as well as reporting compliance by anglers through any organized reporting system (e.g., PFBC on-line, club report, or volunteer log).

Telephone and Web-based Surveys: After several years under the new regulations, a new web survey could be conducted to gauge the opinion of muskellunge anglers on the quality of muskellunge fishing and their satisfaction with the new regulations. This would allow a comparison with information collected from a web-based voluntary survey conducted prior to the regulation change on opinions of the muskellunge fishery (Lorantas *et al*. 2005). Challenges associated with data collected from voluntary web surveys will have to be addressed.

Each survey method has advantages and disadvantages, with some highlighted above. Ultimately funding and need will influence the survey method selected.

VI. Standardization of Muskellunge Sampling Techniques

As an important component of fisheries management strategies for rivers and lakes, fish population assessments and related surveys will continue to serve as a necessary operation; however, with appropriate refinements made that are designed to improve data precision as well as elevate the importance of meeting new objectives. Historically, fishery dependent and independent surveys targeting muskellunge are generally lacking for Pennsylvania. Due to differences in the seasonal catchability of muskellunge, shifts in approaches (*e.g.*, surveys targeting muskellunge instead of routine fish population monitoring) may need to be made in order to establish realistic criteria-specific benchmarks and meet species-specific management objectives. Such a program will increase our understanding and allow us to determine the quality of muskellunge populations throughout Pennsylvania.

In waters where they are managed, muskellunge should be a primary species of concern when choosing sampling times and gear to maximize effectiveness and accuracy of surveys. PA trap nets fished during spring spawning times (mid-April to mid-May) are the most effective gear for shallow lakes since these periods yield the highest catch rates over size ranges of interest to

angler and managers. For flowing waters, the time of year for sampling is less critical, but October or November can be productive.

Managers should make special preparations to consistently sample muskellunge during surveys even when targeting other species in flowing waters. Obtaining individual fish weights would help alleviate a data deficiency. Additionally, a review of historical data, collected beginning in 1977, noted that weight information was often missing from sampled muskellunge. This data deficiency greatly decreased the quality of the overall length-weight information needed for relative weights and other measures of condition. The call for increased consistency in collecting muskellunge data is not new in Fisheries Management and was identified by the Warmwater Unit Leader in a 1989 memo (Hoopes 1989).

Opportunity 1. There is a need to improve and standardize the design and sampling methods of all surveys evaluating the management of muskellunge in Pennsylvania waters.

Strategy 1. Develop a standard field operating guide for both lake sampling and flowing waters, to ensure concise assessment protocols exist and are easily referenced by all managers.

- Standard operating procedures for sampling adult muskellunge in lakes are provided in Appendix C.
- Standardized sampling parameters for sampling adults in flowing water have been developed and are provided in Appendix D.
- Standard operating procedures for sampling of flowing waters to assess natural reproduction (i.e., muskellunge young-of-year) have been developed and are available in Appendix E.

Opportunity 2. There is a need for additional sampling gear (fishery independent) CPUE data to assist in the development of muskellunge specific benchmarks for making informed management decisions. Statewide

trap net and electrofishing catch statistics will be developed from catch data collected during the life of this plan.

Strategy 1. Immediately begin to incorporate data collected utilizing the standard operating procedures provided in this plan to continue to build the statewide muskellunge dataset to help better inform future decisions regarding muskellunge management.

VII. Evaluating Recent Regulation and Management Changes on the Muskellunge and Tiger Muskellunge Populations

In 2007, muskellunge and tiger muskellunge regulations were changed to a 40-inch minimum length limit and a creel of one fish per day from a 30-inch minimum length and a creel of two fish per day. Additionally, stocking rates were simultaneously increased on a few select waters. The possible list of population factors that may be affected by these recent management actions include; changes in total population abundance, biomass, size and age structure, growth rates, condition, total mortality, and fishing mortality.

From an angling perspective, the most important changes to the muskellunge population resulting from the management actions are anticipated changes in abundance and population size structure. Other fish community affects may also occur and should be accounted for. The length and creel limit changes would most likely affect the size structure of the population, and abundance of muskellunge in the newly protected range between 30 and 40 inches. Increased minimum length-limits have the greatest chance of changing the size structure of fisheries where angler harvest was the primary factor shaping the size distribution and abundance of the species in question (Casselman 2007).

Literature Review of Regulation Evaluations

Most studies in the literature that attempt to evaluate a change in muskellunge density following a change in minimum size regulations have used population estimates to characterize population abundance. The Bailey modification of the Petersen method, (Hanson 1986; Hoff and Serns 1986; Cornelius and Margenau 1999; Margenau and AveLallemant 2000) was used in some

studies. Hanson marked muskellunge during the first spring sampling and conducted recapture sampling in the second spring to derive a population estimate. This method was duplicated by Cornelius and Margenau (1999). Use of non-random selection in choosing study waters is common among studies of minimum size limit regulation changes listed in the literature (Hanson 1986; Cornelius and Margenau 1999, Margenau and AveLallemant 2000).

All muskellunge captured during the study should be marked to allow annual mark-and-recapture estimates. McNeil and Crossman (1979) showed that fin clipping muskellunge was unreliable because of regeneration that made identification difficult especially in multi-year assessments. It is recommended that all captured muskellunge be marked with Passive Integrated Transponder or PIT tags. This would allow calculation of annual mark-and-recapture estimates and verifiable growth rate information on individual muskellunge, which could be used to validate other forms of aging such as scales and the non-lethal methods (fin section).

Voluntary (on-line, log book, club records) and telephone surveys might serve to maximize our ability to learn about muskellunge and tiger muskellunge catch and effort. Information describing anglers targeting muskellunge versus other fish species, angler catch and harvest would be useful to better understand the amount of fishing effort directed at muskellunge fisheries. Exploitation rates could be determined by tracking harvest of marked muskellunge.

Potential Negative Effects from Management Changes of 2007

Just as regulation changes are expected to provide positive benefits to the muskellunge population, they may also contribute to negative or unwanted effects in the fishery.

Negative effects may include:

1. Reduced growth and condition.
2. Concentration of harvest on the very largest fish in the population, reducing the ability of the regulation to increase the number of trophy fish available to anglers.
3. Concentration of harvest on females in the population.

Growth and Condition: Growth and condition may be affected if abundance of adult muskellunge increases to a level that enhances intraspecific competition for food. Under the new regulations, if growth rates slow and fewer fish reach 40 inches, any positive outcomes of the additional protection to the population could be negated and thus contribute to a reduced quality fishery. Likewise, decreases in abundance of forage species could adversely affect the condition (i.e., relative weight) of muskellunge. This effect was noted by Cornelius and Margenau (1999) who reported a decline in relative weights after application of elevated minimum size limits and an increase in the density of larger muskellunge.

Harvest of Largest Fish: Further, changes to the population structure as a consequence of the increased minimum size limit could concentrate the harvest on the very largest of fish, which are also the least numerous. Thus, enhancement of the trophy element in the fishery may not occur. Dunning *et al*. (1982) suggested that an overly high minimum size limit on northern pike in the St. Lawrence River could cause overharvest of fish above the proposed minimum size. Similarly, Cornelius and Margenau (1999) reported an initial increase in fishing pressure and exploitation of larger muskellunge in Bone Lake, Wisconsin following a minimum size limit increase. This change in regulation negatively impacted the Relative Stock Density in 1983. Later, the muskellunge population rebounded on that water. Countering this problem of concentrated harvest on larger muskellunge is the growing trend of catch-and-release of muskellunge, which should lessen the chances of this occurring (Fayram 2003).

Harvest of Female Muskellunge: To accurately assess growth rates in any study it is necessary to identify the sex of all sexually mature muskellunge that are sampled. These data are especially important since growth rates in muskellunge are sexually dimorphic (Casselman and Crossman 1986) with male muskellunge growing more slowly and having generally shorter lives than females (Casselman 2007). In Pennsylvania, muskellunge typically reach sexual maturity around 30 inches (762 mm), but problems with consistent sampling of muskellunge <30 inches were noted in past studies (Hanson 1986; Cornelius and Margenau 1999). So, the sex should be determined for all muskellunge ≥30 inches and only these fish ≥30 inches should be considered in the analysis.

Another potential problem with the elevated minimum size limit is that male muskellunge often do not reach 40 inches (1016 mm) in many waters such as the northern waters in Wisconsin (Hanson 1986) and in Canada (Casselman *et al*. 1999). Pennsylvania waters are in the more southerly part of the species range and therefore male muskellunge should be capable of growing to lengths of 40 inches or greater, in productive waters. However, if few male muskellunge reach the 40-inch minimum size limit then the new minimum size will likely be excessively targeting larger females for harvest. Therefore, it is important to know the percentage of male muskellunge exceeding 40 inches, which provides justification to determine the sex of all fish ≥30 inches.

A study will be conducted to assess the effects of the 2007 regulation and management changes on the muskellunge population. This study will provide additional information about muskellunge fisheries across Pennsylvania and help to quantify any changes that may occur as a result of the regulation changes. The study plan will involve selected waters (one per Management Area) and provide for assessment of changes in:

1) abundance of muskellunge and tiger muskellunge of selected sizes,
2) size structure of muskellunge and tiger muskellunge,
3) vital life-history information (e.g., growth, condition, mortality), and
4) density of other desirable gamefish in the fish community (walleye, black bass, channel catfish, and others).

Opportunity 1. The 2007 regulation changes that were enacted to improve muskellunge population size structure and improve angling opportunities for muskellunge have not been evaluated.

Strategy 1. Beginning with the spring 2013 sampling season, evaluate management actions initiated by the PFBC in 2007, including the change in the minimum length limit from 30 to 40 inches, the reduction of creel limit from two to one per day, and the increases in stocking rates on select waters.

- The evaluation will assess the change in these two components of the population. Size distribution will be examined using a Kolmogorov-Smirnov test, which detects changes in the position and shape of the length frequency before and after the treatment. Changes in other factors such as condition and growth rates may be identified in specific waters, if sufficient pre-treatment data are available. Change in density of black bass, walleye and other gamefish will be monitored employing standard operative procedures for those species.
- Select a minimum of eight (8) waters with five (5) or more years of previous survey catch data on muskellunge and sample these waters for five additional years (i.e., through 2023). Employ the standard operating procedures defined in Appendices F to assess any change in trap net catch rate.
- Current muskellunge regulations and management strategies will be reevaluated following the results of this survey.

VIII. Evaluate and Maximize the Effectiveness of Recently Enacted Management Actions, Including Stocking Methods

The objective of the production system should be to provide fingerling muskellunge and tiger muskellunge in lengths and quantities that provide for the greatest potential to develop a high quality muskellunge fishery through the use of hatchery reared fish. This may mean that all muskellunge produced through the Bureau of Hatcheries may be required to be of larger lengths, or that muskellunge of varying lengths, and subsequently varying costs, can be utilized to create high quality fisheries. It is incumbent upon the Area Fisheries Managers to request muskellunge and tiger muskellunge fingerlings in lengths and quantities that, through their knowledge of the resource, provide the greatest potential to develop a high quality muskellunge fishery and then evaluate the success of their recommendations in order to make better informed decisions in the future. Knowledge of the success of different lengths and quantities of muskellunge fingerlings stocked at providing high quality fisheries will lead to more efficient use of these fingerlings and improved angling opportunities.

Opportunity 1. Critically examine muskellunge stocking and management programs on all currently managed waters to ensure high quality fisheries are developed by 2022.

Strategy 1. Immediately initiate a minimum catch-rate of at least 0.01 per hour for PA trap nets (1 muskellunge for every (four) 24-hour trap net sites) for continued stocking of muskellunge and tiger muskellunge managed lakes/reservoirs.

- Management actions within the scope of this plan may be taken to improve trap net catch rates to meet the minimum criteria.
- Stocking will be discontinued in waters not meeting the minimum criteria.
    - The reduction in annual production requests may be used to reduce overall production or increase the number of larger fingerlings produced depending on need.

Strategy 2. Develop a benchmark catch-per-hour of boat electrofishing on flowing waters by making their sampling a high priority in future sampling plans in the Division of Fisheries Management. Protocols referenced in Opportunity 1 (Appendix D) will be used, in part, to develop benchmark catch rate criteria.

Strategy 3. Develop a two-tier allocation system to allow Area Fisheries Managers the option to request either a fall fingerling of 150-225 mm (6-9 inch) or a larger 250-300 mm (10-12 inch) fingerling. This system should be established in 2013 and waters to receive large fingerlings should be selected by the Area Fisheries Managers based upon assessed fish community characteristics.

Opportunity 2. Currently, coded wire tagging (CWT) and passive integrated transponder (PIT) tagging are two methods of marking muskellunge for various experimental purposes. Tagging of fingerlings with coded wire tags began in 2010 and will continue until 2015. High tag retention for a period of two months was shown in 2010 (Appendix A). Long-term, adult tag retention will be assessed as a component of this study and will be completed in 2015. Evaluations of these methods are either ongoing or proposed, and should be completed by 2015. With the strong association among muskellunge propagation, stocking policies and long-term management goals, closer cooperation between hatchery staff and fisheries management staff is recommended. This cooperation will be achieved through an internal focus group composed of staffs from the Division of Fisheries Management and the Bureau of Fish Production which regularly discuss all issues related to muskellunge management.

Strategy 1. Beginning in 2012, evaluate the relative survival of fall fingerlings versus spring yearling stocked muskellunge in lakes/reservoirs according to the study design presented in Appendix A. Sampling should begin in 2015 after muskellunge have matured and are vulnerable to this gear. By December 31, 2020, finalize a report summarizing the findings of the fall versus spring yearling stocked muskellunge evaluation.

Strategy 2. Fisheries Management Area 2 will continue to monitor the reliability of CWT retention and detection in muskellunge for five years once tagged muskellunge are vulnerable to trapnet gear. See Appendix A for study plan and waters.

Strategy 3. By January 1, 2013, create a muskellunge work group within the Bureau of Fisheries and the Bureau of Hatcheries to improve the

exchange of ideas and cooperation between the various groups within the Bureaus dealing with muskellunge management.

Opportunity 3. Many barriers to a muskellunge fishery are a consequence of a broad spectrum of environmental factors such as sedimentation, organic enrichment, low dissolved oxygen levels, loss of aquatic vegetation and human induced development. There is an opportunity to further identify, evaluate, rehabilitate, conserve and enhance the potential of waters to support recreational muskellunge fisheries through natural reproduction.

Strategy 1. Maintain current minimum length and creel limits to enhance natural reproduction of muskellunge populations through the protection of older and larger individuals in the population.

Strategy 2. By January 2016 identify barriers to successful reproduction and recruitment to the sport fishery and the approaches for removing them. Enlist the Habitat Division in deployment/maintenance of water quality monitoring gear. Monitor any remediation effects on water quality and design sampling strategies to track improvements in subsequent natural recruitment.

Opportunity 4. Close cooperation between resource managers and interested anglers can build trust and lead to improved and more open exchange of information regarding the resource. Given the challenges with sampling muskellunge and our current limited availability of robust data sets for Pennsylvania waters, improved information exchange can provide valuable insight into the success of management programs targeting muskellunge. Opportunities exist to improve the exchange of information between the PFBC and anglers. Improved information exchange would allow for more informed decisions to be made

regarding future muskellunge management in Pennsylvania. Following publishing of the draft version of this plan by the PFBC a public comment period was provided so that muskellunge anglers and other interested parties could provide opinions and suggestions on this management plan and on muskellunge management in Pennsylvania. A summary of those comments are provided in Appendix G.

Strategy 1. Continue to use the assistance and cooperation of musky clubs in stocking operations to maximize survival of stocked fingerlings.

Strategy 2. Upon completion of the current modernization of the Agency Resource Database, resume and complete the online angler log book and include a means to specifically report the catch of muskellunge and tiger muskellunge so as to take advantage of the high interest and willingness to participate that is characteristic of most avid muskellunge anglers.

- Rate of voluntary reporting of catch data from a random sample may afford correction of volunteered data such that unbiased catch, effort and catch rate statistics may be secured.

Strategy 3. By January 1, 2014 the Warmwater Unit will consult with PSU Coop Unit regarding sampling design and investigate the statistical utility of capturing angler use and harvest information that does not require on the water surveys.

Strategy 4. By January 1, 2013 the Area 2 staff will investigate the feasibility of using PALS to develop a list of muskellunge anglers for use in a telephone survey to assess waters fished, effort expended, fishing success, catch rate, opinions on the quality of the fishing and contribution of musky angling to the economy.

Catch assessments, angler assessments, and habitat assessments referenced herein are designed to better inform anglers, managers, fish culturists, and those influencing essential muskellunge habitats of how to best enhance muskellunge populations to provide optimal fishing opportunities for Pennsylvania anglers in the most cost effective fashion. Information will permit evaluation of programmatic changes recently made and changes that may be forthcoming. Evaluation of cultured fish survival, better assessment of natural recruitment levels, and evaluation of abundance change due to 2007 harvest management changes represent a few of the groundwork elements this first muskellunge management plan addresses. Although plan tasks are daunting given our many mandates and challenges, the collaboration and cooperation of the musky angling community give all in the agency great hope for a brighter musky fishing future.

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Appendix A

Standard Operating Procedure
November 2011
Evaluation of fall fingerling vs spring yearling stocked muskellunge in lakes.

Objectives: (1) Compare the survival to adulthood of fall fingerling stocked muskellunge versus spring yearling stocked muskellunge in three lakes through 24 hour trap net catches over a five year period following tagged and stocked muskellunge that reach maturity and become vulnerable to trapnet gear.

(2) Determine the reliability and retention of coded wire tags (CWT) in young of the year muskellunge through adulthood.

(3) Track changes in overall density of muskellunge in study waters compared to controls (fingerling stocked waters).

(4) Track any changes in size structure of muskellunge in study waters compared to controls (fingerling stocked waters).

Water Selection & Sampling sites: Three lakes have been chosen in northwestern Pennsylvania (Area 2) to commence the study (Lake Canadohta, Edinboro Lake and Tionesta Lake). Additional waters can be included in this study if other Area Fisheries Managers decide to participate. Sampling site locations can be either historical sites or sites chosen by the Area Fisheries Manager. When new sites are chosen and trapnets are the preferred gear, sites should be restricted to relatively shallow areas where this gear can be fished effectively otherwise a random method of selecting locations should be employed.

Sampling Dates: Sampling should take place between early April and mid May if possible with adjustment for latitudinal differences and annual spring weather variation. This is during the spawning period when muskellunge are most vulnerable to trap net gear. Sampling should begin once water temperatures are consistently above 10° C.

Sampling effort: Sampling should be at least 20 net sites per survey. Effort recorded will be determined by hours of trap net soak time. An individual trapnet site will be considered one overnight set roughly equivalent to 24 hours in length.

Sites location: Record or update the latitude, longitude (determined by GPS using NAD83 datum, in decimal degrees format), date, and water name.

Sample Targets: Primary targets are all sizes of muskellunge. Recording information on other sport and panfish is recommended.

Disease Incidence: Please record any sign of disease, such as red spot, lesions, hemorrhaging or wounds with photos where appropriate.

Gear: Pennsylvania trapnets and associated trapnet lead nets, anchors, buoys and ropes.
Trap net boat, outboard, fuel tank, oars, boat hook,
Safety equipment (fire extinguisher, signaling device, throwable flotation device, boat anchor)
Measuring board, data forms, scale envelopes, scale knife, and clipboard
Various weighing devices that can accurately weigh both small yearling muskellunge and very large and heavy adult fish
Hand held wand for detection of CWT
Thermometer and conductivity meter
Fish holding equipment tubs, buckets, and recirculating pumps with automotive battery
Heavy duty nets, GPS unit, Camera, spare AA batteries

Sampling Procedure: Measuring and weighing the muskellunge in the sock net allows for easier control and facilitates processing with the least chance of stressing these large and powerful fish.

Safety: Personnel should wear PFDs and follow all PFBC boating safety guidelines.

Data Collection: Record length to the nearest mm and weight to at least the nearest 10 gram increment by species of all muskellunge at each trap net site. Determine the presence or absence of a CWT using a hand held detection wand. Record the location of the CWT in the body of the muskellunge, i.e. left or right cheek or dorsal fin area. Record the sex of all mature muskellunge either by extrusion of gametes or through the method outlined in Lebeau and Pageau (1989). A scale sample should be obtained for every muskellunge and tiger muskellunge for age and growth analysis. Record specific conductance of the lake once daily and record water temperature each individual net set daily.

Data Transfer and Processing: Data entry into the Agency Resource Database will be carried out by Area Managers or their designees.

A comparison of methods for marking fish

Currently, methods of marking or tagging muskellunge are being evaluated for a variety of potential management purposes. These purposes include the differential survival of fall stocked fingerling muskellunge versus spring stocked yearling muskellunge in northwestern Pennsylvania lakes (e.g., Edinboro Lake, Tionesta Lake and Lake Canadohta). Evaluating other variables such as size of muskellunge stocked, dry diet formulations, or minnow-reared versus dry-diet would also need a form of tagging. Tagging would also allow differentiation of stocked from naturally reproduced muskellunge.

Fin clipping is the cheapest and mostly easily accomplished method of marking a fish, but it has been shown that regeneration of fins to the point where the clip is no longer discernible is a major problem in muskellunge being studied over several years. For studies lasting only one year, fin clipping is a reliable method of marking but investigations lasting several years following marking or tagging should not use fin clipping. Fin clipping was assessed in a study of fall-stocked fingerling muskellunge versus spring-stocked yearling muskellunge study and detection of various lots of stocked muskellunge was found to be unreliable several years after the marking.

Coded wire tags (CWT) are now being used in Fisheries Management Area 2 to mark muskellunge in the evaluation of survival of fall stocked fingerling versus spring stocked yearling muskellunge in lakes. Table 1 lists the numbers of muskellunge tagged with CWT in 2010. The equipment used to tag paddlefish for the Allegheny River was also used to tag the muskellunge for this study. In the future that may not be an option and other means of obtaining equipment and tags may need to be used. Varying tag location on the body allows for differentiation of fall and spring stocked muskellunge. Passive integrated transponders (PIT) are being used by Linesville hatchery staff to mark adult broodstock muskellunge taken out of Pymatuning Sanctuary. This study is primarily tracking fecundity and egg viability of individual broodstock muskellunge.

Both of these tagging methods have reliable retention rates in multiple year studies. The major problem with both of these methods is cost. Table 2 below gives a cost comparison of the two methods. The primary investment for CWT is the purchase or rental of the Mark IV tagging machine. Individual PIT tags are much more expensive than individual CWT but the equipment needed to implant PIT is much less expensive. Tag readers for each method are roughly the same cost.

The CWT appears best suited for tagging very large numbers of fish. Tagging each fish requires only a few seconds and the benefit/cost ratio improves as more fish are tagged. PIT tags are presumed more suitable for small lots of fish since the tagging process may take more time compared to CWT and individual PIT tags are costly. The advantage of PIT over CWT tags is the ability to identify individual fish without killing the fish or removing the tag. In a multiple year study where an individual muskellunge could be caught several times, it would be beneficial to identify that individual and monitor characteristics such as growth rates, location of capture and frequency of capture. Cost estimates have been developed for using CWT for the fall fingerling versus spring yearling study (Table 3). Currently, equipment and tags from the Allegheny River paddlefish tagging program are being used.

To determine the feasibility of PIT tagging of fingerling sized muskellunge a pilot study is proposed. One hundred fingerling muskellunge would be PIT tagged and held at the Linesville hatchery to determine survival and tag retention rates over several months. If survival and retention rates are satisfactory then PIT tags could be considered for other studies of management actions. The cost of equipment and PIT tags are presented in Table 4.

A recommendation for the statewide study of 2007 management changes is to PIT tag all trapnetted muskellunge to identify individual muskellunge recaptures through the study and follow other characteristics such as growth rates. Table 5 shows the costs associated with that part of the study. Options to obtain grant funds for these various scenarios are being investigated.

Table 1. Fall stocked fingerlings versus spring stocked yearling muskellunge coded wire tag information from the fall of 2010.

Coded Wire Tagging Study - Muskellunge 2010 Fall Fingerlings (Ffing)									
Species	**Date Tagged**	**Mark**	**Tag Location**	**No. Tagged**	**Retention**	**Total Retention Days**	**Date Stocked**	**Number Stocked**	**Average Length (in)**
Purebred Muskellunge	8/17/2010 to 8/20/2010	CWT	Right Cheek	1,656	104/105 99%	45	09/27&28/2010	1,585	8.00

Coded Wire Tagging Study - Muskellunge 2011 Spring Yearlings (SpYr)									
Species	**Date Tagged**	**Mark**	**Tag Location**	**No. Tagged**	**Retention**	**Total Retention Days**	**Date Stocked**	**Number Stocked**	**Average Length (in)**
Purebred Muskellunge	8/17/2010 to 8/20/2010	CWT	Dorsal Area	2,217	103/105 98.1%	63	03/23/2011	1,209*	10.25

* - Due to predation by birds while in a pond the number of tagged yearlings was short of stocking request.

Table 2. Cost comparison of tagging purebred muskellunge with **C**oded **W**ire **T**ag vs. **P**assive **I**ntegrated **T**ransponder Tag.

Coded Wire Tag			
Item	Quantity	Price (New)	Price (Rental)
Mark IV – Tagging Unit	1	$31,800.00	$2,120.00
Handheld Wand Detector	1	$3,750.00	$415.00
CWT	1	$0.15	$0.15
TOTAL		**$35,550.15**	**$2,535.15**

Passive Integrated Transponder Tag		
Item	Quantity	Price(each)
MK10 Implanter	1	$2.00
N125 Needles	1	$2.50
PIT Tag (9mm)	1	$5.75
601 Reader	1	$525.00
TOTAL		**$535.25**

Tag Type	Advantages	Limitations	Image
Coded Wire Tag	• Smallest tag available • Inexpensive • High survival rate from tagging • High retention rates over life of fish	• Machines expensive to rent or own • Fish must be sacrificed to recover tag information • Requires large sample sizes	
Passive Integrated Transponder	• 100% unique ID • Relatively inexpensive • No battery; lasts life of fish • Don't have to kill fish to read tag	• Size limits tagging to only largest fingerling • Retention rate variable and dependent upon tag location	

Table 3. Costs of Fall Fingerlings (Ffing) and Spring Yearlings (SprYr) Coded Wire Tagging study (5 year plan)

Coded **W**ire **T**agging			
Item	Quantity	Price(each)	Total
Mark IV – Tagging Unit	2	$2,120.00	$4,240.00
Handheld Wand Detector	1	$415.00	$415.00
Tags	7,000	$152/1000	$1,064.00
Shipping			$560.00
TOTAL			**$6,279.00**

- All equipment prices are based on 2011 monthly rental charges from Northwest Marine Technology, Inc.

Note: All coded wire tagging equipment and tags are currently being supplied by Area 8 Three Rivers Biologist during the one month rental period following the completion of the Paddlefish tagging program.

Table 4. Proposed cost of PIT Tagging purebred muskellunge fingerlings – Pilot study.

Passive **I**ntegrated **T**ransponder Tagging			
Item	Quantity	Price(each)	Total
MK10 Implanter	10	$5.00	$50.00
N125 Needles	20	$2.00	$40.00
PIT Tags (9mm)	100	$5.75	$575.00
601 Reader	1	$525.00	$525.00
Shipping			$20.00
TOTAL			**$1,190.00**

- All equipment prices are based on 2011 prices from Biomark, Inc.

Table 5. Proposed cost of PIT tagging all captured purebred muskellunge by AFM areas.

Passive **I**ntegrated **T**ransponder Tags			
Item	Quantity	Price(each)	Total
MK10 Implanter	24 (3 per AFM)	$2.00	$48.00
N125 Needles	80 (10 per AFM)	$2.00	$160.00
PIT Tags	400 (50 per AFM)	$5.75	$2,300.00
601 Reader / AFM	8 (1 per AFM)	$500.00	$4000.00
Shipping			$60.00
TOTAL			**$6,568.00**

- All equipment prices are based on 2011 prices from Biomark, Inc.

Note: Each AFM Area will have a portable PIT Tag Reader and approximately 50 PIT tags to inject all captured purebred muskellunge from 8-10 study lakes outlined in the management plan. Individual fish will be tagged onsite and given a unique id number. This will allow for tracking of individual fish, monitoring growth rates, establishing mortality rates and mark/recapture estimates.

Appendix B

Table 6 (expanded). Purebred muskellunge total catch-by-length-frequency in lakes, by gear type, for the period 1977 to 2007.

Size Groups (mm)	Day Boat EF	Night Boat EF	PA TrapNet	Seine	Exp Gill Net 6 Panel	Exp Gill Net 5 Panel	Constant Mesh Gillnet Floating	Constant Mesh Gillnet Sinking	Rod & Reel	Gill Net	Exp Gillnet 6 Panel Floating	Total Catch
100			2	1								3
125				5								5
150				8								8
175	6			4	1							11
200	2	4	3	1		1						11
225	1	7	2									10
250	1	14	4		1							20
275	1	24	7									32
300	2	11	6				1					20
325	1	15	1									17
350		12	1		1	1						15
375	1	2	4		1							8
400		3	4									7
425		1	4	1								6
450		5	1									6
475	2	1	3									6
500		3	4		2							9
525	1	6	4		2	1				1		15
550	1		6		2			1				10
575	1	1	7		1							10
600		1	17									18
625	1	1	18									20
650			44		4					1		49
675		2	39		7	2				1		51
700		6	64		6					1		77
725		2	78		3			1		1		85
750		1	84		4							89
775	4	2	131		1	1				2		141
800	1	3	140		1	1	1			1		148
825	1	1	182		2		1	4		1		192
850	2	2	197		1	1				1		204

Size Groups (mm)	Day Boat EF	Night Boat EF	PA TrapNet	Seine	Exp Gill Net 6 Panel	Exp Gill Net 5 Panel	Constant Mesh Gillnet Floating	Constant Mesh Gillnet Sinking	Rod & Reel	Gill Net	Exp Gillnet 6 Panel Floating	Total Catch
875	1	3	168				1			1		174
900		2	178			1		2		2		185
925		2	152			1		1		2		158
950			157							2		159
975			125		1	1		1				128
1000		2	107		1	1		2		4		117
1025		2	71		2					2	1	78
1050	2	2	59									63
1075		1	65					2				68
1100			44		1							45
1125			34									34
1150			38									38
1175	1		21									22
1200			23			2				1		26
1225			10						1			11
1250			7									7
1275			2				1					3
1300			1									1
Total	33	144	2319	20	45	14	5	14	1	24	1	2620
Unmeasured		1	60	5								66
Grand Total	33	145	2379	25	45	14	5	14	1	24	1	2686
% of Total	1.2	5.4	88.6	0.9	1.7	0.5	0.2	0.5	0.04	0.9	0.04	

Table 7 (Expanded). Tiger muskellunge total catch–by-length-frequency in lakes by gear type for the period 1977 to 2007.

Size Groups (mm)	Day BoatEF	Night BoatEF	BackPackEF	PA TrapNet	ConnTrapNet	Seine	Exp Gill Net 6 Panel	Exp Gill Net 5 Panel	Constant Mesh Gillnet Floating	Constant Mesh Gillnet Sinking	Gill Net	Total Catch
75						1						1
100						6						6
125		1		1		1						3
150	4	2										6
175	26	9				3						38
200	74	11		2		5						92
225	59	38		12		1	1					111
250	25	56	1	29		4	2					117
275	14	50		30								94
300	14	31	1	18			2					66
325	13	28	2	8	1		5					57
350	6	17		15			5	1				44
375	8	7		5	1	1	2					24
400	6	14		5		1						26
425	2	7		8		1	1					19
450	1	4		8								13
475	1	13		10			3				1	28
500	1	5		11	1		3				1	22
525	1	3		11			5	2				22
550	2	11		14						1	1	29
575	2	5		13			10		1		1	32
600	4	3		8			8				1	24
625	1	9		15			3			1	1	30
650	3	6		11			7		2	2	3	34
675		2		14			15	1	3	2	4	41
700	1	5		19			3	4	2	2	6	42
725	2	3		29			9		11	7	4	65
750	2	9		22			6	1	9	2		51
775	1	4		31			3	1	6	3		49
800		4		23			2	1	8	5		43
825		4		28			5		7	4	1	50
850	2	1		24			5		2	2	2	38
875		5		19			4	1	3		1	33
900	1	2		23			2		2	3	3	36

Size Groups (mm)	Day BoatEF	Night BoatEF	BackPackEF	PA TrapNet	ConnTrapNet	Seine	Exp Gill Net 6 Panel	Exp Gill Net 5 Panel	Constant Mesh Gillnet Floating	Constant Mesh Gillnet Sinking	Gill Net	Total Catch
925		3		16			5		1	4		29
950		1		19			6		1	9		36
975	1	1		11			1	2		2		18
1000				13			2		1	1		17
1025		1		8			1	2	1			13
1050	2	2		8						1		11
1075		1		9				1	1	1		13
1100				3								3
1125								1				1
1150				3								3
1175	1			3					2			5
1200				2								2
1225				2								2
1250												0
1275				1								1
Total	277	378	4	564	3	24	126	19	63	52	30	1540
Unmeasured		3		1								4
Grand Total	277	381	4	565	3	24	126	19	63	52	30	1544
% of Total	17.9	24.7	0.26	36.6	0.19	1.6	8.2	1.2	4.1	3.4	1.9	

Appendix C

Standard Operating Procedures
November 2011
Adult muskellunge sampling in lakes and impoundments.

Objectives: (1) Estimate the density of muskellunge and tiger muskellunge in lakes and impoundments primarily based on 24 hour spring trapnet catches. On muskellunge managed standing waters where trapnetting is ineffective closely tended gillnets will be recommended.

(2) Use catch per 24 hour spring trapnet catch to compare to established benchmark to maintain a muskellunge management program on lake.

(3) Standardize sampling procedures in sampling muskellunge and tiger muskellunge to allow for consistent information collection that will facilitate comparison of muskellunge managed standing waters across Pennsylvania.

(4) Document any changes in density or trends in density through time.

(5) Document any changes in size or age structure.

(6) Document any changes in growth, condition and mortality.

Water Selection & Sampling sites: Muskellunge and tiger muskellunge have been periodically monitored in lakes and impoundments since 1974 and were usually sampled during routine inventory of the entire fish community. Very few surveys conducted in the past primarily targeted muskellunge. This often led to sampling at less than optimum times for muskellunge. Future surveys of muskellunge managed standing waters should be designed to sample during optimum catch periods for this species. Sampling site locations can be either historical sites or sites chosen by the Area Fisheries Manager. When new sites are chosen and trapnets are the preferred gear, sites should be restricted to relatively shallow areas where this gear can be fished coupled with a random method of selecting locations.

Sampling Dates: Sampling should take place between early April to mid May if possible with adjustment for latitudinal differences and annual spring weather variation. This is during the spawning period when muskellunge are most vulnerable to trap net gear. Sampling should begin once water temperatures are consistently above 10° C.

Sampling effort: Sampling effort should include at least 20 net sites per survey. If however, past sampling effort exceeded this level then that should be duplicated. Effort recorded will be determined by hours of trap net soak time. An individual trapnet site will be considered one overnight set roughly equivalent to 24 hours in length. If gillnets are used site length will be shorter given that nets must be frequently checked for catches to avoid stressing any captured muskellunge.

Sites location: Record or update the latitude, longitude (determined by GPS using NAD83 datum, in decimal degrees format), date, and water name.

Sample Targets: Primary targets are all sizes of muskellunge and tiger muskellunge. Recording information on other sport and panfish is recommended.

Disease Incidence: Please record any sign of disease, such as red spot, lesions, hemorrhaging or wounds with photos where appropriate.

Gear: On standing water where Pennsylvania trapnets are effective in catching muskellunge:

Pennsylvania trapnets and associated trapnet lead nets, anchors, buoys and ropes.
Trap net boat, outboard, fuel tank, oars, boat hook,
Safety equipment (fire extinguisher, signaling device, throwable flotation device, boat anchor)
Measuring board, data forms, scale envelopes, scale knife, and clipboard
Various weighing devices that can accurately weigh both small yearling muskellunge and very large and heavy adult fish
Thermometer and conductivity meter
Fish holding equipment tubs, buckets, and recirculating pumps with automotive battery
Heavy duty nets, GPS unit, Camera, spare AA batteries

Gear: On lakes where Pennsylvania trap nets are **not** effective in catching muskellunge:

Six panel floating 5 inch stretch constant mesh gillnets and associated anchors, ropes and floats
Boat, outboard, fuel tank, oars, boat hook
Safety equipment (fire extinguisher, signaling device, throwable flotation device, boat anchor)
Measuring board, data forms, scale envelopes, scale knife, and clipboard
Various weighing devices that can accurately weigh both small yearling muskellunge and very large and heavy fish
Thermometer and conductivity meter
Fish holding equipment tubs, buckets, and recirculating pumps with automotive battery

Heavy duty nets, GPS unit, Camera, spare AA batteries

Sampling Procedure: Measuring and weighing the muskellunge in the sock net allows for easier control and facilitates processing with the least chance of stressing these large and powerful fish.

When using gillnets, closely monitor and check the nets for any captured muskellunge to avoid stressing the fish. Avoid overnight sets for muskellunge when using gillnets.

Safety: Personnel should wear PFDs and follow all PFBC boating safety guidelines.

Data Collection: Record length to the nearest mm and weight to at least the nearest 10 gram increment by species of all muskellunge and tiger muskellunge at each trap net site. Determine and record the sex of all mature muskellunge and tiger muskellunge either by extrusion of gametes or through the method outlined in Lebeau and Pageau (1989). A scale sample should be obtained for every muskellunge and tiger muskellunge for age and growth analysis. Record specific conductance of the lake once daily and record water temperature each individual net set daily.

Data Transfer and Processing: Data entry into the Agency Resource Database will be carried out by Area Managers or their designees

Appendix D

Standard Operating Procedures
November 2011
Adult muskellunge sampling in flowing waters.

Objectives: (1) Estimate the density of muskellunge and tiger muskellunge per hour of electrofishing effort (CPUE) or meter of shoreline sampled.

(2) Establish a baseline of CPUE to use to evaluate the level of density needed to maintain a management program on flowing water.

(3) Establish sampling procedures that allow the most effective methods of sampling muskellunge populations in flowing waters.

Water Selection & Sampling sites: Waters should be chosen by Area Fisheries Managers and should have the greatest probability of catch of muskellunge and tiger muskellunge. Selection of sample sites is governed by the ability to access the water by boat and conduct night electrofishing operations. This means long deep pools are best to sample.

Sampling Dates: Sampling time of the year for muskellunge on flowing waters has not been rigorously evaluated in the past and at this time no set period appears to be optimum for maximizing catch. Sampling for adult muskellunge can be conducted at any time and can be incorporated into other sampling efforts such as adult black bass or fall walleye young-of-year sampling.

Sampling Effort: Time, distance, and catch should be recorded for each electrofishing run. Recommended individual electrofishing run time is 20 minutes. Where electrofishing collections depart from shoreline areas, distance or distance tracks (GPS) should be recorded for each electrofishing run as well as electrofishing time for each run.

Sample site selection: Sites sampled on each water will be limited to areas accessible by boat and trailer, generally deep long pools. This coincides with adult muskellunge habitat. Night boat electrofishing is recommended as a sampling method as it gives the greatest probability of catches. Day boat electrofishing may also be used in areas of rivers where night boat electrofishing would not be considered safe. Past sampling has suggested vegetated coves and back channels often hold adult muskellunge.

Sites measurement: It is recommended that sampled distances be measured with a hip-chain rangefinder or GPS unit.

Sample Targets: Primary target species include all sizes of muskellunge and tiger muskellunge including young of year. Sampling of other fish species is secondary.

Gear: Flatbottom boat equipped with bow safety railing, outboard, fuel tank, navigation lights, fish collection lights, and oars. Safety equipment (fire extinguisher, signaling device, throwable flotation device, anchor, flashlight, night distress signal) Electrofishing boom configured with two sets of four copper droppers**.** Measuring board, data forms, scale envelopes, scale knife, and clipboard. Various weighing devices that can accurately weigh both small yearling muskellunge and very large and heavy fish. Thermometer, and conductivity meter. Fish holding equipment tubs, buckets, and recirculating pump with automotive battery. Long handled landing nets sufficient to retain a 1000 to 1270 mm muskellunge, GPS Unit, rangefinder, hip chain and scale-knife.

Safety: Personnel will wear PFD's at all times when underway. Personnel should be cognizant of waterfowl hunters and notify appropriate personnel of night time operations given increased security applied to structures on our waterways.

Electrofishing set up: A dual set of droppers (4) affixed to two booms should be used to make all collections. Voltage, amperage (or watts) and pulse width (for those with variable pulse width) should be adjusted to deliver between 3 and 6 amps of current to the anode array. Two bow netters should collect stunned targets and secondary targets.

Date Collection: Record all muskellunge and tiger muskellunge catches. Measure each fish to the nearest mm and weigh to the nearest 10 g increment. Determine and record the sex of all mature muskellunge and tiger muskellunge either by extrusion of gametes or through the method outlined in Lebeau and Pageau (1989). Take scale samples from all captured muskellunge and tiger muskellunge. Note any sign of disease such as red spot, hemorrhages, lesions, sores, fungus or parasites. Record gauge height and discharge from the nearest USGS gauging station on the date and time of collection. Record surface water temperature (and time) and specific conductance at the time collections are made.

Data Transfer and Processing: Area personnel will be expected to enter the data into the Agency Resource database.

References

Lebeau, B., and G. Pageau. 1989. Comparative urogenital morphology and external sex determination in muskellunge, Esox masquinongy Mitchell. Canadian Journal of Zoology 67:1053-1060.

Appendix E

Draft
Standard Operating Procedures
November 2011
Muskellunge Young of-Year (Y-O-Y) Sampling in Flowing Waters

Objectives: (1) Determine the extent of natural reproduction in rivers and streams.
(2) Estimate density of muskellunge Y-O-Y per 300 m of shoreline in selected rivers and streams. Density recorded both as catch per effort and catch per m of shoreline electrofished.
(3) Establish a baseline of occurrence, density and variation in density through time in order to guide future restoration efforts.
(4) Identify critical nursery habitat for increased protection and restoration.

Water Selection & Sampling sites: Flowing waters should be selected where AFMs have evidence to suggest that natural reproduction of muskellunge may be occurring through sampling of Y-O-Y muskellunge in waters prior to stocking by hatcheries. Waters not stocked with muskellunge or likely to have stocked muskellunge moving in from other stocked waters that have historic catches of Y-O-Y muskellunge may also be chosen. Individual 300 m sites should be selected where the likelihood of capturing Y-O-Y muskellunge is greatest. Generally, these sites are heavily vegetated and range from 0.2 to 1.25 m in depth.

Sampling Dates: Sampling should take place prior to stocking of hatchery reared muskellunge in the survey water if this is occurring. Identify the hatchery that is designated to stock the water and maintain communication as to when the stocking will take place. Generally, muskellunge stocking takes place in September but may occur earlier if hatchery operations warrant an earlier stocking date. This suggests a July to August sampling period. Y-O-Y muskellunge sampling can be accomplished independently or by incorporation with smallmouth bass Y-O-Y sampling if it does not lessen the results of that study or this effort.

Sampling effort: The 300 m site distances should be accurately measured with a hip-chain or rangefinder. Sites measurement: The latitude, longitude (determined by GPS using NAD83 datum, and decimal degrees format), river mile (determined by Terrain Navigator or ArcGIS at the office), date, and water name of the downstream-most location of each 50 m site within a site group should be recorded or updated as required. All measurements should relate to the

downstream-most location of each 300 m site. In addition it is encouraged that proximity to a physical landmark be recorded on a field data form using a rangefinder for the downstream-most site of a site group. (e.g. start 350 m upstream of SR22 bridge).

Sample Targets: Primary targets are Y-O-Y muskellunge. Identification of Y-O-Y muskellunge can be difficult in the field and the taking of voucher specimens may be necessary to insure correct identification back at the office. Y-O-Y muskellunge are usually between 100 and 200 mm in July or August.

Disease Incidence: For each river/stream please note any disease incidence in your catch sample and characterize it as to type (e.g. sore, lesion, parasite, hemorrhage, eroded fin, fungus, etc.).

Gear: One may choose between backpack electrofishing or day electroboat depending on which method is deemed potentially more effective in capturing Y-O-Y muskellunge. Coffelt backpack electrofisher–with two 12" diameter electrodes constructed of 3/8"o.d. stainless steel or aluminum. The shocking unit should be capable of producing 75-125 watts of output power using Alternating Current (AC). Shocking should take place at near shore locales from 0.2 m depth to approximately 1.5 m depth at a typical distance of 3-6 m or more from shoreline. If employing day boat electrofishing the gear needed would be flatbottom boat equipped with bow safety railing, outboard, fuel tank, and oars. Safety equipment (e.g., fire extinguisher, signaling device, personnel PFD's, throwable flotation device, anchor,). Electrofishing boom configured with two sets of four copper droppers**.** Measuring board, data forms, scale envelopes, scale knife, and clipboard, thermometer, and conductivity meter, fish holding equipment tubs, buckets, and recirculating pump with automotive battery.
GPS Unit, rangefinder, hip chain, scale-knife
Measure water temperature and specific conductance prior to collection

Safety: Personnel should follow all PFBC electrofishing safety guidelines.

Data Collection: Note visibility problems if they exist (typically few exist in summer). Record individual length of each YOY muskellunge to the nearest mm and time electrofished for each 300 site.

Data Transfer and Processing: Data entry in Agency Resource Database by AFM or designee.

Appendix F

Standard Operating Procedures
November 2011
Muskellunge Management Change Evaluation

Objectives: (1) Estimate abundance of muskellunge per 24 hour spring trap net site in lakes and impoundments. Assessments should occur at historic sites or sites randomly identified by the Area Fisheries Manager.
(2) Document any changes in abundance or trends in abundance through time.
(3) Document any changes in size or age structure.
(4) Document any changes in growth, condition and mortality.

Study Start Date and Duration: The evaluation can begin in 2013, which should allow for the management changes to fully or nearly fully manifest themselves in the population. At least five years of post treatment evaluations should be completed within a 10 year period after the start of sampling.

Water Selection & Sampling sites: Muskellunge and tiger muskellunge have been periodically monitored in lakes and impoundments since 1974 which covers the time period for all pretreatment surveys that may be used in the evaluation. The selection of study lakes for this survey is dependent primarily on the waters where at least five or more surveys have previously been performed where muskellunge or tiger muskellunge were targeted, and the ability of trap nets to effectively sample muskellunge or tiger muskellunge populations in these waters. Based on these criteria the following muskellunge or tiger muskellunge waters are recommended for each Area sample during this evaluation:
Area 1 – Lake Arthur
Area 1 – Pymatuning Reservoir as control water.
Area 2 – Lake Canadohta
Area 3 – Glendale Lake
Area 4 – Francis Slocum Lake
Area 5 – Beltzville Lake
Area 6 – Blue Marsh Lake
Area 7 – Little Buffalo Lake
Area 8 – Lake Somerset
These waters were chosen because of the amount of past survey information available which should allow the best chance of detecting a change in population density and size structure due to the management changes made in 2007. Area Fisheries Managers may choose different study waters if they have the appropriate rationale subject to the approval of the Division Chief.

Sampling Dates: Sampling should take place between mid April and mid May if possible with adjustment for latitudinal differences and annual spring weather variation. This time frame is during the spawning period when muskellunge are most vulnerable to trap net gear. Sampling should begin once water temperatures are consistently above 10° C.

Sampling Effort: Sampling effort should include at least 20 net sites per survey. If however, past sampling effort exceeded this level then that should be duplicated. Effort recorded will be determined by hours of trap net soak time. An individual site will be considered one overnight set roughly equivalent to 24 hours in length.

Sites Location: Record or update the latitude, longitude (determined by GPS using NAD83 datum, in decimal degrees format), date, and water name.

Sample Targets: Primary targets are all sizes of muskellunge and tiger muskellunge. Recording information on other sport and panfish is necessary as stated previously in the management plan.

Disease Incidence: Please record any sign of disease, such as red spot, lesions, hemorrhaging or wounds with photos where appropriate.

Gear: Pennsylvania trap nets and associated anchors, lead nets, ropes and floats.
Trap net boat, outboard, fuel tank, oars, boat hook,
Safety equipment (fire extinguisher, signaling device, throwable flotation device, boat anchor)
Long, narrow, small mesh sock net with a sturdy handle
Measuring board or device capable of measuring fish often longer than the standard meter board, data forms, scale envelopes, scale knife, and clipboard
Various weighing devices that can accurately weigh both small yearling muskellunge and very large and heavy fish
Thermometer and conductivity meter
Fish holding equipment tubs, buckets, and recirculating pumps with automotive battery
Heavy duty nets, GPS unit, Camera, spare AA batteries
PIT tags if available and tagging equipment

Sampling Procedure: Measuring and weighing the muskellunge in the sock net allows for easier control and facilitates processing with the least chance of stressing these large and powerful fish.

Safety: Personnel should wear PFDs and follow all PFBC boating safety guidelines.

Data Collection: Record length to the nearest mm and weight to at least the nearest 10 gram increment by species of all muskellunge and tiger muskellunge at each trap net site. Determine and record the sex of all mature muskellunge and tiger muskellunge either by extrusion of gametes or through the method outlined in Lebeau and Pageau (1989). A scale sample should be obtained for every muskellunge and tiger muskellunge for age and growth analysis. If available tag all muskellunge with PIT tags. In succeeding years after muskellunge have been PIT tagged follow up studies will be conducted to detect presence of tagged fish. Record specific conductance of the lake once each day and record water temperature at each individual trap net site daily.

Data Transfer and Processing: Data entry into the Agency Resource Database will be carried out by Area Managers or their designees.

Recommendations for an Evaluation Study

1. At least five years should elapse following implementation of regulations to allow the effect of the treatment to manifest itself on the population. We recommend a post-treatment sampling start date of 2013.
2. Evaluate at least eight (8) lakes within the Commonwealth managed for muskellunge or tiger muskellunge, selecting one lake within each Fisheries Management Area. These lakes should be selected by the Area Fisheries Manager.
3. Candidate waters should have at least five (5) previous surveys where muskellunge were targeted as part of the sampling effort. It is preferred that these surveys would have been completed prior to 2007, but if that is not possible, then no later than 2010. Consideration should be given, when available, to waters with more than five (5) previous surveys. These waters may provide a higher likelihood of detecting a change in the post-treatment population.
4. Lake surveys should be conducted using PA trap nets. Sampling using PA trap nets should be conducted during the spring spawning period when water temperatures reach, and consistently exceed, 50° F and when muskellunge are most vulnerable to this type of gear. This assessment should consider historical sampling protocols/sites to reduce sampling variation. Due to sample size considerations and the amount of historical data available for pre-treatment comparison, lakes that cannot be effectively sampled by PA

trap nets, as well as flowing waters, should not be chosen for the post-treatment component of this study.

5. A minimum of five (5) annual post-treatment surveys should be completed prior to evaluating the effects of management actions. These five surveys should be completed within a 10-year period after sampling has been initiated.
6. A minimum of 20 trap net sites per survey are required to achieve a sufficient sample size for detecting a treatment effect (i.e., management actions). However, if historical surveys used more than 20 sites, then that sample size should be replicated.
7. Include Pymatuning Reservoir as a "control" lake since management of this water has been maintained under the previous regulations of 30-inch minimum size and two fish per day creel.
8. Measure all muskellunge captured to the nearest mm and weigh to at least the nearest 10 g increment.
9. The sex of all mature muskellunge should be determined. If extrusion of gametes is not possible, Lebeau and Pageau (1989) provide a method of sexing mature muskellunge using the difference in shape of the urogenital pore between males and females.
10. A scale sample should be taken on all captured muskellunge for age and growth analysis.
11. Tagging of all captured muskellunge should be done using PIT tags. This will allow both the tracking of individual sampled muskellunge throughout the survey and mark and recapture estimates through multiple years to be accomplished.
12. Test for changes in abundance with analysis of variance of the grand mean of pretreatment survey to the grand mean of the post-treatment surveys.
13. Test for changes in population size structure using Kolmogorov-Smirnov tests.
14. Test for changes in growth, condition and mortality, where possible.

Recommendations for minimum general inventory sampling

1. Length, weight, scales and sex information should be routinely collected on all muskellunge caught during survey work. The infrequent catch of muskellunge indicates that greater effort should be made to collect data whenever fish are captured.
2. Muskellunge must be the primary sampling target in waters where they are stocked to concisely identify future management changes/needs. Often, muskellunge are sampled at less than optimum times on waters because other sportfish take precedence over them in

choosing sampling gear and times. Managers need to identify data needs in waters now stocked with muskellunge, and intensify efforts to adequately evaluate their populations. This information can then be used to justify continued muskellunge management and improve the quality of the fishery, where possible.

3. The sex of all adult muskellunge should be determined, if possible. This information provides much more accurate age, growth and condition analysis for planning management strategies for muskellunge.

References

Lebeau, B., and G. Pageau. 1989. Comparative urogenital morphology and external sex determination in muskellunge, Esox masquinongy Mitchell. Canadian Journal of Zoology 67:1053-1060.

Evaluation Sampling Design

The sampling design for evaluating change in abundance or CPUE for muskellunge and tiger muskellunge followed that developed by Lester *et al*. (1996) and here utilized trap net CPUE data collected from Pennsylvania lakes. Lakes that are effectively sampled with PA trap nets are the primary target waters for this evaluation because PA trap nets were the most consistently and uniformly used gear to obtain the best pre-treatment information. Pre-treatment data was used to calculate the required sampling effort and duration to detect a change in population abundance caused by the treatment detailed above. Among-year variance was calculated, which is caused by natural variation in recruitment and mortality, but also by changes in catchability of the gear caused by weather conditions (Lester *et al*. 1996). The sample size in years must be large enough to detect a change in the population related to the treatment against a backdrop of this annual variation (Lester *et al*. 1996). Within-year variance or variation in catch among sites was also calculated. The level of sampling effort recommended accounts for variability in CPUE both within years trapnet lifts and between years trapnet lifts. We plot the number of years (before and after combined) to be sampled as a function of the detectable change (R) in CPUE in study waters at significance levels α=0.05 and 0.10, at various power levels and at various annual sampling rates: 20, 40, and 60 lifts (Figures 15a & 15b). Detectable change is the detectable "number fold" change in CPUE using computed CPUE variability values; thus R=1.2 is a 1.2 fold change or potentially a more

than doubling of CPUE. Lester *et al*. (1996) stated that to detect change related to the treatment, a lengthy study in years is often necessary to take into account the high annual variability of abundance estimates, which cannot be greatly reduced by increasing the within-year sample size. Based upon these analyses we have recommended a minimum of 20 net lifts per water annually (Figures 15a & 15b) with a minimum of 5 years of post-treatment sampling.

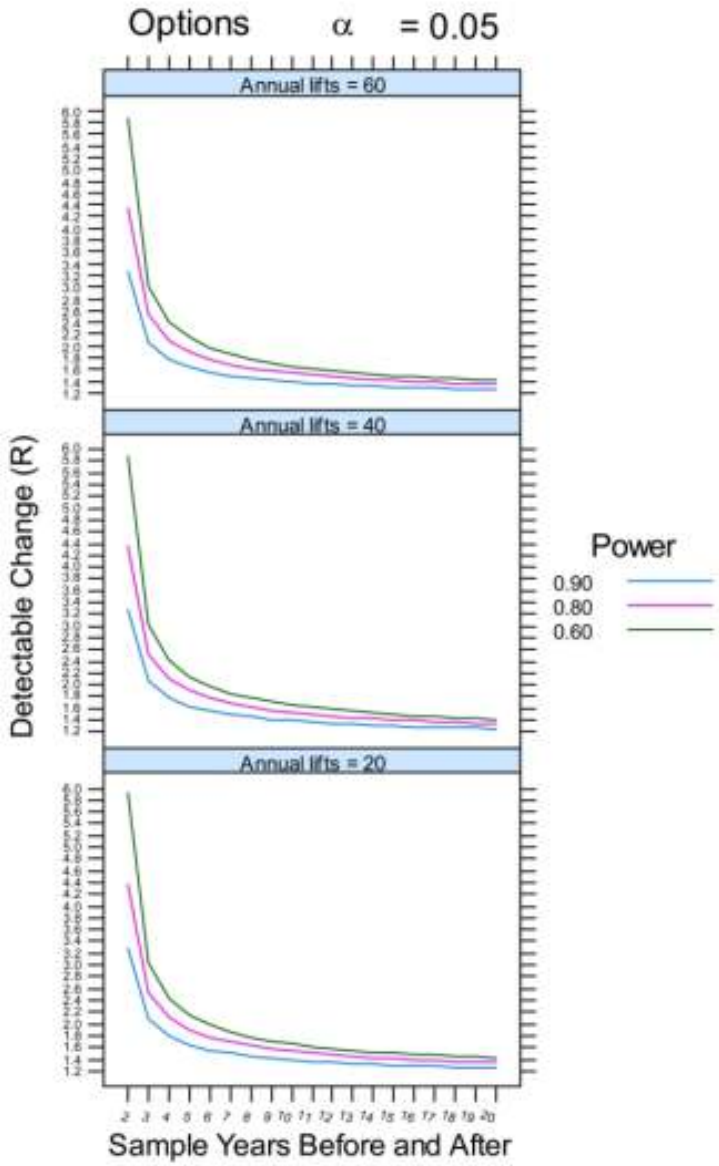

Figure 1a. Prediction of sampling effort needed to detect a change in abundance in muskellunge from management changes at different power levels and a significance level a=0.05.

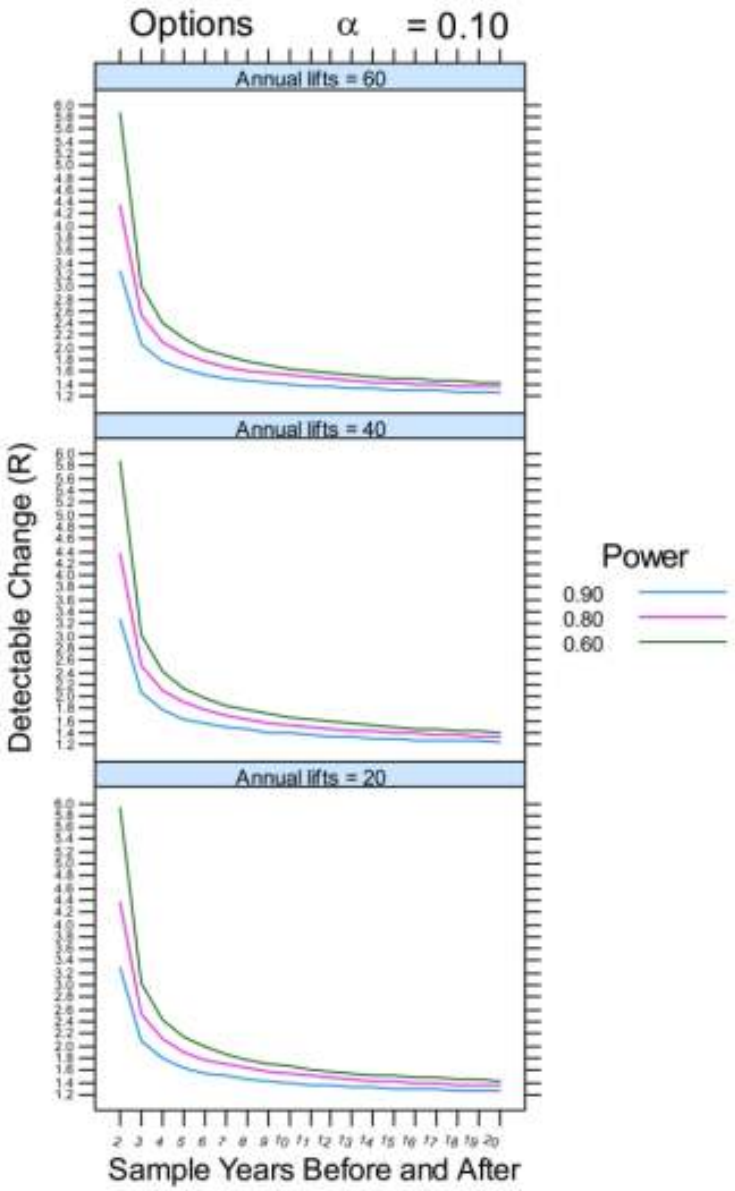

Figure 1b. Prediction of sampling effort needed to detect a change in abundance in muskellunge from management changes at different power levels and a significance level a=0.10.

Appendix G

Summary of public comments to the Pennsylvania Muskellunge Management Plan

Following the publishing of the Pennsylvania Muskellunge Management Plan on the Pennsylvania Fish and Boat Commission web site http://www.fish.state.pa.us/ and distribution to the public through other means, a public comment period was observed for muskellunge anglers and other interested parties to provide input on the plan and on muskellunge management in Pennsylvania. The Pennsylvania Fish and Boat Commission also hosted an evening meeting on October 2, 2012 in Allegheny County to preview its draft Pennsylvania Muskellunge Management Plan and to provide opportunities for public comment. This meeting was well attended by the public with a beneficial exchange of information, suggestions and opinions between muskellunge anglers and agency personnel.

A total of 61 comments were received through the PFBC website. Comments came in from all regions of Pennsylvania indicating that musky fishing truly is a statewide fishery with dedicated anglers throughout the Commonwealth. Most opinions and concerns fell into the broad categories of the muskellunge stocking program and regulations affecting muskellunge. Anglers often provided detailed commentary on muskellunge management covering several topics in a single email. Other topics such as the effect of aquatic vegetation herbicide treatments on muskellunge fisheries (4), educating the public to counteract the negative opinion many general anglers have of musky (4), conducting creel surveys on muskellunge managed waters (2), creating a musky tag or stamp (5) and volunteering to help in the muskellunge management program (4) were also brought up.

Within the broad category of the muskellunge stocking program calls to continue, resume or add stocked waters (25) were most commonly received from anglers. Calls to stock larger and older muskellunge (7), stock more muskellunge (5), refine and improve methods and procedures of stocking a water (3), stock fewer waters (2), and stock more waters (2) were also received. Many of the comments on the stocking program advocated stocking purebred musky over tiger musky (10).

Regulation comments most often called for more restrictive regulations on muskellunge harvest, either through increasing the statewide minimum size limit (8) with a variety of lengths suggested such as 42, 45, 48 or 50 inches. Implementation of the 45 inch special regulation was called for on certain waters (2) and catch and release fishing was proposed on certain waters or statewide (3). While most anglers were either satisfied with current minimum size regulations or advocated increases, two felt regulations were too severe and should be returned to the previous 30 inch minimum size. Closing the spawning period was also mentioned by one angler as was in effect prior to the 2007 regulation changes.

Muskellunge anglers are dedicated and involved in their fishing and they are interested in ways to improve fishing and many are willing to pay more or volunteer to make this happen. They are generally very attached to their favorite muskellunge fishing locations and are open to changes that they think will improve fishing and very opposed to changes that they think might cause damage. Thanks to all the anglers that took time to provide comments on musky management.