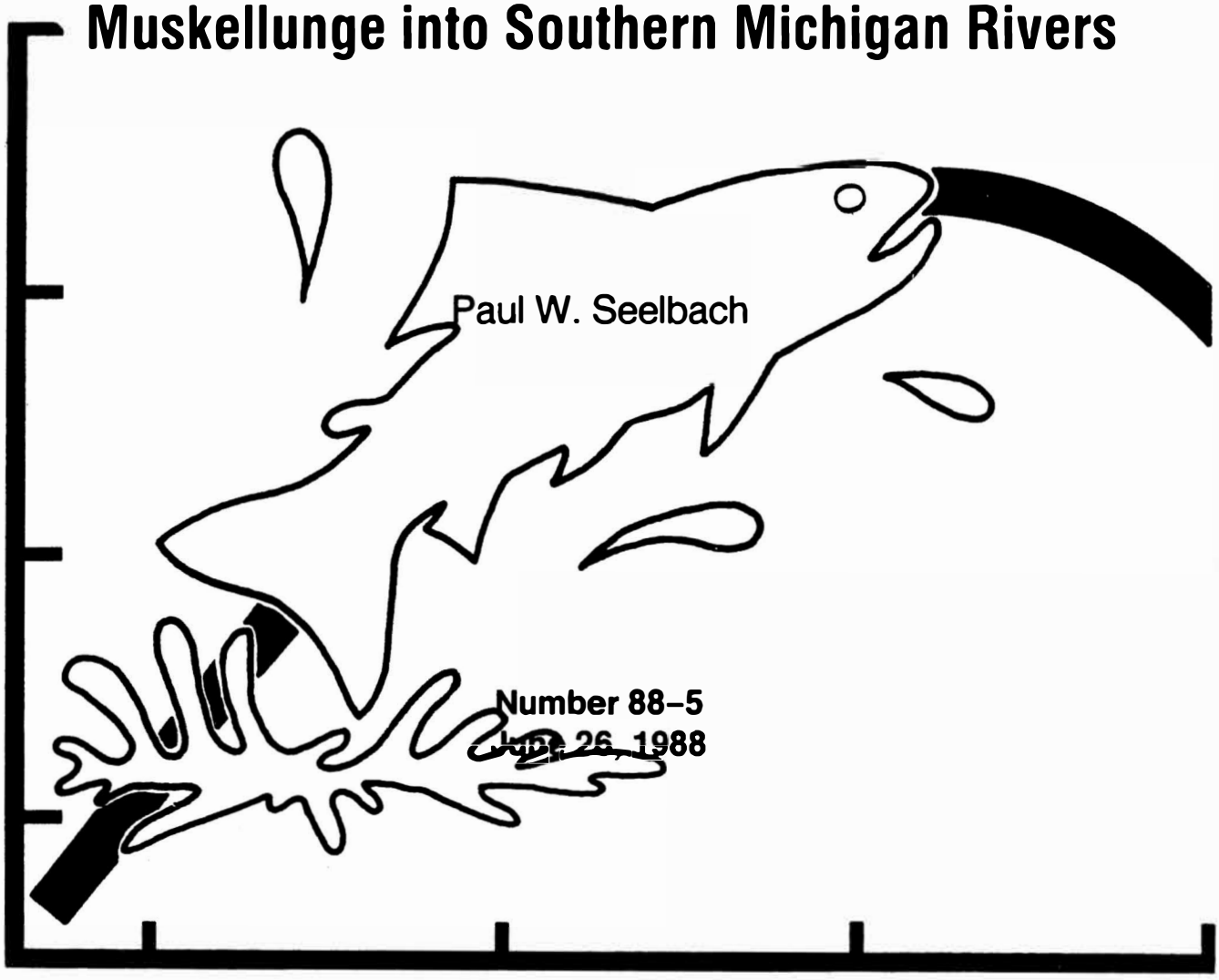
FISHERIES DIVISION

TECHNICAL REPORT

Considerations Regarding the Introduction of Muskellunge into Southern Michigan Rivers



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CONSIDERATIONS REGARDING THE INTRODUCTION OF MUSKELLUNGE INTO SOUTHERN MICHIGAN RIVERS[1]

Paul W. Seelbach

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[1]A contribution from Dingell-Johnson Project F-35-R, Michigan

INTRODUCTION

The Michigan Department of Natural Resources (MDNR) is considering introduction of a riverine form of the muskellunge (*Esox masquinongy*) into some inland warmwater rivers in southern Michigan (Scott et al. 1985). These rivers presently support, to various degrees, sportfishing for smallmouth bass (*Micropterus dolomieui*), northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), channel catfish (*Ictalurus punctatus*), and rock bass (*Ambloplites rupestris*) (Towns 1987). However, fish communities in these rivers are dominated by rough fish (70–90% by biomass and 50–90% by numbers) including suckers (*Catostomus commersoni* and *Hypentelium nigricans*), redhorse (*Moxostoma* sp.), and carp (*Cyprinus carpio*), and fishing interest in most areas is relatively low. The MDNR is hoping that introduction of the muskellunge would add a large, attractive predator to these river fisheries. In addition it could feed on the abundant, presently underutilized, rough fishes present.

The muskellunge is the largest esocid and a voracious predator which is highly regarded as a trophy sport fish throughout its range (Porter 1977; Becker 1983; Crossman 1986). Angling for muskellunge has a rare "charisma" (Porter 1977) due to the fish's large size (adults are commonly greater than 30 inches), its vicious fighting abilities, and its moody behavior. It is one of the few sport fishes to generate enough interest to prompt the formation of significant angler organizations (the two largest are Muskies, Inc., and Muskies Canada, Inc.), groups which can be important allies of resource agencies in fishery development and environmental protection (Oehmcke et al. 1986).

The muskellunge is found in both lakes and rivers, however, Crossman (1986) stated that it may have originally been a riverine species which secondarily became a lake dweller during the post-glacial dispersal period. It became established in the Great Lakes basin during this period. Early records show that the muskellunge was well known from coastal waters on both sides of southern Michigan and from some Lake Michigan-drainage inland waters, including Gun Lake, Thornapple Lake, and the Thornapple River (Hubbs 1933). Additional anecdotal records indicate that muskellunge were native to a number of southern Lake Michigan tributaries (D. Johnson, personal communication, 1988, MDNR, Plainwell). No records of the muskellunge in inland southeastern Michigan rivers exist (Hubbs 1933; MacGregor et al. 1960; Crossman 1978). It is not clear whether the apparent absence of the muskellunge from this area of the state is a result of actual habitat limitations or dispersal patterns, or whether the muskellunge was originally present in some of the rivers in this area but accurate records are lacking (E. J. Crossman, personal communication, 1988, Royal Ontario Museum, Toronto). Large muskellunge populations once existed in the Maumee River, an Ohio tributary to western Lake Erie (Clark 1964) and large populations presently exist in Lake St. Clair (Crossman 1986). It seems feasible that muskellunge populations may have existed in the

Michigan tributaries of lakes Erie and St. Clair. None of the original southern inland populations exist today; these were presumably destroyed as water quality deteriorated during the industrialization of the early 1900s. Following the clean water legislation of the 1970s, water quality improved dramatically, however, the native muskellunge were gone. One self-sustaining muskellunge population, the product of stocking of the northern form (muskellunge "forms" are discussed below), currently exists in the Thornapple River system in southwestern Michigan (D. Johnson, personal communication, 1988, MDNR, Plainwell). Muskellunge are presently stocked in several lakes in southern Michigan but not in rivers. As the muskellunge was native to certain waters in southern Michigan but not to others, the MDNR's interest in introducing this fish could be considered a reintroduction to some waters and an introduction to others. As the records are not clear on the original distribution of this species, and as the term "introduction" probably elicits more caution than does "reintroduction", in this paper I will take a conservative stance and treat both situations as introductions.

The introduction of muskellunge into southern Michigan rivers would involve both potential benefits and risks. The American Fisheries Society (AFS) has developed a protocol for introductions designed to increase the odds that the benefits will outweigh the risks (Kohler and Courtenay 1986). The first three steps in this protocol are as follows: (1) Rationale—outline the reasons why the proposed introduction would be better than existing native species; (2) Search—consider all possible contenders for introduction; and (3) Preliminary impact assessment—review the literature and examine potential impacts. The objectives of this paper are to review the literature on the biology and management of riverine muskellunge, carry out the above three protocol steps, assess the potential for its successful introduction, and if deemed appropriate, suggest a course of action for introduction and evaluation.

Biology and Management of Riverine Muskellunge

Detailed studies of riverine muskellunge populations are few. The following discussion incorporates information from these and, where appropriate, studies of lake populations.

Taxonomy and distribution

Three forms of the muskellunge are recognized based on coloration patterns and general distribution patterns (Crossman 1978). The northern or western form is generally found in northern Wisconsin, Minnesota, the northwestern border of Michigan's Upper Peninsula, and southern Ontario. The Great Lakes form is found in the Great Lakes, in the large connecting rivers, and in connected inland waters. The muskellunge which were native to Michigan's southwestern rivers were of this form. The Ohio form is found in the upper Ohio River drainage and in Chataugua Lake, New York. It is not clear whether any ecological differences

exist among these forms. In fact, all three color forms have been found to occur together in certain locations (Crossman 1986). Ecological differences may exist, however, among populations. Evidence supporting this idea includes the demonstration of distinct genetic population groupings (Koppelman and Philipp 1986) and among-population differences in spawning habits (see below). Riverine muskellunge populations are found within all three forms and throughout the species' range. Within Michigan, self-sustaining riverine populations presently exist in the Thornapple River system in southwestern lower Michigan and in the Tahquamenon River in eastern upper Michigan (D. Johnson and J. Schrouder, personal communication, 1988, MDNR, Plainwell and Newberry, respectively).

Abundance

Riverine muskellunge are solitary predators which are found in low densities. Miles (1978) and Brewer (1980) reported adult densities in Ohio River drainage streams to average about 1.5 to 2.2 fish per hectare (0.7–1.0 per acre), with the highest densities ranging from 3.5 to 4.5 fish per hectare (1.6–2.0 per acre).

Age, growth, and maturity

Muskellunge are long-lived fish which commonly attain ages of 15 years or more (Porter 1977; Becker 1983). The older fish reported from riverine populations typically range in age from 6 to 9 years (Miles 1978; Scott and Crossman 1979; Monaghan 1985). Growth varies among populations (Hourston 1952). Reasons for this are not well understood, however, the availability of large forage fishes has frequently been suspected to be the primary factor. No trends in growth have been seen among the three forms, however, growth in the middle latitudes of the species' distribution is generally faster than at the northern or southern extremes (Parsons 1959; Schrouder 1973). Fish in relatively fast-growing populations generally reach 762 mm (30 inches) and 3.2–3.6 kg (7–8 pounds) in 4–5 years (Hourston 1952; Schrouder 1973; Porter 1977; Scott and Crossman 1979). Muskellunge in such populations generally mature at ages 3–5 (Scott and Crossman 1979).

Mortality

Lyons and Margenau (1986) reported annual mortality for adults in a lake population to range from 16 to 51%. Klingbiel (1981) reported the average annual mortality for adults in Wisconsin lakes to be about 25%. Mortality is thought to be relatively high for young-of-the-year, which are fairly immobile and thus susceptible to predation (Porter 1977).

Spawning and early life history

Muskellunge spawn in spring during the period mid-April to late May, when water temperatures warm to approximately 13 °C (55 °F) (Porter 1977; Scott and Crossman 1979; Brewer 1980). The Great Lakes form typically spawns later than the others (mid-May), however, it is not clear whether this is the result of water temperatures warming later or some genetic influence. Riverine spawning sites vary. In some situations muskellunge spawn in the river channel, usually in shallow, slow reaches of a pool in areas where organic detritus or vegetation are present (Parsons 1959; Miles 1978; Brewer 1980). Brewer (1980) reported that in a Kentucky stream spawning took place at the upper or lower ends of a low-gradient pool. Spawning has also been reported to occur out of the main channel, in areas more similar to those used by lake populations—shallow mud flats and backwater areas, again where organic detritus or vegetation were present (Williams 1954; MacGregor et al. 1960).

Little information is available on the early life history of muskellunge in streams. It is suspected that late spring freshets may cause high mortalities to newly hatched fish, thus affecting recruitment in some years (MacGregor et al. 1960; Brewer 1980). Dombeck (1986) reported that young fish use pool habitat similar to that used by adults. In lakes, young muskellunge remain close to shore near vegetation and other cover (Becker 1983).

Movements

In lakes muskellunge undergo extensive movements during spring and fall, but move little during winter and summer (Minor and Crossman 1978; Dombeck 1979). In streams muskellunge make spring upstream spawning migrations, sometimes into tributaries (Williams 1954; Oehmcke et al. 1958; Parsons 1959; Clark 1964; Brewer 1980). Parsons (1959) felt that riverine fish moved little during summer, however, Miles (1978) reported extensive upstream and downstream summer movements.

Food

The muskellunge is a fairly non-selective carnivore (Engstrom-Heg et al. 1986) whose diet in lakes consists chiefly of yellow perch (*Perca flavescens*), catostomids, and cyprinids (Hourston 1952; Oehmcke et al. 1958). In addition, cannibalism is not uncommon (Parsons 1959). Muskellunge appear to feed selectively according to prey size (Crossman 1962), with large fish preferring large prey items. The presence of these large, single food items are believed to be important to adult growth (Porter 1977; Diana 1979; Harrison and Hadley 1979). An abundance of forage fishes of all sizes are needed to support good muskellunge growth (Oehmcke et al. 1958; MacGregor et al. 1960; Harrison and Hadley 1979). Very little

information is available on the diets of stream muskellunge. Young fish in streams are thought to feed chiefly on small cyprinids (Harrison and Hadley 1979). Several authors have stated that the primary forage of adults in streams are redhorse (*Moxostoma* sp.), in particular the golden redhorse (*Moxostoma erythrurum*) (Harrison and Hadley 1979; Jones and Stephens 1984; Axon and Kornman 1986).

Habitat

Muskellunge are generally found in streams with low gradients between 0.4 and 2.0 m/km (2 and 10 ft/mi) (Miles 1978; Brewer 1980; Monaghan 1985; Axon and Kornman 1986; Dombeck 1986). Typical habitat is a long pool, 1.0–1.2 m (3–4 ft) in depth, with a maximum depth greater than 1.5 m (5 ft), which have an abundance of cover in the form of large woody debris (Miles 1978; Jones and Stephens 1984; Monaghan 1985; Axon and Kornman 1986; Dombeck 1986; S. Schell, personal communication, 1988, Ohio Department of Natural Resources, Athens). Preferred temperatures are 25–28 °C (77–83 °F), however, temperatures as high as 32 °C (90 °F) may be tolerated for short periods (Schrouder 1973; Dombeck 1986; S. Schell, personal communication, 1988, Ohio Department of Natural Resources, Athens). Muskellunge are sight feeders and are generally found where turbidity is minimal. Oehmcke et al. (1958) felt that much muskellunge habitat in Wisconsin's larger rivers has been destroyed due to increases in turbidity. Muskellunge are commonly found in association with, and presumably share habitat similarities with, various redhorse species, in particular the golden redhorse (Parsons 1959; Brewer 1980; Jones and Stephens 1984; Axon and Kornman 1986).

Exploitation

As a rare and long-lived species, muskellunge populations are vulnerable to overharvest (Porter 1977). Members of organizations such as Muskies, Inc. release all captured fish in an effort to minimize mortality (Oehmcke et al. 1986). Parsons (1959) reported that, once a large fish is located in a stream, it is fairly easy to capture because it will generally remain in a given pool throughout the summer. Annual exploitation rates in streams range from 15 to 83% (Miles 1978; Axon and Kornman 1986) and in one lake 71% of annual mortality was due to harvest (Lyons and Margenau 1986).

Survival of stocked fish

Several studies have shown that the survival of stocked fish is positively related to length at stocking (Hanson et al. 1986). Initial post-stocking mortalities are generally attributed to stress and predation and can be quite high (Porter 1977; Stein et al. 1981). Mortalities due to predation are believed to decrease with increased length at stocking. Stocking of age-0+ fish, at least 8–10 inches in length, is recommended. In lakes stocked fish nearly always contribute significantly to the population (Porter 1977). No published information is available on the contributions of fish stocked in rivers, however, stocked fish are believed to contribute significantly to the muskellunge population in Michigan's Tahquamenon River (J. Schrouder, personal communication, 1988, MDNR, Newberry).

Competition with northern pike and grass pickerel

A great deal of evidence exists, much of it circumstantial, that northern pike compete with muskellunge to the detriment of the muskellunge (Inskip 1986). Sympatric occurrences of the two species are rare and numerous case histories exist (though none are clearly documented) of dramatic declines in lake populations of muskellunge following the introduction of pike (Inskip 1986; E. J. Crossman, personal communication, 1988, Royal Ontario Museum). It is generally believed that since pike spawn earlier and hatch earlier, most newly hatched muskellunge are eaten by the larger pike fry. This belief was strongly supported by the results of two experimental studies but direct field evidence does not exist (Inskip 1986). Pike are also believed to have other competitive advantages, such as a higher food conversion efficiency rate and a more rapid population turnover rate, however, these have not been clearly demonstrated. All of the evidence of pike impacting muskellunge comes from lakes. Interactions between these species in rivers are not well understood. Inskip (1986) stated that it appears that muskellunge evolved in relatively lotic habitats and pike evolved in relatively lentic ones. Thus pike may have an advantage in lake environments but not in riverine ones. In addition, a number of sympatric populations have been reported from rivers, where in at least one case, the two species utilized different spawning and living microhabitats (Harrison and Hadley 1978; Crossman 1986; J. Schrouder, personal communication, 1988 , MDNR, Newberry).

Grass pickerel (*Esox americanus*) are found in most of the rivers of southern Michigan. No information is available on the interactions between muskellunge and grass pickerel. Brewer (1980), however, reported that grass pickerel lived in sympatry with muskellunge in several Kentucky streams.

Steps 1–3 in the American Fisheries Society Protocol for Introductions of Aquatic Species

Rationale

The warmwater rivers of southern Michigan lack a large predatory fish species which can attract angler interest to the river fisheries, can use as forage the abundant large catostomids and cyprinids which presently dominate the fish communities, and can live and reproduce successfully within the available habitat. The MDNR is interested in introducing such a fish.

Search

The fishes which best fit the above description are the large esocids—the muskellunge, the northern pike, and the tiger muskellunge (the hybrid of the first two species). The muskellunge seems to fit best of all. Its advantages over the pike (which is already fairly common in southern Michigan warmwater rivers) include (1) a longer life span which results in larger fish, (2) more general, size-selective feeding habits which may make better use of abundant large catostomids and cyprinids, (3) lower vulnerability to angling mortality, and (4) a greater ability to generate angler interest, due to both its fighting abilities and its mystique. The tiger muskellunge has a number of attractive characteristics including ease of hatchery rearing, fast growth (Brege 1986), and a preference for bottom-oriented, catostomid prey (Engstrom-Heg et al. 1986). The muskellunge, however, has the advantages of (1) being able to reproduce naturally—the tiger muskellunge is sterile, and (2) being apparently more adapted to the riverine environment. I say "apparently" because direct comparisons between the two fish in rivers have not been made, however, the tiger muskellunge is almost exclusively stocked in lakes and reservoirs, and previous attempts at stocking it into southern Michigan rivers have not been successful (K. Dodge, D. Johnson, and B. McClay, personal communications, 1988, MDNR, Jackson, Plainwell, and Lansing, respectively).

Preliminary impact assessment

The introduction of the muskellunge into southern Michigan warmwater rivers would potentially have both positive and negative impacts on existing aquatic communities and associated fisheries.

Potential positive impacts include (1) an increased interest in the river fisheries, (2) a subsequent increase in interest in the river ecosystems as a whole, and (3) an increased use of the abundant rough fishes present.

Potential negative impacts include:

1. Some alteration of the aquatic ecosystem, most likely through the consumption of various fishes. The introduction of a predator can sometimes alter the abundance or age structure of prey populations.

2. Predation on valued game fishes, in particular the walleye, various anadromous salmonids, and the smallmouth bass. Predation on walleye appears of greatest concern, as it is quite similar to the yellow perch, a favorite prey which is generally present in low numbers in these rivers. Large size, cylindrical shape, and soft-rayed fins make the anadromous salmonids attractive prey items, however, these enter the rivers in such large numbers that predation by a relatively rare predator such as the muskellunge is not likely to have a noticeable impact. Predation is also unlikely to have a noticeable impact on smallmouth bass populations. Muskellunge and smallmouth bass coexist in many rivers and the diets of riverine muskellunge have not been reported to contain many bass.

3. Predation on threatened or endangered species. Several threatened and endangered cyprinids and catostomids are present in southern Michigan rivers, including the redside dace (*Clinostomus elongatus*), the bigeye chub (*Hybopsis amblops amblops*), the silver shiner (*Notropis photogenis*), and the river redhorse (*Moxostoma carinatum*) (Anonymous 1983). The three cyprinid species are all found only in Lake Erie tributaries and the redhorse has been found in two Lake Michigan tributaries, the Muskegon and the St. Joseph rivers (Anonymous 1983; MDNR Stream Survey Records, 1987, Lansing). It is unlikely that the introduction of the muskellunge would affect the abundance of these protected species, as both predator and prey are relatively rare, and as other similar prey species are abundant. The river redhorse may have the greatest potential to be affected, as it attains a larger size than many of the more abundant redhorse and may thus be attractive to large muskellunge. Finally the muskellunge originally either did coexist, or may have coexisted, with these protected species; thus its introduction does not seem to pose a threat.

4. An adverse public reaction to the introduction of muskellunge. This has occurred on several inland lakes where muskellunge have been introduced—the main objection being a perceived subsequent reduction in panfish populations. A similar reaction is unlikely to occur on rivers.

Overall, the potential negative impacts of introduction are fairly small, with the exception of possible predation on walleye.

Potential for Successful Introduction

Several things suggest that the muskellunge could successfully live and reproduce in southern Michigan warmwater rivers. The muskellunge was native to much of the area surrounding southern Michigan, to some inland waters in southwestern Michigan, and perhaps to some waters on the southeastern side. For areas where it was absent, the reasons for this are not clear. It is quite possible that its absence is a result of post-glacial dispersal patterns and that the available habitat is suitable. More specifically, the habitat characteristics of the southern rivers appear ideal for muskellunge. Gradients range from 0.4 m/km to 1.1 m/km (2.0 ft/mi-5.6 ft/mi) (Michigan Department of Agriculture Drainage Basin Map, Lansing). Summer water temperatures do not rise much above 25 °C (77 °F) (Linton 1967). Peak spring discharges occur prior to May in most years (Vannote 1963; Linton 1967). Turbidity is not excessive in many areas. Long moderately deep pools with cover in the form of woody debris are common. Finally food is extremely abundant in the form of small catostomids and cyprinids for younger muskellunge and larger catostomids and cyprinids for older fish. The golden redhorse, which is commonly associated with the muskellunge and is a primary prey species, is the most abundant fish species (by weight) in most reaches (Nelson and Smith 1981; Towns 1984; 1986; 1987). The two things that may stand in the way of a successful introduction are competition with northern pike and overexploitation. The former poses the greatest threat. Northern pike are common throughout the southern rivers. Nelson and Smith (1981) and Towns (1984; 1985; 1987) collectively found pike at 60 of 67 sampling stations on four rivers. Densities averaged approximately six fish per acre, with 9–12% of the fish being greater than 20 inches in total length.

Suggested Course of Action

There appears to be some potential for introducing the muskellunge into the fish communities of Michigan's southern rivers. My suggested course of actions follows:

1. Determine whether fishery managers and anglers are interested in this introduction.

2. If interest is sufficient solicit a review of the proposed introduction from a few out-of-house fishery experts, as recommended by AFS.

3. If the above review is favorable, choose a candidate stock from a riverine population. This could conceivably be from any of the three muskellunge forms. However, a stock of the Great Lakes form should receive primary consideration. The Great Lakes form was the native form in southern Michigan rivers. In addition, its introduction would pose the smallest possible threat of genetic contamination to the Great Lakes form muskellunge stocks which currently exist in Great Lakes waters, in particular in Lake St. Clair and its connecting waters. Potential candidate stocks include ones from these waters and from the "inland waterways" chain of Burt, Mullet, and Black lakes and their connecting waters.

4. Introduce the fish into one or two river systems not currently managed for walleye and evaluate the following:
   (a) Differences between adult muskellunge and pike in habitat preferences, food habits, spawning, survival, catchability, and growth. This could be accomplished by introducing adult muskellunge and following both these and resident adult pike using radio telemetry.
   (b) Survival and ecology of stocked fingerlings. Habitat preferences, food habits, and growth could be compared with these characteristics for young pike. These could be studied using traditional sampling techniques (i.e., electrofishing) and radio telemetry.

5. Review the results of the above evaluations using both MDNR and out-of-house biologists (as suggested by AFS). Base further actions on this review.

LITERATURE CITED

Anonymous. 1983. Michigan's endangered and threatened species. Michigan Department of Natural Resources, Lansing.

Axon, J. R., and L. E. Kornman. 1986. Characteristics of native muskellunge streams in eastern Kentucky. American Fisheries Society Special Publication 15:263–272.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Brege, D. A. 1986. A comparison of muskellunge and hybrid muskellunge in a southern Wisconsin lake. American Fisheries Society Special Publication 15:203–207.

Brewer, D. L. 1980. A study of native muskellunge populations in eastern Kentucky streams. Kentucky Department of Fish and Wildlife Resources, Fisheries Bulletin 64, Frankfort.

Clark, C. F. 1964. Muskellunge in Ohio and its management. Ohio Department of Natural Resources, Division of Wildlife, Publication W-329, Columbus.

Crossman, E. J. 1962. Predator-prey relationships in pikes (Esocidae). Journal of the Fisheries Research Board of Canada 19:979–980.

Crossman, E. J. 1978. Taxonomy and distribution of North American esocids. American Fisheries Society Special Publication 11:13–26.

Crossman, E. J. 1986. The noble muskellunge: a review. American Fisheries Society Special Publication 15:1–13.

Diana, J. S. 1979. The feeding pattern and daily ration of a top carnivore, the northern pike (*Esox lucius*). Canadian Journal of Zoology 57:2121–2127.

Dombeck, M. P. 1979. Movement and behavior of the muskellunge determined by radio telemetry. Wisconsin Department of Natural Resources, Technical Bulletin 113, Madison.

Dombeck, M. P. 1986. Muskellunge habitat—with guidelines for fish management. American Fisheries Society Special Publication 15:208–215.

Engstrom-Heg, R., R. T. Colesante, and G. A. Stillings. 1986. Prey selection by three esocid species and a hybrid esocid. American Fisheries Society Special Publication 15:189–194.

Hanson, D. A., M. D. Staggs, S. L. Serns, L. D. Johnson, and L. M. Andrews. 1986. Comparative survival and growth of three sizes of muskellunge fingerlings stocked in four Wisconsin lakes. American Fisheries Society Special Publication 15:216–228.

Harrison, E. J., and W. F. Hadley. 1978. Ecological separation of sympatric muskellunge and northern pike. American Fisheries Society Special Publication 11:129–134.

Harrison, E. J., and W. F. Hadley. 1979. Biology of the muskellunge (*Esox masquinongy*) in the upper Niagara River. Transactions of the American Fisheries Society 108:444–451.

Hourston, A. S. 1952. The food and growth of the maskinonge (*Esox masquinongy* Mitchell) in Canadian waters. Journal of the Fisheries Research Board of Canada 8:347–368.

Hubbs, C. L. 1933. Data on muskellunge in Michigan. Michigan Department of Natural Resources, Fisheries Research Report 192, Ann Arbor.

Inskip, P. D. 1986. Negative associations between abundances of muskellunge and northern pike: evidence and possible explanations. American Fisheries Society Special Publication 15:135–150.

Jones, A. R., and D. E. Stephens. 1984. Muskellunge streams investigation in the South Fork Kentucky River drainage. Kentucky Department of Fish and Wildlife Resources, Fisheries Bulletin 71, Frankfort.

Klingbiel, J. 1981. The status of the muskellunge program: an informational report to the Natural Resources Board. Wisconsin Department of Natural Resources, Fish Management Bureau, Administrative Report 11, Madison.

Kohler, C. C., and W. R. Courtenay, Jr. 1986. American Fisheries Society position on introduction of aquatic species. Fisheries 11:39–42.

Koppelman, J. B., and D. P. Philipp. 1966. Genetic applications in muskellunge management. American Fisheries Society Special Publication 15:111–121.

Linton, K. J. 1967. The dynamics of five rock bass populations in a warm-water stream. Michigan State University, Doctoral Dissertation, East Lansing.

Lyons, J., and T. Margenau. 1986. Population dynamics of stocked adult muskellunge (*Esox masquinongy*) in Lac Court Oreilles, Wisconsin 1961–1977. Wisconsin Department of Natural Resources, Technical Bulletin 160, Madison.

MacGregor, J., J. Scott, and B. Dean. 1960. A review of the life history and proposed management of the northern muskellunge, *Esox m. immaculatus*. Michigan Department of Conservation, Lake and Stream Improvement Report, Lansing.

Miles, R. L. 1978. A life history study of the muskellunge in West Virginia. American Fisheries Society Special Publication 11:140–145.

Minor, J. D., and E. J. Crossman. 1978. Home range and seasonal movements of muskellunge as determined by radiotelemetry. American Fisheries Society Special Publication 11:146–153.

Monaghan, J. P., Jr. 1985. A study of riverine muskellunge populations and habitat in North Carolina. North Carolina Wildlife Commission, Division of Boating and Inland Fisheries Report, Raleigh.

Nelson, D. D., and D. W. Smith. 1981. Rotenone fisheries survey of the Grand River. Michigan Department of Natural Resources, Fisheries Technical Report 81-3, Ann Arbor.

Oehmcke, A. A., L. Johnson, J. Klingbiel, and C. Wistrom. 1958. The Wisconsin muskellunge—its life history, ecology, and management. Wisconsin Conservation Department Publication 225, Madison.

Oehmcke, A. A., D. Stange, K. Ogden, J. D. Addis, and S. R. Mooradian. 1986. The role of anglers and private organizations in muskellunge management. American Fisheries Society Special Publication 15:323–334.

Parsons, J. W. 1959. Muskellunge in Tennessee streams. Transactions of the American Fisheries Society 88:136–140.

Porter, L. R. 1977. Review of selected literature on muskellunge life history, ecology, and management. Minnesota Department of Natural Resources, Fisheries Section, Special Publication 119, St. Paul.

Schrouder, J. D. 1973. Muskellunge management in Michigan. Michigan Department of Natural Resources, Fisheries Technical Report 73–31, Ann Arbor.

Scott, J. A., D. P. Borgeson, W. C. Latta, and D. B. Jester, Jr. 1985. Proceedings of the workshop on future direction in coolwater-warmwater fisheries research and management in Michigan, May 20–22, 1985. Michigan Department of Natural Resources, Fisheries Technical Report 85–1, Ann Arbor.

Scott, W. B., and E. J. Crossman. 1979. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Stein, R. A., R. F. Carline, and R. S. Hayward. 1981. Largemouth bass predation on stocked tiger muskellunge. Transactions of the American Fisheries Society 110:604–612.

Towns, G. L. 1984. A fisheries survey of the Kalamazoo River, July and August 1982. Michigan Department of Natural Resources, Fisheries Technical Report 84–7, Ann Arbor.

Towns, G. L. 1985. A fisheries survey of the River Raisin, August 1984. Michigan Department of Natural Resources, Fisheries Technical Report 85–3, Ann Arbor.

Towns, G. L. 1987. A fisheries survey of the Battle Creek River, August 1986. Michigan Department of Natural Resources, Fisheries Technical Report 87–3, Ann Arbor.

Vannote, R. L. 1963. Community productivity and energy flow in an enriched warmwater stream. Michigan State University, Doctoral Dissertation, East Lansing.

Williams, J. E. 1954. Creel census and life history observations concerning muskellunge in Michigan inland waters. Michigan Department of Natural Resources, Fisheries Research Report 1432, Ann Arbor.

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