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Conference report: muskellunge science and management: progress through partnerships

Jonathan D. Midwood · Steven J. Kerr · Peter Levick · Steven J. Cooke

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Abstract Muskellunge (*Esox masquinongy*) are an elusive yet highly prized species in eastern North America that can attain trophy sizes. As a result, a dedicated catch-and-release recreational Muskellunge fishery has developed throughout their range. Management of this fishery has largely been facilitated by partnerships between anglers, researchers, and managers. To explore and encourage interactions among these groups a 2-day workshop was held in Ottawa, Canada in August 2014. Three key themes emerged from presentations at this workshop highlighting: 1) the success of Muskellunge management in most of their natural range, 2) knowledge gaps regarding their habitat requirements at various life-stages, and 3) the utility of genetic tools to assist with their management. Through a series of facilitated discussions, concerns were raised by participants regarding the threat posed by non-specialized anglers, the response of Muskellunge populations under future novel conditions, the appropriate scale for management of populations, the potential consequences of cumulative stressors, and the challenges associated with managing cumulative effects and threats. The major take-home message from the workshop was that Muskellunge management is largely a success story that can serve as an example for other recreational fisheries, particularly in terms of building productive partnerships that engage anglers, managers and scientists. Here we present a discussion of the major themes and concerns identified through the workshop in the hopes of spurring future research on Muskellunge, and encouraging managers of other fisheries to adopt some of the strategies that have made Muskellunge fishery management successful.

Keywords Muskellunge · Angling · Fisheries · Management · Muskie

J. D. Midwood (✉) · S. J. Cooke
Fish Ecology and Conservation Physiology Laboratory, Department of Biology and Institute of Environmental Science, Carleton University, 1125 Colonel By Dr., Ottawa, ON K1S5B6, Canada
e-mail: midwoodj@gmail.com

S. J. Kerr
264 Clonakilty Line, Ennismore, Ontario K0L1T0, Canada

P. Levick
Muskies Canada Inc., Ottawa, Ontario, Canada

Introduction

Muskellunge (*Esox masquinongy*) are an apex predator in freshwater ecosystems. Unlike the congeneric Northern Pike (*Esox lucius*) that have a circumpolar distribution, Muskellunge are only found in eastern North America. Here, fisheries for Muskellunge have transitioned over the past 30 years from commercial harvest and catch-and-kill recreational angling to almost complete catch-and-release by specialized anglers. In many waters, Muskellunge can grow to "trophy" sizes (up to 1.8 m; Holm et al. 2009), which has encouraged the development of a highly-specialized, dedicated, and passionate angler community committed to preserving Muskellunge

populations. As a result numerous symposia over the years have focused on sharing science and management strategies for Muskellunge. One of the earliest of these collaborative efforts was an international Muskellunge Symposium held in LaCrosse, Wisconsin, in 1984 (American Fisheries Society 1986). In 1995, a workshop held in Kemptville, Ontario, brought together Muskellunge researchers and managers to discuss some of the key issues in Muskellunge conservation (Kerr and Oliver 1995). A similar symposium followed 10 years later in Indianapolis, Indiana (Diana and Margenau 2007). Since these last symposia, knowledge and management strategies have continued to evolve and improve and Muskellunge research has advanced such that it was deemed necessary and appropriate to convene a symposium on the topic. To emphasize the role that partnerships have played in the ongoing management of Muskellunge, a symposium entitled Muskellunge Science and Management: Progress Through Partnerships was organized centered around six general topics: the important role of specialized angler groups, advances in Muskellunge ecological research, use of genetics in Muskellunge management, catch-and-release practices, current management strategies, and approaches for creating or remediating Muskellunge habitat (Table 1). In this report we highlight some of the major themes that emerged from the symposium and the results from two discussions focused on 1) perceived future

Table 1 Authors and presentation titles at the International Muskellunge Symposium, superscript letters represent presentations associated with the different themes. The conference agenda and associated abstracts can be accessed at: http://www.muskiescanada.ca/whats_new/symposium.php

Author(s)	Title
C. Purdy[a]	An introduction to Muskies Canada Inc.
J. Zahn[a]	An introduction to Muskies Inc.
S. J. Kerr and I. Young[a]	Partnerships between MNR and MCI: an historic overview
J. Farrell[b]	Survival of St. Lawrence River Muskellunge revisited: can today's nursery habitat support adequate recruitment to fuel population recovery?
A. Liskauskas[b]	Distribution and population characteristics of Muskellunge in Georgian Bay and the north channel of Lake Huron
J.P. Leblanc[b]	Unique Georgian Bay Muskellunge nursery habitat features allows for successful habitat determination: steps towards a spatially explicit Muskellunge nursery habitat
J. Midwood[b]	Perceived threats to Ontario's Muskellunge fishery in the future (Discussion)
C. Wilson[c]	What genetics have told us about Muskellunge in Ontario
L. Miller[c]	Using genetic information for Muskellunge management in Minnesota
S. Landsman[d]	My my, how far we've come: an examination of the impacts of catch-and-release angling for muskies
S. Cooke[d]	Ethics of catch-and-release angling practices (Discussion)
D. Taillon[e]	Ontario's approach to Muskellunge management
M. Robbins[e]	Ontario's Muskellunge regulations and enforcement issues
T. Simonson[e]	Muskellunge management in Wisconsin: 20 years of progress
D. Crane and J. Farrell[f]	Future directions for Muskellunge conservation and restoration
J. Casselman[g]	Sustainability of Muskellunge populations
G. Liddle[f]	An overview of the Lake Simcoe Muskellunge restoration project
J. Lamoureux[f]	The Jock River Muskellunge embayment project
P. Levick[f]	Muskellunge habitat rehabilitation: multi perspective case study in stakeholder involvement in the success of the Brewer Park project

[a] Role of Muskies Canada Inc. and Muskies Inc. and the importance of partnerships, [b] Muskellunge ecology, [c] Role of genetics in Muskellunge management, [d] Catch-and-release angling for Muskellunge, [e] Management of Muskellunge (government perspectives), [f] Habitat creation and restoration for Muskellunge, [g] Plenary

threats and knowledge gaps for Muskellunge management, and 2) the current state of science and practice related to catch-and-release of Muskellunge.

Major themes

During the 2-day workshop, three major themes emerged. First, several of the presenters at the conference emphasized that, to date, Muskellunge management in most of their natural range is largely a success story with stable populations and natural reproduction. This success has been brought about by appropriate management strategies at the government level (e.g., modifying angling seasons, implementing catch limits, developing regional biologically-based minimum size limits, and improving education and communication programs) as well as by adoption of best handling and catch-and-release practices by dedicated anglers. For example, in Ontario, Canada, the results from research by *John Casselman* (*Queens University*) have been adopted for regional fisheries planning. By assessing the growth potential for Muskellunge populations in distinct regions, a maximum size that is achievable within these regions can be determined. Based on this knowledge in conjunction with maturation schedules, biologically-based minimum size limits were established to provide various types of fisheries in Ontario. Similarly, in Wisconsin waters, minimum size limits were increased to encourage the development of a trophy fishery; the result has been normalization in the size structure of the population, which had previously seen overharvesting of smaller individuals (*Tim Simonson; Wisconsin DNR*). The take home messages from several talks was that through partnerships between anglers, government, and non-government organizations, Muskellunge fisheries are well managed and should serve as an example for other species in terms of how to rally support within the angler community (e.g., adopting catch-and-release and best handling practices or assisting with data collection) and adapt novel research for management purposes (e.g., growth potential as well as habitat creation and remediation). Although Muskellunge fisheries can be generally regarded as well managed throughout most of their range, some major issues still threaten these populations (outlined in detail below).

The second key theme that emerged from the workshop was the need to understand Muskellunge habitat requirements at various life-stages, particularly during spawning and the early years of a Muskellunge's life (e.g., nursery habitat). To ensure maintenance of healthy Muskellunge populations, sustaining natural recruitment is essential and given their high level of spawning site fidelity, identifying and protecting core habitat is the best approach to achieve this objective (*John Farrell; State University of New York*). Researchers are now trying to identify core spawning-habitat using statistical models so that it can be applied across a regional landscape to identify areas that should be protected (*John Paul Leblanc; McMaster University*). Similarly, *Derek Crane* (*Lake Superior State University*) identified the need to characterize the historical distribution of habitat to provide a baseline and ultimate goal when developing habitat creation and remediation projects. Since spawning and nursery habitat have been lost as a result of development and changes in water levels (particularly in the Great Lakes), once the key features of these habitats are identified, targeted habitat creation or remediation can occur. These types of works are ongoing in many regions where Muskellunge occur; however, there is a need to monitor ongoing efforts to determine what approaches work best and ultimately if they result in improved Muskellunge recruitment (*Gabrielle Liddle; Ontario MNRF and Jennifer Lamoureux; Rideau Valley Conservation Authority*).

Finally, the last major theme that emerged was the use of genetics as a management tool for Muskellunge. Two speakers summarized unique applications of genetic profiling for managing Muskellunge. *Chris Wilson* (*Ontario MNRF*) used micro-satellite loci to demonstrate the strong spatial patterns of Muskellunge populations along the eastern shoreline of Georgian Bay, Lake Huron. The distinct groupings in this area reinforce the notion of discrete stocks having strong spawning site fidelity, which is largely focused around landscape level features such as rivers or large embayments. Using similar techniques, *Chris Wilson* went on to demonstrate how genetics can be used to help with the reintroduction of Muskellunge into areas where they have been extirpated. By identifying the most genetically similar regional population to that of the extirpated population, reintroduction may be more successful. Stocking of Muskellunge has a long history, yet until recently it has not used genetic techniques to select for the most regionally adapted species. In Wisconsin lakes, *Loren Miller* (*Minnesota DNR*) showed how genetics are being used to track the ancestry of a population and see to what extent different source populations of stocked Muskellunge are contributing to the current genetic structure (essentially a post-hoc

measure of successful stocking and recruitment). Through this work some of the drawbacks to stocking became apparent such that the genetic diversity within stocked lakes is considerably lower than in natural source populations; an issue that could potentially lead to population crashes in the future. In general, genetic techniques offer an exciting new management technique that can be used to group regional populations, establish the legacy of Muskellunge range expansion, identify appropriate populations to use for stocking, and ensure there is sufficient genetic diversity to buffer future changes in the environment.

Facilitated discussion outputs

During the meeting we had a number of opportunities to engage the audience via facilitated discussions to exploit the expertise in the room from three perspectives: managers, stakeholders (anglers) and researchers. One of the products of those interactions was the identification of some of the key challenges and knowledge gaps from ecological and management perspectives (summarized in Table 2). Among all participants, a major concern was the threat posed by uninformed or non-specialized anglers. Despite major advances in the development of best-handling practices for Muskellunge (e.g., Landsman et al. 2011), the extent to which these practices are known by non-specialized anglers is unclear. Indeed, anglers unaware of these practices can incidentally capture Muskellunge and, given their trophy size, these anglers may not know how to remove hooks without injuring the fish, they may hold the Muskellunge incorrectly, and/or increase air exposure by keeping the Muskellunge out of the water for extended periods of time. Independently or in combination, these mistakes can result in the death of the fish and removal of an important breeding adult from the population. Moreover, being unaware of local size limits can also result in removal of undersized fish since these Muskellunge may be the largest fish a novice angler has ever captured. Consequently, effective communication and outreach strategies targeted at non-specialist anglers that incidentally encounter Muskellunge are needed.

In addition to threats from inexperienced anglers, another issue identified was the potential for cumulative impacts from multiple different factors including, but not limited to: loss of spawning, nursery, and foraging habitat, impacts from invasive species (e.g., Round Goby [*Neogobius melanostomus*] predation of eggs), and adult mortality from disease (e.g., viral hemorrhagic septicemia). While on an individual level some research has been conducted on each of these issues, we do not know how Muskellunge will respond as individuals or

Table 2 Perceived threats, knowledge gaps, and management challenges for Muskellunge and Muskellunge fisheries as identified by managers, stakeholders, and researchers at the 2014 Muskellunge Symposium

Perceived threats	Non-specialized anglers
	Cumulative impacts
	Habitat loss (loss of recruitment)
	Invasive species
	Lack of public interest in fisheries in general
Knowledge gaps	Identification of critical habitat, particularly in isolated systems (e.g., inland lakes)
	How or if Muskellunge can adapt to novel conditions
	Core ecology (e.g., movement of juveniles, what their role is in the community)
	Impact of toxicity on their condition
	Best practices for successful stocking
Management challenges	Best practices for management, particularly ideal scale for management
	Limited control over external variables that affect Muskellunge
	Inter-jurisdictional issues
	Financial resources, particularly for education and enforcement
	Public misperception (e.g., Muskellunge negatively impact other recreational fishery target species)
	Protection and remediation of spawning areas
	Conflict of interest within management agencies that have to both protect fisheries and encourage exploitation

at the population level if the aforementioned individual impacts are compounded when they occur in concert.

Similarly, as noted previously, identification of core habitat for distinct Muskellunge populations (e.g., latitudinal variation, small versus large lakes and rivers) and life-stages (e.g., fry, young-of-year, sub-adults) is essential for moving forward with Muskellunge management and research. Once these core habitat areas are defined, the next step will be to try and determine how Muskellunge will respond to novel conditions in the future. Given climate change projections that suggest water temperatures, phenology (e.g., timing of spawning), and the amount of available habitat may vary in the future, being proactive with Muskellunge management is important to ensure this species can adapt to these novel conditions.

Finally, in terms of management challenges, the first issue that was identified was the need to identify the appropriate scale for Muskellunge management. While the use of growth potential has been successful, its application occurs at a regional scale and therefore encompasses many distinct populations found in isolated lakes. The regional applicability of this approach should be tested to ensure some lake populations are not being harvested at inappropriate size limits. The second and biggest issue that was raised is the challenge of dealing with some of the aforementioned cumulative impacts at a management level. Fisheries managers have a limited scope over what they control, therefore when external or large-scale changes impact regional processes (e.g., water level changes within the Great Lakes or increased surface water temperatures), Muskellunge managers may be unable to make changes that alleviate these impacts. When the challenges are beyond the control of the managers, the only solution is likely public outreach and education of how these challenges will impact sought-after fishes such as Muskellunge.

Conclusions

The major goal of the 2014 International Muskellunge Symposium was to bring together anglers, researchers, and managers whom have all played an important cooperative role in making management of Muskellunge successful. This should serve as an example for other recreational fisheries of how to integrate science with management and the important role that anglers play in ensuring the resiliency of fisheries resources.

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