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Identifying important micro-habitat characteristics of muskellunge spawning locations in the upper Niagara River

Derek P. Crane [a,*], John M. Farrell [b,1], Kevin L. Kapuscinski [c]

[a] State University of New York, College of Environmental Science and Forestry, 104 Illick Hall, 1 Forestry Drive, Syracuse, NY 13210, USA
[b] State University of New York, College of Environmental Science and Forestry, 250 Illick Hall, 1 Forestry Drive, Syracuse, NY 13210, USA
[c] State University of New York, College of Environmental Science and Forestry, 304 Illick Hall, 1 Forestry Drive, Syracuse, NY 13210, USA

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ABSTRACT

Conserving and restoring muskellunge (*Esox masquinongy*) spawning habitat are essential for maintaining self-sustaining populations. A Maxent model was developed based on presence and background data to investigate the relationship between the occurrence of spawning muskellunge and habitat features in the upper Niagara River. Muskellunge spawning points (n = 15) were determined by direct observation of spawning pairs. Model inputs were based on micro-habitat features collected at each spawning point and a sample of 250 background habitat points. The full model was reduced to a four variable model to remove uninformative variables and reduce overfitting and redundancy. Model performance was evaluated based on the mean test gain of cross-validated models (n = 15). Model outputs identified aquatic macrophyte/algae coverage as the most important habitat feature at spawning locations. The relative probability of muskellunge spawning increased with the percent rank of total aquatic macrophyte/algae coverage, water velocity, and water depth and it was highest at points with muddy-sand to sand substrates. Mean test gain (0.68; SE = 0.52) of the cross-validated models indicated that the likelihood of an average muskellunge spawning point was nearly two times greater than an average background point. Results from this research advance our knowledge of muskellunge reproductive ecology, while providing scientists and managers with quantitative measures to guide habitat conservation and restoration.

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Introduction

The muskellunge (*Esox masquinongy*) is ecologically important as the apex native aquatic predator in the Niagara River and has supported a recreational fishery since at least the 1850s (Harrison and Hadley, 1978). The population is self-sustaining, and no stocking has occurred since 1974 (Kapuscinski et al., in press). However, habitat in the upper Niagara River has been substantially altered since the early 19th century, and the cumulative effects of habitat degradation and other ecosystem changes may limit the muskellunge population (Kapuscinski et al., in press). Muskellunge spawning habitat conservation and restoration are priorities for resource management agencies in several Great Lakes waters, including the upper Niagara River (Farrell et al., 2003, 2007; Kapuscinski et al., in press; Rowe and Hogler, 2012; Thomas et al., 2010). Additionally, restoration and protection of wetlands, including vegetated shallow water habitat (<2 m), which is essential for spawning and early life stages of muskellunge (Craig and Black, 1986; Farrell, 2001; Farrell and Werner, 1999; Harrison and Hadley, 1978, Kapuscinski and Farrell, in press; Murry and Farrell, 2007) and other native fishes, are priorities for the >$1 billion Great Lakes Restoration Initiative (Allan et al., 2013; Great Lakes Restoration Initiative Task Force, 2010).

Despite the substantial amount of money and effort being spent on nearshore and wetland habitat conservation and restoration in the Great Lakes, little information exists to guide actions that will benefit muskellunge. The few studies that have investigated muskellunge spawning habitat in the Great Lakes have only provided general descriptions (e.g., Haas, 1978; Harrison and Hadley, 1978), focused on populations that are not self-sustaining (e.g., Battige, 2011) or lacked predictive power beyond specific sites (e.g., Farrell, 2001; Farrell et al., 1996).

Acquiring information that can be used to bolster natural reproduction of muskellunge should be a primary research and management goal (Kapuscinski et al., 2007). Farrell et al. (2007) called for development of models that increase our understanding of the relationship between muskellunge reproduction and habitat, and can help guide habitat restoration. Contemporary muskellunge populations typically occur at low densities,

* Corresponding author at: 7808 119th Lane North, Champlin, MN 55301, USA. Tel.: +1 517 643 1193.
E-mail addresses: dpcrane@syr.edu (D.P. Crane), jmfarrell@esf.edu (J.M. Farrell), klkapusc@esf.edu (K.L. Kapuscinski).
[1] Tel.: +1 315 470 6990.

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which create challenges for researchers attempting to develop distribution or habitat models based on presence/absence data. Identifying true absences for species that occur at low densities can be difficult because individuals may go undetected and such detection errors may lead to bias in models and incorrect conclusions about habitat use (Baldwin, 2009). New technologies and modeling techniques are now available to develop habitat use models for fishes with presence-only data (Elith et al., 2006; Franklin, 2009). Presence-only methods may provide a means for effectively modeling habitat use by low density, cryptic aquatic organisms such as muskellunge. Nohner (2009) recently used presence-only methods to model muskellunge spawning habitat in self-sustaining northern Wisconsin lakes. Battige (2011) modeled spawning habitat and distribution of muskellunge in the lower Menominee River, Wisconsin, a tributary to Green Bay; however, this population is not self sustaining and was recently developed by stocking (Kapuscinski et al., 2007). In order to develop a better understanding of muskellunge reproductive ecology in the upper Niagara River and provide information to guide habitat management, we (1) quantified micro-habitat features at muskellunge spawning locations in the upper Niagara River, (2) developed a Maxent model of muskellunge spawning locations based on habitat features at muskellunge spawning points and randomly selected background points, and (3) used model results to identify habitat features that were most important at muskellunge spawning locations.

Material and methods

Study area

This investigation focused on US waters of the upper Niagara River (Fig. 1). The Niagara River flows north from the outlet of Lake Erie at Buffalo, New York, to Lake Ontario. Niagara Falls divides the river into upper and lower sections about 32 km downstream from Lake Erie (measured along the international border). Despite being over 2.5 km wide at its widest point, water depths in the upper Niagara River are generally <6 m and the river contains many shallow shoals. The upper Niagara River and surrounding landscape have been extensively altered over the past 200 years by urban, residential, and industrial development, and about 60% of the US shoreline is artificially "hardened" (Wooster and Matthies, 2008). Additionally, gravel mining, dredging, and dumping of sediment have altered in-river habitat to an unknown extent. Despite its history of habitat alteration and degradation, the upper Niagara River still has areas of high quality habitat to support important native game (e.g., smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and muskellunge) and non-game fishes (e.g., emerald shiner (*Notropis atherinoides*), bluntnose minnow (*Pimephales notatus*), and *Moxostoma* spp.).

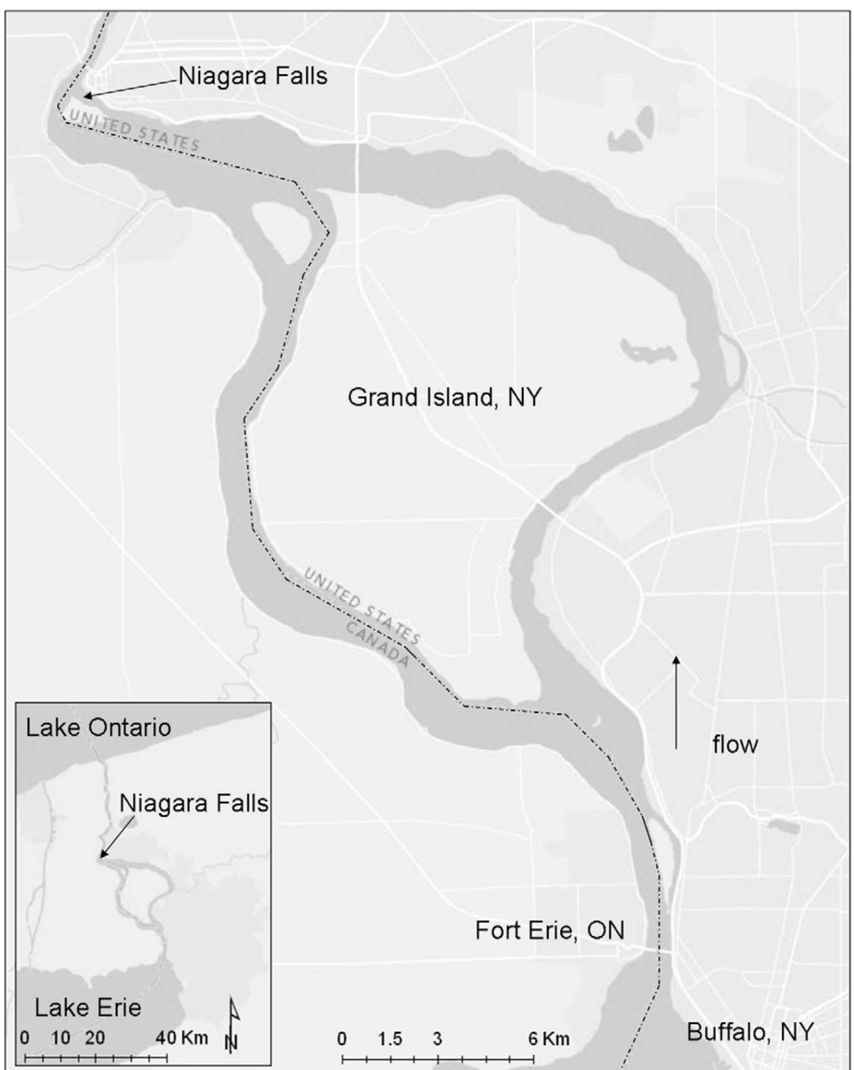

Fig. 1. Map of the upper Niagara River. Basemap from ESRI Inc., 2013.

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