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Habitat factors influencing fish assemblages at muskellunge nursery sites

Kevin L. Kapuscinski [a,*], John M. Farrell [b,1]

[a] State University of New York, College of Environmental Science and Forestry, 304 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

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ABSTRACT

Nearshore sites of the Great Lakes and their connecting channels provide critical nursery habitat for muskellunge (*Esox masquinongy*) and the fishes they prey upon. However, limited understanding of habitat–fish assemblage relations hinders informed management and restoration of these communities. To help fill this information gap, we (1) described fish assemblages at 25 sites in Buffalo Harbor (Lake Erie), the upper Niagara River, and the St. Lawrence River, (2) compared assemblages among sites and waters, and (3) determined if assemblage structure was related to habitat variation. The structure of fish assemblages at muskellunge nursery sites was influenced by suitability of habitats for particular reproductive strategies and providing refugia from predation. Sites that had flowing water, coarse substrates, high macrophyte column density, and little or no macroalgae supported greater fish densities and more species-rich assemblages that were dominated by small-bodied, fusiform cyprinids. These complex habitats provided refugia from predation and were suitable for open substratum spawners. Shallow sites with negligible stream flow, fine substrates, low macrophyte column density, and greater macroalgae coverage contained small-bodied, fusiform fishes; deeper sites with similar habitat were dominated by larger-bodied, laterally-compressed centrarchids and yellow perch (*Perca flavescens*), whose reproductive strategies and anti-predator adaptations allow them to persist in such habitats. Small-bodied, fusiform fishes such as banded killifish (*Fundulus diaphanus*), cyprinids, and darters are important prey for young-of-the-year muskellunge, whereas laterally-compressed centrarchids and yellow perch are typically avoided. Managing for habitats that support abundant fusiform fishes should provide better nursery conditions and promote stronger year-class formation for muskellunge.

Introduction

Growth, size, and condition influence survival of young-of-the-year (YOY) piscivorous fishes (Garvey et al., 1998; Johnson, 1982; McKeown et al., 1999; Wahl, 1999; Wahl and Stein, 1988). While prey availability is an important driver of piscivore growth (Carline et al., 1986; Johnson, 1982; Szendrey and Wahl, 1996; VanDeValk et al., 2008), the anti-predator behavior and morphology of a prey species influences its energetic value to predators (Scharf et al., 1998; Selch and Chipps, 2007). Consequently, piscivores feed selectively among prey species (Beyerle and Williams, 1968; Einfalt and Wahl, 1997; Wahl and Stein, 1988) and prey fish assemblage structure can have a strong influence on survival rates of YOY piscivores (Wahl and Stein, 1988). The increasing evidence for YOY piscivore dependence on supporting prey fish assemblages is helping biologists shift the focus of management programs from single-species approaches (the piscivore) toward community-based management programs. Such a shift in management philosophy is occurring for muskellunge (*Esox masquinongy*), an apex aquatic predator and economically important sport fish (Menz and Wilton, 1983; Simonson, 2008). For example, management of muskellunge in the Niagara and St. Lawrence Rivers is shifting from harvest regulation to identification, protection, and restoration of spawning and nursery habitats (Farrell et al., 2007; Kapuscinski et al., 2014–this issue).

Harrison and Hadley (1978) reported that muskellunge in the Niagara River spawned exclusively in main channel habitats where typical flow velocities were 0.2 m/s, and nursery habitats utilized by YOY muskellunge often had flow velocities >0.1 m/s. In contrast, muskellunge in the Thousand Islands region of the St. Lawrence River use bays off the main channel as spawning (Farrell et al., 1996) and nursery habitats (Farrell and Werner, 1999). Young-of-the-year muskellunge remain within nursery habitats until their first fall, at which time they emigrate (Farrell and Werner, 1999), presumable to deeper habitats for overwintering. Several studies have described the habitat at muskellunge nursery sites, which are characterized as shallow (<1.5 m) nearshore areas containing moderate densities of submersed and emergent vegetation (Craig and Black, 1986; Bendig, 1996; Werner et al., 1996; Farrell and Werner, 1999; Lake, 2005). However, few studies have quantitatively described the fishes present at muskellunge nursery sites (Craig and Black, 1986) or quantified relations among YOY muskellunge and the fish assemblages and habitat

* Corresponding author. Tel.: +1 315 877 2923.
E-mail addresses: klkapusc@esf.edu (K.L. Kapuscinski), jmfarrell@esf.edu (J.M. Farrell).
[1] Tel.: +1 315 470 6990.

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at nursery sites (Murry and Farrell, 2007). Such information is critical for the development of successful community-based management approaches because muskellunge are almost entirely piscivorous after they are about five weeks old (Elson, 1941). Murry and Farrell's (2007) study was the first to quantify relations between YOY muskellunge presence and abundance and the fish assemblage and vegetative habitat characteristics of nursery habitats in the St. Lawrence River. In general, their results showed that YOY muskellunge were positively associated with prey availability and macrophyte coverage, richness, and density in the water column, but negatively related to water depth, the density of yellow perch (*Perca flavescens*), and macroalgae (*Chara vulgaris*) coverage. A recent dietary analysis showed that YOY muskellunge from the St. Lawrence and upper Niagara Rivers were specialized predators that relied heavily upon fusiform fishes such as banded killifish (*Fundulus diaphanus*), cyprinids, and darters as prey (Kapuscinski et al., 2012). Conversely, YOY muskellunge from the St. Lawrence River consumed relatively few centrarchids and yellow perch, and neither of these prey types were recovered from stomachs of YOY muskellunge collected from the Niagara River. Thus, rather than simply being opportunistic predators, YOY muskellunge appear to rely on specific prey during the critical first year of life—such dependencies may have important consequences for year-class formation if prey fish populations are impaired. Unfortunately, the habitat factors that influence fish assemblage structure at muskellunge nursery sites are largely unknown, and it is therefore difficult to manage for or restore optimal nursery habitats.

In this study, we sought to (1) quantify fish density, species richness, diversity, evenness, and dominance of fish assemblages at muskellunge nursery sites in Buffalo Harbor (Lake Erie), the upper Niagara River, and the St. Lawrence River, (2) compare fish assemblages among sites and waters, and (3) determine if differences among assemblages were related to habitat variation. It was our goal that the results of this study and the dietary analysis conducted by Kapuscinski et al. (2012) could be used to protect and manage for favorable nursery conditions for muskellunge.

Material and methods

We sampled 25 nearshore sites in Buffalo Harbor ($n = 2$), the upper Niagara River ($n = 8$), and the St. Lawrence River ($n = 15$) that were previously identified as muskellunge spawning or nursery areas (Table 1; Fig. 1; Culligan et al., 1994; Farrell et al., 2007). Fish assemblage data were collected with fine-mesh bag seine (9.14 m-long, 1.83 m-height, 1.6 mm-mesh) hauls (each 30.48 m in length) conducted during daylight hours. Every site was visited once in 2008 and once in 2009; data from the first three seine hauls conducted at each site in each year were included (total of six hauls/site) to standardize the amount of capture effort. All seine hauls at a site were conducted on the same date within a given year, and all sites were sampled during 27 July–6 August in Buffalo Harbor and the upper Niagara River, and 13 July–7 August in the St. Lawrence River. Standardizing our sampling effort in this way (1) ensured that similar habitats within a site were sampled each year, (2) minimized variation caused by sampling sites at different times of the year, and (3) ensured that our interpretation of fish assemblages was not biased by unequal sampling effort among sites. In most cases, fishes were identified to the species level, counted, and immediately released. Voucher specimens were retained for later identification when necessary. When many (e.g., >1000) cyprinids were captured at a site, a subsample was identified and the proportions of identified species were applied to the total number of cyprinids counted. Young-of-the-year common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), and their hybrids were collected from Buffalo Harbor and upper Niagara River sites, but they were not always differentiated in the field because their barbels could not be easily seen. Therefore, they are referred to as YOY carp/goldfish herein and considered a single species in our analyses. Similarly, blacknose shiner (*Notropis heterolepis*) and bridle shiner (*Notropis bifrenatus*) collected from the St. Lawrence River could not be differentiated in the field and were not sacrificed for laboratory identification, so they are considered a single species in our analyses.

Description of fish assemblages

Fish assemblages at each site were described on the basis of mean fish density (catch/seine haul), species richness, diversity, evenness, and dominance. Richness was determined by counting the number of species and families captured at each site in the standardized amount of sampling effort. Diversity was quantified using Simpson's index (D):

$$D = \sum_{i=1}^{s}\left(p_i^2\right) \quad (1)$$

Table 1
Site codes and locations of 25 nearshore sites sampled for fish assemblage and habitat data in Buffalo Harbor (BH), the upper Niagara River (UNR), and the St. Lawrence River (SLR) during 2008–2009.

Body of water	Site	Site code	Latitude	Longitude
BH	Bell Slip	BELL	42°51′36.96″N	78°52′28.15″W
BH	Ice Boom Bay	IBB	42°52′15.81″N	78°53′04.17″W
UNR	Strawberry Island Bay	SIB	42°57′20.48″N	78°55′24.46″W
UNR	Downstream of Strawberry Island	DSSI	42°57′24.37″N	78°55′36.27″W
UNR	Outside breakwaters protecting a wetland on southeast Grand Island	WET	42°57′57.40″N	78°56′24.06″W
UNR	Motor Island, northwest shore	MOTOR	42°57′56.08″N	78°56′08.29″W
UNR	Downstream of Big Six Mile Creek	DSB6	43°01′37.85″N	79°00′42.15″W
UNR	Northwest shore of Grand Island, south of Buckhorn Island	NWGISB	43°03′27.03″N	78°59′50.91″W
UNR	102nd Street Embayment	NDST	43°04′18.51″N	78°56′53.12″W
UNR	East River, upstream of north Grand Island Bridge	ERUSGIB	43°03′49.92″N	78°59′02.60″W
SLR	Peos Bay	PEOS	44°10′06.85″N	76°15′01.68″W
SLR	Millens Bay	MILL	44°10′12.75″N	76°14′40.71″W
SLR	Rose Bay	ROSE	44°11′06.66″N	76°13′33.79″W
SLR	Lindley Bay	LIND	44°14′57.30″N	76°08′45.52″W
SLR	Aunt Jane's Bay	AUNTJ	44°15′48.11″N	76°06′28.62″W
SLR	Frinks Bay	FRINK	44°14′33.30″N	76°04′49.52″W
SLR	Boscobel Bay	BOSCO	44°15′34.76″N	76°06′32.64″W
SLR	Salisbury Bay	SALIS	44°17′29.60″N	76°04′22.11″W
SLR	Delaney Bay	DEL	44°17′53.21″N	76°05′23.11″W
SLR	Blind Bay	BLIND	44°16′02.55″N	76°00′46.86″W
SLR	Hoffman Bay	HOFF	44°17′41.76″N	75°59′52.42″W
SLR	Cobb Shoal Bay	COBB	44°17′53.21″N	75°58′59.63″W
SLR	Garlock Bay	GAR	44°19′03.40″N	75°56′50.07″W
SLR	Seven Isles	SISLES	44°19′30.80″N	75°56′35.60″W
SLR	Deer Island Bay	DEER	44°21′49.18″N	75°54′22.76″W