Quantifying Relationships between Fish Assemblages and Nearshore Habitat Characteristics of the Niagara River

An Application for Funding Through the Greenway Ecological Fund Standing Committee

By

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Purpose

Site-level habitat characteristics and habitat selection by species are two important factors that shape the species composition of local assemblages. Habitat characteristics have been shown to influence the species composition of fish assemblages in both marine (Gladfelter et al. 1980; Guidetti 2000) and freshwater environments (Tonn and Magnuson 1982; Berkman and Rabeni 1987). Similarly, fish assemblages have been shown to differ along habitat gradients at muskellunge (*Esox masquinongy*) nursery sites of Buffalo Harbor, the upper Niagara River, and the St. Lawrence River (Kapuscinski and Farrell 2013). Eight of these muskellunge nursery sites in the upper Niagara River have been surveyed each year since 2008, but an understanding of the relationships between site-level habitat characteristics and the species composition of fish assemblages has yet to be acquired for a larger (river-wide) spatial scale. If this significant information gap remains unfilled, it may jeopardize the success of the numerous ongoing and planned habitat enhancement projects in the Niagara River (Federal Energy Regulatory Commission 2007). Therefore, we seek to develop models based on data collected throughout the upper Niagara River that can predict occurrence of fish species from site-level habitat characteristics. These models can be used to prioritize sites for protection and restoration, and to aid in making choices among alternative habitat enhancement designs. In addition, we seek to quantify prey selection by age-0 muskellunge and the caloric content of different prey types to gain a better understanding of how fish assemblage structure relates to growth and survival of the Niagara River's apex native predator. Lastly, we propose to continue the standardized seining

survey of nearshore fish assemblages at two sites in Buffalo Harbor and eight sites in the upper Niagara River that begun in 2007, as a means to monitor trends through time.

Objectives & Justification

Objective #1: Predicting occurrences of Niagara River fishes from habitat characteristics

Predictive models for species distributions are essential for conservation and habitat restoration planning (Franklin 2009). New technologies and powerful modeling techniques are now available to develop such models for fishes (Elith et al. 2006; Ferrier and Guisan 2006; Franklin 2009). We seek to develop predictive models of the occurrence (relative probability of presence) of fish species based on habitat characteristics in the upper Niagara River. These models will function as an important tool to maximize effectiveness and efficiency of nearshore habitat conservation and restoration activities. As Geographic Information System (GIS) layers become available for the upper Niagara River, they can be linked to the model and model outputs can be used to prioritize areas for habitat conservation. The models can also be used to guide designs of nearshore habitat restoration projects. For example, the models can be linked to GIS data for several potential restoration designs and the model output can be analyzed to determine which design maximizes critical habitats for native fishes. We describe two applications of these predictive models below, but alternative species-specific or multispecies (assemblage) models can be constructed to address management needs.

Application 1: Develop a model that predicts the occurrence of age-0 muskellunge from physical habitat characteristics

The muskellunge is ecologically important as the apex native predator in the Niagara River and has supported a recreational fishery since at least the 1850s (Harrison and Hadley 1978). The muskellunge remains culturally and economically important to the Buffalo-Niagara region, despite recent declines in the population (Kapuscinski et al. 2013). Understanding muskellunge habitat requirements at all life stages is necessary for successful conservation of the species and management of the fishery. Current efforts are focused on developing a predictive model of muskellunge spawning habitat for nearshore areas of the upper Niagara River (Farrell et al. 2010; Kapuscinski et al. 2011). Recent investigations have identified key habitat and fish assemblage components of age-0 muskellunge nursery areas during the summer months in Buffalo Harbor

and the upper Niagara River (Kapuscinski and Wilkinson 2008; Kapuscinski et al. 2009; Kapuscinski et al. 2010; Kapuscinski et al. 2012 a; Kapuscinski et al. 2012 b; Kapuscinski and Farrell 2013). Research in the St. Lawrence River (Farrell and Werner 1999; Murry and Farrell 2007) and Georgian Bay (Craig and Black 1986) has provided additional information regarding age-0 muskellunge habitat and fish community associations. However, a reliable model that can predict age-0 muskellunge occurrence from habitat data has not been published.

Application 2: Develop a model that predicts the occurrence of native and non-native fishes from physical habitat characteristics

A clear understanding of habitat requirements of native and non-native fishes is needed to maximize benefits of habitat restoration activities in the upper Niagara River. For example, Jude and DeBoe (1996) suggested that managers should consider the potential competitive advantages given to round goby (*Neogobius melanostomus*) over native fishes when incorporating large quantities of riprap in restoration designs. We will develop predictive models for both native and non-native nearshore fishes, which will allow us to identify differences and overlap in habitat use. If differences in habitat use exist between native and non-native fishes, then restoration efforts can be tailored toward creation of habitats that maximize benefit to native species while minimizing benefit to non-native species (i.e., identify which habitats to avoid creating). Similar to the age-0 muskellunge model, a predictive model for native and non-native fishes at the assemblage level will function as an important decision making tool when developing habitat restoration designs. GIS data for multiple designs can be linked to the predictive models, creating spatially explicit maps of native and non-native fish distributions for each individual design plan. The model output will provide insight to which designs provide the greatest quantity and quality of habitat for native species while minimizing preferred habitats of non-native species.

<u>Objective #2: Quantify prey selection by age-0 muskellunge and the caloric content of different prey types</u>

Determining if age-0 muskellunge feed selectively among prey species and quantifying caloric content of different prey fishes is vital to understanding how growth and condition of age-0 muskellunge is related to fish assemblage structure at nursery sites. Growth, size, and condition

all influence survival of age-0 piscivorous fishes (Johnson 1982; Wahl and Stein 1988; Garvey et al. 1998; McKeown et al. 1999; Wahl 1999), and overwinter survival of age-0 muskellunge is thought to be strongly linked to their size at the end of the first growing season (Carline et al. 1986; Szendrey and Wahl 1996). While prey availability is an important driver of piscivore growth (Johnson 1982; Carline et al. 1986; 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). Therefore, the species composition of prey assemblages at nursery sites may influence growth and survival of age-0 piscivores. Recent disruptions to prey assemblages (e.g., by invasion of non-native round goby) increase the need for understanding relationships between prey assemblages and piscivore growth. Carline et al. (1986) observed that tiger muskellunge (*E. masquinongy* x *E. lucius*) growth was dependent on prey fish assemblages, size, and density. Kapuscinski et al. (2012 a) identified which prey fishes were most important in the diets of age-0 muskellunge in the Niagara and St. Lawrence rivers, but could not determine if muskellunge were feeding selectively or simply consuming the most abundant prey species. We will conduct laboratory experiments to determine if age-0 muskellunge feed selectively among prey fish species, and if selection is related to the caloric content and anti-predator morphology of prey species. By integrating knowledge about prey fish selection by age-0 muskellunge with knowledge of fish assemblage-habitat relationships (Objective 1), we can evaluate prey assemblages at muskellunge nursery sites and provide guidance for habitat restoration efforts that will promote optimal prey assemblages.

<u>Objective #3: Monitor nearshore fish assemblages at muskellunge nursery sites</u>

Achieving this objective will provide catch rates of age-0 muskellunge and other fishes at 10 nursery sites (Figure 1), continuing an effort begun in 2007. These catch rates serve as relative abundance estimates of fishes and allow for site-specific comparisons and examination of trends through time (Figure 2). Data collected during previous efforts were used to identify the prey species muskellunge depended upon during their first year of growth (Kapuscinski et al. 2012 a) and to determine which habitat factors influenced fish assemblage structure at muskellunge nursery sites (Kapuscinski and Farrell 2013). In the future, these data can be used to determine how habitat restoration efforts (e.g., at Motor Island, Strawberry Island, etc.) affect fish assemblage structure and muskellunge abundance and production. In addition, important

information on species of greatest conservation need in NY State may be collected during this seining effort. For example, we collected a number of rare species during 2007-2012, including blackchin shiner (*Notropis heterodon*). Blackchin shiner has a NY Natural Heritage Program rank of S1, meaning typically five or fewer occurrences (see http://www.dec.ny.gov/animals/9406.html). Information on these rare species is unlikely to be collected in the absence of this survey. Finally, this standardized seining survey will serve as a monitoring tool to document changes in the distribution and relative abundance of non-native species such as rudd (*Scardinius erythrophthalmus*), round goby, and future invasive fishes.

Methods

Objective 1: Site selection

Sites will be defined as distinct polygons within nearshore waters (<1.5 m deep) of the upper Niagara River. Sites will then be divided into two categories (known and unknown muskellunge nursery sites) to account for habitat variability within the river and maximize probability of identifying an adequate number of age-0 muskellunge presence points. An equal number of sites within each category will be selected randomly and surveyed twice in a given year (once in early to mid-July and once in early to mid-September). We will use a stratified random sampling design within each site. Sites will be stratified by water depth (<0.75 m, 0.75 m > x <1.5 m). A wetland stratum will be added if protected wetland habitat is available at a selected site (e.g., the restored wetland at Beaver Island or the southeast side of Grand Island). The number of seine hauls within each stratum will be proportional to the area of each stratum.

Objective 1: Habitat sampling

Habitat surveys will be conducted at each seining location 24-48 hr prior to fish sampling. Weighted buoys will be used to mark the centerline of each individual seine haul, and habitat will be systematically sampled within 1 m^2 grids at four points along the centerline of the area to be covered by each seine haul (Murry and Farrell 2007; Kapuscinski and Farrell 2013). We will collect data describing vegetation coverage, species composition, and physical habitat (e.g., water velocity, depth, substrate type, and temperature), and mean habitat conditions for each seine haul area will be estimated from the four sampling points. Shoreline development and distance to the nearest tributary mouth will be quantified using aerial imagery. Substrate type

will be described following the Udden-Wentworth grain size scale (Udden 1914; Wentworth 1922), and temperature data will be collected using a handheld thermometer. All vegetation and algal species at a sampling point will be identified to the genus or species level. Total vegetation and algal coverage and percent coverage of the three most dominant species will be visually estimated at each point. Vegetation or algal height will be measured at five points within each 1 m^2 grid. Water velocity will be sampled using an electromagnetic water velocity meter (Hach FH950, Hach Company, Loveland, CO).

Objective 1: Fish assemblage sampling

Fish will be sampled using a fine mesh seine (9.14 m long, 1.6-mm mesh; Farrell and Werner 1999; Murry and Farrell 2007; Kapuscinski et al. 2012). Seine hauls will be conducted parallel to the shoreline, 15.24 m long, and sample 139 m^2. All fish will be identified to the species level, counted, and when possible, classified as age-0 or >age-0. Fish that cannot be identified in the field will be preserved and identified in the lab.

Objective 1: Model development

We will develop predictive models for age-0 muskellunge and native and non-native fish assemblages using a community modeling feature of multivariate adaptive regression splines (see Leathwick et al. 2005 for an example). The models will be fit with data collected during 2013-2015. Model results will predict relative probability of occurrence of age-0 muskellunge and native and non-native fishes based on nearshore habitat conditions.

Objective 2

We will collect age-0 muskellunge and prey fishes (native and non-native) from the upper Niagara River by seining during late July-early August, and transport them to a laboratory. Muskellunge will be held in individual tanks and presented with equal numbers of each prey species. Prey sizes will be standardized across treatments. Plastic plants will be installed to simulate the structural complexity of aquatic vegetation at nearshore rearing sites, and laboratory lights will be set to simulate natural day night cycles. The number and order of prey consumed by muskellunge will be analyzed to determine which species are selected. In addition, prey morphology (e.g., length, body depth, fin ray height, etc.) and caloric content will be quantified

to determine which factors influence prey selection. Prey fish caloric content will be quantified using a calorimeter.

Objective 3

We will sample fish assemblages at nearshore sites with a fine-mesh bag seine (9.14 m long, 1.6 mm mesh), using the standardized protocol employed during 2007-2012 (for methods see Farrell and Werner 1999; Kapuscinski et al. 2009). Seine hauls will be of equal length (30.5 m) to allow for comparisons of catch rates among sites and across years. Seining will be conducted during 27 July-7 August to be consistent with efforts during previous years. All fish captured will be identified and released, and all northern pike (*Esox lucius*) and muskellunge will be measured for total length (mm). Stomach contents will be flushed out of northern pike and muskellunge ≥80 mm (non-lethal lavage technique, see Farrell 1998), and prey items will be identified and measured for total length when possible. At least 10 sites will be sampled, including two in the Buffalo Harbor and eight in the upper Niagara River (Figure 1). Site-specific catch rates of age-0 muskellunge will be calculated, and differences among sites and across years will be examined to monitor trends in muskellunge production.

Deliverables

Anticipated deliverables include: (1) models for predicting occurrences of age-0 muskellunge, native fishes, and non-native fishes based on habitat variables; (2) data describing muskellunge prey selection and caloric content of prey species; (3) a minimum of two articles submitted for publication in peer-reviewed scientific journals; (4) annual reports which may be included in NYSDEC's Lake Erie Annual Report; and (5) a Master of Science thesis.

Organization

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Evidence of Consultation with the Niagara River Greenway Commission

We received a positive consistency determination at the 15 January 2013 Commission meeting and a decision letter (enclosed) with a list of comments on 16 January 2013. Here we address comments from the Commission and the Niagara Relicensing Environmental Coalition:

<u>Questions asked by Commissioners</u>

1. *Will you focus on near-shore zones?*

Yes, nearshore zones of the upper Niagara River (UNR) will be the focus of all proposal objectives.

2. *How will this benefit the public?*

Developing a model that predicts the occurrence of age-0 muskellunge from physical habitat characteristics (Objective 1, Application 1) will have direct benefits to the public. The self-

sustaining muskellunge fishery in the upper Niagara River is internationally known and its importance to the local community is exemplified by organizations such as the Niagara Musky Association. Conservation and restoration of rearing habitat for muskellunge is essential for sustaining this valuable fishery. Currently, no model exists for predicting age-0 muskellunge occurrence based on habitat features. Developing such a model will help identify essential habitat features for age-0 muskellunge and provide a framework for conserving and restoring this habitat. Managers will be able to evaluate competing restoration designs with this model in order to maximize beneficial habitat for age-0 muskellunge. This type of habitat restoration will help sustain the economically important muskellunge fishery, which has existed for over 150 years in the upper Niagara River.

Developing a model that predicts the occurrence of native and non-native fishes from physical habitat characteristics (Objective 1, Application 2) will aid in identifying habitat features that native fish species are most often associated with, and non-native species least often associated with. This will provide a decision making tool for directed restoration and conservation of nearshore habitats. For example, if geographic information system (GIS) habitat layers are available for competing restoration designs, the model can be integrated with GIS software and display which restoration design maximizes native fish habitat and minimizes non-native fish habitat. Similarly, the model will help managers prioritize habitats for conservation. Without direction, habitat alteration activities may inadvertently be detrimental to native fish species by providing habitat for non-native species. Outcomes from this objective will directly benefit the public by providing a tool for increasing the effectiveness and efficiency of habitat restoration and conservation of nearshore habitats. Many species (e.g., largemouth and smallmouth bass, yellow perch, northern pike, and muskellunge) that provide substantial recreational fisheries in the upper Niagara River rely on nearshore habitats for spawning and rearing. Effectively conserving and restoring habitats for these species will aid in sustaining important recreational fisheries.

Objective 2 seeks to determine if age-0 muskellunge feed selectively, identify the mechanisms that lead to selective feeding, and to determine if selective feeing affects growth of age-0 muskellunge. This information will aid resource managers in conserving and restoring the fish

assemblages that are most important for age-0 muskellunge growth, and therefore, survival. Optimizing nursery conditions for age-0 muskellunge will enhance recruitment, thereby enhancing the population of adult muskellunge that is so ecologically important and economically valuable to the public.

Monitoring nearshore fish assemblages (Objective 3) during 2013-2015 will continue a standardized survey that began in 2007. This is the longest, continuous data set that exists for fishes of Buffalo Harbor and the upper Niagara River. These data provide information to resource managers regarding the relative abundance and annual production of sport, prey, and nonnative fishes, which can be used to guide fishery management plans for the public good.

3. How long will the research take?

The research is scheduled for three years, beginning in the summer of 2013 and continuing through March 2016. Having at least three years of data is essential for developing reliable models based on environmental conditions that may vary annually (Objective 1). For example, the greater Buffalo region experienced the wettest May on record in 2011, but May 2012 was the fifth driest on record (National Weather Service). This type of variation in environmental conditions can directly affect fish populations and their associated habitat. Therefore, accounting for environmental variation by collecting three years of data will aid in producing reliable models. Two field seasons are also required for Objective 2. Field collections and laboratory experiments to determine if age-0 muskellunge feed selectively among prey species will be completed in Year 1, and additional experiments to determine how rearing age-0 muskellunge on individual prey species affects growth of age-0 muskellunge can be completed in Year 2. Objective 3, monitoring nearshore fish assemblages, will occur each field season and add to this continuous data set.

4. How will the final project be recognized?

The results of Objective 1 will be realized by a suite of models for predicting age-0 muskellunge, native fish, and non-native fish occurrence based on habitat characteristics. The models will be able to integrate with GIS software to produce spatially explicit maps that aid managers in habitat restoration and conservation decision making. We will publish our results from

Objectives 1 and 2 in annual NYSDEC reports and scientific journals, which are available to the public. Information from this research will be presented at regional and national conferences to disseminate our results to other researchers and managers. Additionally, we will present our findings to public interest groups if requested.

Comments from the Niagara Relicensing Environmental Coalition

1. This project is more relevant to the Habitat Enhancement and Restoration Fund than to Greenway funding sources.

Our projects will add to the base of scientific information that resource managers depend upon to successfully manage the ecological resources of the Niagara River. We do not propose to physically alter habitat. Therefore, we believe our proposal is most relevant to the Greenway Ecological Fund. Please see our "Project Consistency with the Niagara River Greenway Plan" section below and the enclosed determination letter from the Niagara River Greenway Commission regarding project relevance to the Niagara River Greenway Plan.

2. Research should be designed to be useful not only to readers of scientific journals, but also to Niagara Greenway stakeholders, decision-makers and habitat practitioners.

Project outcomes will directly benefit Greenway stakeholders, resource managers, and habitat practitioners by providing tools and knowledge to aid in effective and efficient habitat conservation, enhancement, and restoration. Additionally, results and deliverables from the project will contribute to protecting and sustaining valuable public resources such as the muskellunge fishery.

Comments from the Department of State

1. One concern appears that the project actually develop a usable product for those doing restoration and monitoring, and it not be and academic exercise for someone to get their master's degree (it appears that tuition is part of the budget). Having a usable model should be a key project element. Often these projects include peer-reviewed papers but do not include something that can actually be utilized. It might be good if there is some sort of training aspect to the model, so that they could train managers on how it can be used in practice.

The goal of Objective 1 is to produce a tool that can be utilized by resource managers for guidance during habitat conservation, enhancement, and restoration planning. The models will be able to integrate with GIS software and produce maps that can aid managers during restoration design (e.g., maximizing habitat for native fish, while minimizing habitat for non-native fish) or habitat conservation planning. We will provide training and a user manual to resource managers who wish to implement the model.

Evidence of Consultation with Affected Municipalities, Counties, or Indian Nations

N/A – Project activities will not be conducted on municipal, county, or Indian Nation lands.

Evidence of Consultation with State and Federal Agencies

The New York State Department of Environmental Conservation (NYSDEC) is a project cooperator and has reviewed this application in full. NYSDEC project reviewers were Michael Clancy, Michael Wilkinson, and Timothy DePriest (Buffalo office, phone: 716-851-7010). Consultation with U.S. federal agencies was not applicable for this project and therefore not conducted.

Operation and Maintenance Plan

N/A – No permanent physical structures are being built.

Project Consistency with the Niagara River Greenway Plan (NRGP)

Our project objectives are guided by the NGRP Priority Status: *Restoration of Niagara River Ecosystem,* principles of *Sustainability*, *Ecological Integrity*, and *Restoration,* and Greenway goals of *Protect and Restore Environmental Systems,* and *Promote Long Term Sustainability*. Models developed during this project will be available for use as decision making tools for nearshore habitat restoration designs. Model outputs will also help identify key environmental variables that contribute to native and non-native fish assemblages. These models will guide development of restoration strategies that maximize benefits to native species and minimize benefits for non-native or invasive species. Quantifying prey selection by age-0 muskellunge and the caloric content of different prey types will provide managers with a better understanding of which prey fish are most important for age-0 muskellunge growth and subsequently survival.

Integrating knowledge from habitat models and prey fish studies will allow for a holistic approach to management of nearshore fishes.

Our project will also advance the NRGP's principles of *Partnerships* and *Community* by continuing the collaborative effort among the NYSDEC and SUNY-ESF to gain knowledge about the Greenway's aquatic resources. This partnership and communication with user groups such as the Niagara Musky Association is critical for conservation of ecological resources used by the public. As critical habitats are protected and restored, improvements to native sport fish populations (e.g., muskellunge) will attract anglers, who will spend money locally and help *Spark Revitalization and Renewal.*

Project activities will be conducted almost entirely within the *Focus Area*; some habitat and fish sampling may be conducted in Ontario waters. We believe that all aspects of our project are *Implementable*, because they build on existing data and research efforts completed during 2007-2012—our prior experience allows us to propose a realistic workload and budget. A total of $244,713 in *Matching Funds* will be provided by SUNY-ESF. The results of this project will provide *Clear Benefit*s to the Greenway and local community by obtaining information required for proper management, conservation, and restoration of nearshore fishes and aquatic vegetation.

Project Consistency with State and Federal Laws

NYSDEC collaborators reviewed the project description for consistency with state laws, and NYSDEC staff will be involved with most project activities, providing real-time consultation on any changes to the project. We will obtain a collector's permit from OMNR for any activities in Ontario waters, and therefore be in compliance with all Ontario laws. Our proposed activities do not require exemption from federal laws, so U.S. agencies were not consulted.

Efforts and Opportunities to Obtain Matching Funds

Approximately $244,713 in matching funds from SUNY-ESF will support this project. In addition, the NYSDEC has agreed to provide services (salary, mileage, etc.), but the amount is unknown at this time (please see enclosed letter of support).

Existing Costs as of 31 August 2007

We will not use any awarded Greenway Funds to defray obligations, operations, or maintenance costs existing prior to 31 August 2007.

Land Ownership Associated with Project

N/A

Project Budget

Field sampling, laboratory experiments, data analysis, and report writing will be conducted during 1 April 2013-31 March 2016 to achieve the project objectives. Therefore, funding for three years is being requested at a total of $801,436 (see Table 1 for a detailed budget).

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Table 1. Proposed budget for 2013-2016 project activities.

CATEGORY	4/1/13-12/31/13	1/1/14-12/31/14	1/1/15-12/31/15	1/1/16-4/1/16	Total
Senior Personnel:					
PI: Kevin Kapuscinski, 50%	21,125	40,943	42,171	10,859	115,097
Total Senior Personnel	21,125	40,943	42,171	10,859	115,097
Other Personnel:					
(1) Other Professionals (Post Doc - Crane, 85%)	25,783	45,526	46,892	14,205	132,407
(1) Other Professionals - tech - summer	7,200	7,416	7,638	-	22,254
(1) Other Professionals - tech - summer	6,720	6,922	7,129	-	20,771
(1) Other Professionals - tech - summer	6,720	6,922	7,129	-	20,771
(1) Graduate Student, 50% CY/pt hourly	-	18,000	18,540	-	36,540
Total Salaries and Wages	67,548	125,728	129,500	25,064	347,840
Benefits:					
Regular @ 43%; 43.25%; 44%; 44.25% (Kapuscinski)	9,084	17,708	18,555	4,832	50,179
Regular @ 43%; 43.75%; 44%; 44.25% (Crane)	11,087	19,690	20,632	6,321	57,731
Summer Salary @ 17% (technician 1)	1,224	1,261	1,299	-	3,783
Summer Salary @ 17% (technician 2)	1,142	1,177	1,212	-	3,531
Summer Salary @ 17% (technician 3)	1,142	1,177	1,212	-	3,531
Graduate Students @ - ; 16.75% ; 18%	-	3,015	3,337	-	6,352
Total Benefits	23,679	44,027	46,247	11,154	125,107
Total S, W and B	91,228	169,754	175,747	36,218	472,947
Permanent Equipment:					
Boat Purchase or Lease	25,000	-	-	-	25,000
Truck Lease	25,000	-	-	-	25,000
Total Equipment	50,000	-	-	-	50,000
Domestic travel US/Canada/Mexico	4,500	4,500	4,500	-	13,500
Other Direct Costs:					
1. Materials and Supplies	8,500	2,000	2,000	-	12,500
2. Housing	12,000	12,000	12,000	-	36,000
3. Publication Costs/Page Costs			1,000	-	1,000
4. Tuition - 1 AY tuition scholarship	-	11,194	11,642	-	22,836
5. General services: Boat Maintenance	1,000	1,000	1,000	-	3,000
Total Other Direct Costs	21,500	26,194	27,642	-	75,336
Total Direct Costs	167,228	200,448	207,889	36,218	611,783
Indirect Costs @ 31% TDC (waived from 71%)	51,841	62,139	64,445	11,228	189,653
Total Direct and Indirect Costs	219,069	262,587	272,334	47,446	801,436
Amount of Request	**219,069**	**262,587**	**272,334**	**47,446**	**801,436**
Unrecoverable Indirect 71% TDC	66,891	80,179	83,156	14,487	244,713
Total Matching Funds	**66,891**	**80,179**	**83,156**	**14,487**	**244,713**

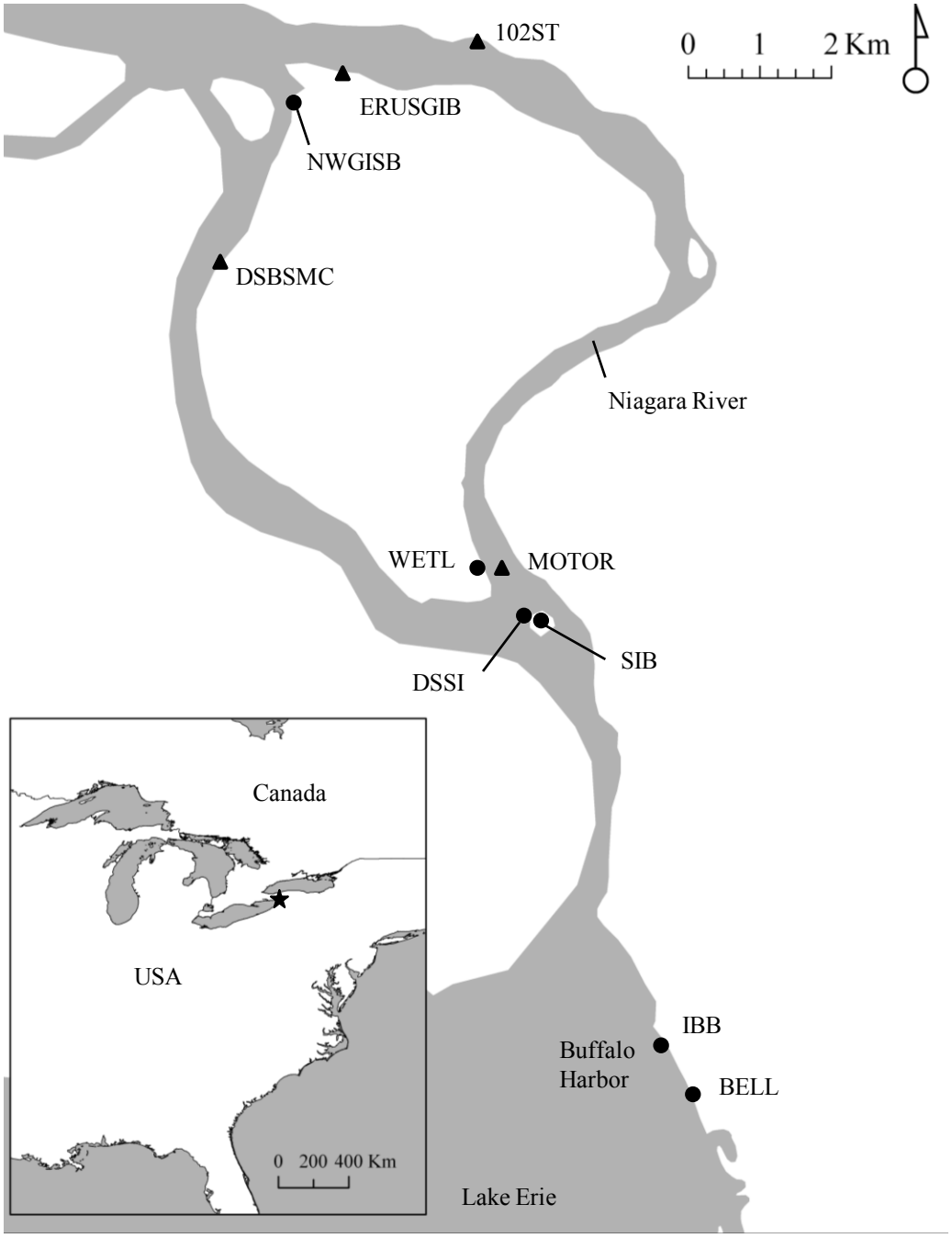

Figure 1. Map of Buffalo Harbor and the upper Niagara River indicating sites sampled in a standardized seining survey during 2007-2011 (circles) and 2008-2011 (triangles).

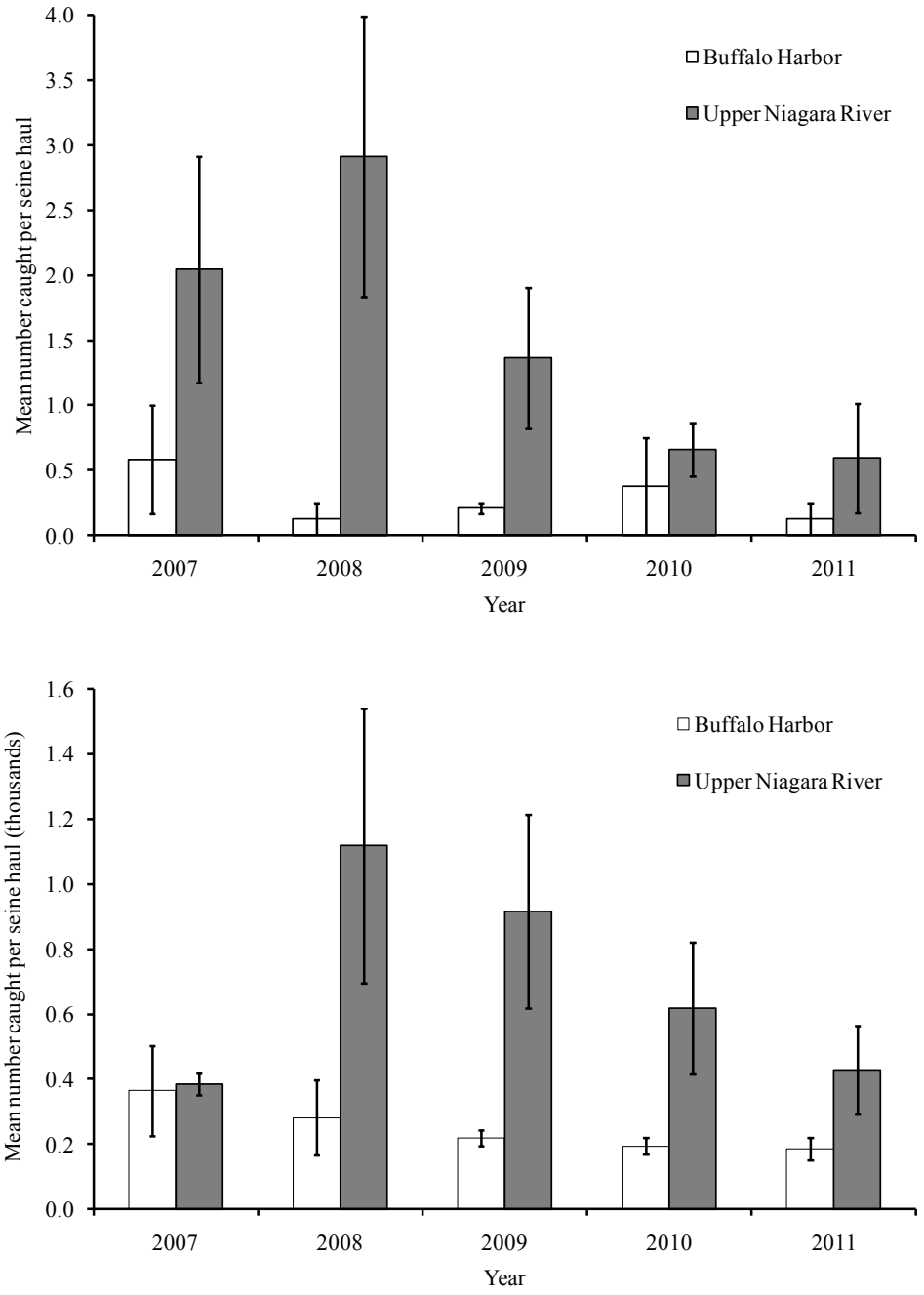

Figure 2. Mean (± SE) number of young-of-the-year muskellunge (top panel) and all fishes (thousands, bottom panel) caught per seine haul at nearshore index sites of Buffalo Harbor and the upper Niagara River during 2007-2011.