Canadian Journal of Fisheries and Aquatic Sciences
Journal canadien des sciences halieutiques et aquatiques

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Journal:	<i>Canadian Journal of Fisheries and Aquatic Sciences</i>
Manuscript ID	cjfas-2016-0160.R3
Manuscript Type:	Article
Date Submitted by the Author:	22-Nov-2016
Complete List of Authors:	Crane, Derek P.; Coastal Carolina University, Farrell, John M.; State University of New York
Keyword:	INVASIVE SPECIES < Organisms, body condition, St. Lawrence River, round goby, dreissenid mussels

Trends in body condition of smallmouth bass and northern pike (1982-2013) following multiple ecological perturbations in the St. Lawrence River

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Draft

Abstract

Body condition indices can be used to investigate fish response to biological or environmental change. We used quantile regression to analyze a 32-year weight-length dataset (1982–2013) for smallmouth bass (*Micropterus dolomieu*) and northern pike (*Esox lucius*) from the St. Lawrence River to examine changes in condition (weight-at-length) during three ecologically distinct time periods. Condition of both species varied among time periods, with smallmouth bass experiencing greater proportional changes than northern pike. Smallmouth bass weight-at-length was greatest during 2005–2013 and lowest during 1982–1992. Northern pike weight-at-length was greatest during 2005–2013 for quantiles ≥ 0.5 , similar between the 1982–1992 and 2005–2013 time periods for lower quantiles, and lowest during 1993–2004. The most likely weight-length model for smallmouth bass included terms for length, presence of round goby (*Neogobius melanostomus*), presence of dreissenid mussels, and an interaction between length and dreissenid mussels ($w_i = 0.93$). The most likely model for northern pike included terms for length, presence of round goby, presence of dreissenid mussels, water temperature, conspecific abundance, and sex ($w_i = 0.56$). Invasive species and environmental change related to invasive species have altered the condition of smallmouth bass and northern pike in the St. Lawrence River.

Keywords: invasive species, round goby, dreissenid mussels, St. Lawrence River, body condition

58 **Introduction**

59 Changes in aquatic food web structure and function and environmental conditions can
60 affect the availability and composition of prey, physiological function, and subsequently, body
61 condition of fishes (Johnson et al. 2005; Rennie et al. 2009; Crane et al. 2015). Body condition
62 of fishes is commonly determined with a variety of indices (e.g., Fulton's K, relative condition
63 factor, relative weight, mean or quantile weight-length relationships; Pope and Kruse 2007, Cade
64 et al. 2008) that assume heavier fish are in a better nutritional state than lighter fish of the same
65 length. Recruitment potential (Ratz and Lloret 2003; Marshall and Frank 1999), growth (Willis
66 1989; VanDeValk et al. 2008), and mortality (Dutil and Lambert 2000; Johnson 2008) have been
67 related to body condition indices. Indices of body condition based on weight-length
68 relationships are frequently incorporated in fisheries assessments because they are a relatively
69 reliable measure of energy reserves, collection of weight and length data are often standard parts
70 of fisheries surveys, and data collection is non-invasive and relatively inexpensive (Blackwell et
71 al. 2000; Pope and Kruse 2007). Body condition analyses can be used to assess availability of
72 prey to commercial and sport fishes (Marwitz and Hubert 1997; Porath and Peters 1997) and
73 investigate fish response to biological or environmental change in aquatic ecosystems (Rennie et
74 al. 2009, Staton et al. 2014; Crane et al. 2015). Rennie et al. (2009) emphasized the importance
75 of using long term data sets with multiple explanatory variables to better understand the effects
76 of biological and environmental change on fish condition, yet analyses considering effects of
77 multiple biotic and abiotic factors on body condition are relatively rare.

78 The availability of long-term weight-length data for predatory fishes such as smallmouth
79 bass (*Micropterus dolomieu*) and northern pike (*Esox lucius*) and major ecological changes that
80 have occurred over the past several decades make the St. Lawrence River an excellent model

ecosystem for investigating how biological and environmental factors affect the body condition of predatory fishes. Smallmouth bass and northern pike are the most abundant predatory fishes and most important sport fishes in the Thousand Islands region of the St. Lawrence River (McCullough and Gordon 2014). Smallmouth bass and northern pike also have different feeding strategies, habitat use, and thermal preferences. The smallmouth bass is a warmwater, generalist predator that typically occupies rocky habitats and feeds on benthic prey, whereas, the northern pike is a coolwater species that occupies vegetated littoral zones and typically feeds on fishes higher in the water column. Therefore, body condition of smallmouth bass and northern pike may respond differently to changes in biological and environmental conditions of the ecosystems they inhabit. Body condition can also vary between sexes within a species (Doyon et al. 1988); thus, the response in body condition to ecological change may also vary between sexes. For example, male smallmouth bass in Lake Erie experienced increased energetic costs of nest guarding following invasion by round goby (Steinhart et al. 2005) because the round goby is an aggressive nest predator that male smallmouth bass must defend against. Female smallmouth bass do not nest guard and therefore are not subject to increased energetic costs associated with defending a nest against round gobies. The objectives of this study were to (1) document long-term trends in smallmouth bass and northern pike body condition across a range of quantiles, (2) identify any differences in body condition between male and female fish and determine if male and female fish responded differently to biological and environmental change, and (3) identify important ecological and environmental factors that affect body condition of smallmouth bass and northern pike across a range of body condition quantiles and make comparisons between the two species. We used quantile regression to analyze 32 years of weight-length data for northern

pike and smallmouth bass from the Thousand Islands region of the St. Lawrence River to address these objectives.

Materials and methods

Study location and fish collection

The St. Lawrence River is part of the Great Lakes ecosystem, which has experienced substantial ecological change due to complex, interacting top-down and bottom-up drivers over the past several decades (Mills et al. 2003; Farrell et al. 2010; Murry and Farrell 2014). Some of the most rapid and dramatic ecological changes have been associated with invasion and proliferation of dreissenid mussels in the early 1990's and the round goby (*Neogobius melanostomus*) in the mid 2000's (Farrell et al. 2010). Dreissenid mussels sequestered nutrients in the benthos, which resulted in increased water transparency and decreased pelagic productivity (i.e., decreased food for many fishes; Mills et al. 2003). The round goby, a benthic-oriented consumer of dreissenid mussels, rapidly populated the upper St. Lawrence River in 2005 and became an important food resource for many predators; thus, creating a link between dreissenid mussels and higher trophic levels (Farrell et al. 2010). Coinciding with the invasions of dreissenid mussels and round goby, the double-crested cormorant population (*Phalacrocorax auritus*) expanded in the St. Lawrence River region. Double-crested cormorants prey heavily on a variety of fishes. From 1999 through 2013 double-crested cormorants from three islands in the St. Lawrence River consumed an estimated 145 million fish (Johnson et al. 2015). Competition between double-crested cormorants and piscivorous fishes for food may directly and indirectly affect body condition of fishes in competition with double-crested cormorant.

Smallmouth bass and northern pike were sampled from the Thousands Islands region of the St. Lawrence River from 1982-2013 as part of the New York State Department of

Environmental Conservation's annual fish stock assessment (McCullough and Gordon 2014). Sampling was conducted annually in the St. Lawrence River from Clayton, New York, USA downstream to Morristown, New York, USA and occurred from late July through early August (Fig. 1). Fishes were sampled with multifilament gillnets from 1982 through 2003 and monofilament gill nets from 2004 through 2013. Paired sampling indicated that catchability of smallmouth bass and northern pike did not appreciably differ between the two net types (McCullough and Gordon 2014). Nets were 61 m long and 8 m deep. Each net contained eight panels with stretch mesh ranging in size from 38–152 mm. Thirty-two net sets were fished overnight at fixed sites each year. Sample locations were in 3–20 m of water, and all nets were fished on the bottom. Total length (mm) and weight (g) were recorded for collected fish. To eliminate potential biases by including small fish that were not well represented in the samples, we only included smallmouth bass ≥ 200 mm and northern pike ≥ 475 mm in weight-length analyses.

Body condition analyses

We used two quantile regression analyses, based on weight-length data for 4499 smallmouth bass and 2623 northern pike, to investigate the response in body condition of smallmouth bass and northern pike to ecological change in the St. Lawrence River (Table 1). First, we analyzed weight-length relationships for smallmouth bass and northern pike to determine if body condition changed during three time periods in 1982–2013 and if weight-length relationships differed between sexes. Next, we investigated the effects of several biological and environmental factors on weight-length relationships for northern pike and smallmouth bass to identify the most important drivers of change in body condition during the

three specified time periods. Models for the 0.1–0.9 quantiles (in increments of 0.1) were fitted using the ‘quantreg’ package (rq () function) in R (Koenker 2016). Model parameters were estimated using the “br” method and 95% confidence intervals were estimated using the “rank” method (Koenker 2016).

We used Bayesian information criterion (BIC; Schwarz 1978), information loss (Δ BIC; Raftery 1995), and Schwarz weights (w_i ; Wagenmakers and Farrell 2004; Link and Barker, 2006) to evaluate and select the most likely model structure for each analysis (i.e., variables to include in the model) based on the 0.5 quantile. Bayesian information criterion allows for comparison of the likelihood individual models in a series of models fitted on common data. We chose to use BIC over Akaike information criteria (AIC) for model selection because our samples sizes for smallmouth bass and northern pike were large (i.e., $n \gg$ parameter numbers creating the true model) and when samples size are large, AIC may lead to selection of an overparameterized model that includes variables with limited biological importance or effect sizes. The use of BIC provided a conservative model selection approach that satisfied our objective of identifying the most important drivers of change in body condition of smallmouth bass and northern pike in the St. Lawrence River. Increasing likeliness of a model corresponds to lower BIC values (Raftery 1995; Murtaugh 2014). Information loss is the difference in BIC between a given model and the model with the lowest BIC value. Schwarz weight is the comparative probability that a given model is the most likely model within the set of models analyzed (Link and Barker 2006).

Time period analysis

To investigate trends in body condition of smallmouth bass and northern pike during 1982 through 2013, we examined weight-length relationships during three ecologically different time periods. The first time period (1982–1992) was defined as the base time period, prior to significant invasive species introductions. We used 1992 as the upper end point for this time period because dreissenid mussels were first detected in the study area in 1991 but were not prolific until 1993 (Rodger Klindt, New York State Department of Environmental Conservation – Region 6, 317 Washington St # 7, Watertown, NY 1360, personal communication). The second time period (1993–2004) was characterized by expansion and growth of dreissenid mussel and double-crested cormorant populations in the upper St. Lawrence River (Fig. 2), and decreased abundance of smallmouth bass and northern pike (Fig. 2). The third time period (2005–2013) was defined by invasion of round goby (Farrell et al. 2010), increased abundance of smallmouth bass, decreased abundance of northern pike, and a large but variable population of double-crested cormorant.

Eight competing weight-length models were fitted for the 0.5 quantile to determine the most likely model structure (Table 2). The most likely model structure for the 0.5 quantile was then applied to models for the 0.1–0.9 quantiles to investigate the effects of time period, sex, and one-way interactions between length, sex, and time period on body condition of smallmouth bass and northern pike. Applying the underlying model for the 0.5 quantile to additional quantiles is reasonable because parameters that are uninformative in additional quantiles would have estimates near zero. The standard weight-length relationship for fish is described by the equation:

194 (1) $W = \beta_0 TL^{\beta_1}$

195

196

197 where W = weight (g), TL = total length (mm), β_0 = intercept, and β_1 = allometric growth

198 parameter (Keys, 1928). Weight-length models were log-transformed and adapted to include

199 time period and sex as categorical variables. A variable for sex (0 = male, 1 = female) was

200 included to determine if body condition differed between sexes and if changes in body condition

201 during the time periods examined differed between sexes. Models were log₁₀-transformed prior

202 to being fitted because linear quantile regression methods are better developed than nonlinear

203 methods (Cade et al. 2008, 2011).

204 Following model selection, the most likely log₁₀-transformed models for each species

205 were back-transformed to estimate percent changes in weight-at-length between time periods and

206 estimate time period and species specific weight-at-length lengths for quantiles 0.1–0.9.

207 Differences in parameter estimates between time periods were calculated using the

208 ‘contr.treatment’ option when fitting models in R. Unlike back-transformed parameter estimates

209 for mean weight-length relationships, back-transformed parameter estimates for quantile weight-

210 length relationships are unbiased and can be used to provide valid estimates of weight-at-length

211 (Cade et al. 2008). Because an important interaction was identified between time period and

212 length in the smallmouth bass model, multiplicative changes in weight-at-length for smallmouth

213 bass needed to be estimated at specific lengths. Multiplicative changes in weight for smallmouth

214 bass were estimated by back-transforming models and rescaling the intercepts (time period

215 variable) to the desired length of interest. This was accomplished by estimating parameters for

216 models where the total lengths were divided by the length of interest. In rescaled models the

base 10 exponentiated differences in intercept values (and 95% confidence intervals) between time periods were equal to the multiplicative change in weight for the target length class. We chose to use the median values of lengths for stock, quality, preferred, and memorable size class smallmouth from Gabelhouse's (1984) five-cell model to examine changes in smallmouth bass weight-at-length. Interactive effects of time period and length or time period and sex were not identified as important predictors in the northern pike model; therefore, multiplicative changes in weight-at-length (and 95% confidence intervals) were not size or sex specific and were estimated by base 10 exponentiating the differences between parameter estimates and the upper and lower bounds of 95% confidence intervals for the time period parameters in the model. For example, the difference in time period parameter estimates between time periods 1 and 2 in the northern pike model (0.5 quantile) was -0.0119. When base 10 exponentiated, this equated to a multiplicative change in weight of 0.972 (i.e., 2.8% decrease in weight) between time periods 1 and 2. To visually examine changes in weight-at-length between time periods and across quantiles 0.1–0.9, we plotted multiplicative changes in weight-at-length and 95% confidence intervals for changes that occurred from time period 1 to time period 2, time period 1 to time period 3, and time period 2 to time period 3. We also plotted time-specific weight-at-length across quantiles 0.1–0.9 for selected length classes of smallmouth bass and northern pike. The BIC analysis indicated that weight-at-length was dependent on sex for northern pike but not smallmouth bass; therefore, plots of weight-at-length are sex-specific for northern pike but not smallmouth bass. The size distribution of male northern pike was more restricted than the size distribution of female northern pike, so we estimated weight-at-length for fewer length classes of male northern pike.

Biological and environmental effects

To investigate the effects of biological and environmental change on body condition of smallmouth bass and northern pike we fitted a series of weight-length models for quantiles 0.1–0.9 (Table 3), including terms for the presence of dreissenid mussels, presence of round goby, mean summer water temperature (Fig. 2), catch per unit effort (CPU) of conspecifics (Fig. 2), and abundance of double-crested cormorants (Fig. 2). In the time period analysis, indicator variables encompassed all factors affecting weight-length relationships during each specific time period. Replacing time period variables with variables for biological and environmental factors allowed us to partition the effects observed between time periods across the environmental and biological variables examined. Based on results from the time period analysis, sex specific models were fitted for northern pike but not smallmouth bass. Median weight-length models, based on the standard weight-length equation (eq. 1), were log-transformed and adapted to include variables for biological and environmental factors and their one-way interactions. Indicator variables were used to account for the presence round goby and dressinid mussels. Annual CPU data for northern pike and smallmouth bass were based on the NYSDEC's annual summer stock assessment for the Thousand Islands region of the St. Lawrence River (described above). Annual abundance data for double-crested cormorants in the Thousand Islands region were based on nest count surveys conducted by the NYSDEC. Variance inflation factors (VIF) were calculated for all environmental and biological variables, using the `vif()` function in the 'car' package for R (Fox and Weisberg, 2016), to identify and remove highly correlated variables because collinearity can affect estimation and interpretation of model coefficients. Variables with highest VIF were sequentially dropped until VIF was < 5.0 for all predictors. Zurr et al. (2010) suggested that multicollinearity may be an issue when VIF is as low as 2 if effect sizes

are small. However, O'Brien (2007) demonstrated that substantially higher VIF values may be acceptable because multicollinearity is not the only factor affecting variation of parameter estimates (e.g., increasingly larger sample sizes decrease variation of parameter estimates). Northern pike CPU had the greatest VIF that was < 5.0 ($VIF = 4.77$) in our study and we found confidence intervals around the parameter estimate for this variable to be acceptable (Fig. 3). The variable for double-crested cormorant abundance had high VIF values for the smallmouth bass ($VIF = 10.24$) and northern pike ($VIF = 7.28$) models, and was therefore not included in analyses for both species.

Ambient water temperature is a major determinant of fish bioenergetics and may affect fish weight-length relationships. Mean annual summer water temperatures for 1982–2002 were based on St. Lawrence River daily water temperature data collected at the DuPont Canada facility in Maitland, Ontario. May–July was considered the summer growing season for northern pike because sampling commenced in late July. June through July was considered the summer growing season for smallmouth bass because low water temperatures and spawning limit smallmouth bass growth during May. Since water temperature data were not available for 2003–2013, we used the relationship between mean monthly summer water temperature for the St. Lawrence River at Maitland, Ontario and mean monthly air temperature at Watertown International Airport for 1965–2002 (Watertown, New York; data retrieved from the National Climatic Data Center, available at: www.ncdc.noaa.gov/cdo-web/) to predict mean summer water temperatures at Maitland, Ontario for 2003–2013. Mean monthly water temperatures for May–July were predicted for each year (2003–2013) with the equation:

(2) $St. Lawrence R. temp = 2.2235e^{0.0997 \times Watertown temp}$

Predicted mean monthly temperatures were averaged for each year to determine the average growing season temperature for northern pike (May-July) and smallmouth bass (June-July). Observed and predicted water temperatures (1965-2002) were moderately correlated for May-June ($r = 0.75$) and June-July ($r = 0.66$). However, plots of observed versus predicted mean annual summer water temperature (May-July and June-July) indicated that predicted values followed the general trends of observed values (Fig. 4). Therefore, it was reasonable to include predicted water temperatures for 2003–2013 in the body condition analyses.

To evaluate the body condition models and select the mostly likely model, data were randomly split into training and testing data; 75% of data were allocated for model training and 25% were allocated for model testing. The most likely model was selected based on BIC analyses of 0.5 quantile models fitted with training data, as described for the time period analysis. Once the most likely model was selected, we estimated the weight-at-length for the 0.1 and 0.9 quantiles for each fish in the test data sets. We then calculated the proportion of fish in the test data set that fell within the 0.1-0.9 quantile weight intervals. For reasonably well performing models, about 80% of the test would fall within the 0.1-0.9 quantile interval, 10% of predicted weights would be <0.1 quantile, and 10% would be greater than the predicted weight for the 0.9 quantile. Finally, we plotted model parameters and 95% confidence intervals across quantiles 0.1-0.9. Reported model parameters are based on models fitted using all data.

Results

Time period analysis

Model results indicated that body condition of smallmouth bass and northern pike varied among time periods, with smallmouth bass experiencing greater proportional changes between time periods than northern pike (Figs. 5-9). The most likely weight-length model for smallmouth bass included terms for length, time period, and an interaction between time period and length (Table 2; Fig. 10). The most likely model for northern pike included terms for length, time period, and sex (Table 2; Fig. 11). Smallmouth bass body condition increased between each subsequent time period over the entire study period, and changes in smallmouth bass weight-at-length were greater between time periods 2 and 3 than between time periods 1 and 2 (Figs. 5 and 6). Changes in smallmouth bass weight-at-length were relatively homogenous across quantiles and the 470 mm length class experienced the greatest proportional increases in weight-at-length (Fig. 6). Northern pike weight-at-length decreased for quantiles <0.7 and increased for quantiles >0.7 between time periods one and two, increased across all quantiles between time periods two and three, and increased for quantiles >0.4 but decreased for quantiles <0.3 between time periods 1 and 3 (Figs. 7-9). Parameter estimates for sex indicated that male northern pike were slightly heavier or similar in weight to female northern pike at a given length for all quantiles except the 0.1 quantile (Fig. 11).

Biological and environmental effects

Ecological and environmental changes in the St. Lawrence River had varying effects on body condition of smallmouth bass and northern pike. The most likely weight-length model for smallmouth bass contained terms for length, presence of round goby, presence of dreissenid mussels, and an interaction between length and the presence of dreissenid mussels ($w_i = 0.93$;

Table 3; Fig. 12). The most likely model for northern pike include terms for length, presence of round goby, presence of dreissenid mussels, water temperature, northern pike CPU and sex ($w_i = 0.88$; Table 3; Fig. 3). Body condition of smallmouth bass was positively associated with the presence of round goby across all quantiles (Fig. 12). For example, weight-at-length for median condition smallmouth bass was about 13.5% (95% CI = 12.6–14.5%) greater when round goby were present compared to when round goby were absent. Changes in body condition associated with dreissenid mussels were also relatively homogenous across quantiles (Fig. 12), but dependent on smallmouth bass length; the presence of dreissenid mussels had a negative effect on body condition of the smallest fish sampled and positive effect on fish > 235 mm (Fig. 13). Similar to smallmouth bass, northern pike weight-at-length was positively associated with the presence of round goby across all quantiles. However, unlike smallmouth bass, northern pike weight-at-length was negatively associated with the presence of dreissenid mussels across all quantiles (Fig. 3). Higher water temperatures were also associated with decreased weight-at-length for northern pike across all quantiles (Fig. 3). On average, northern pike weight-at-length decreased by 0.8% (95% CI = -1.3–0.5%) per 1 °C increase in mean summer water temperature across the range of mean summer water temperatures that occurred during 1982-2013 (13–17 °C). Finally, northern pike weight-at-length was inversely related to conspecific CPU for all but the lowest quantiles examined (Fig. 3)

Testing of the weight-length models revealed that both models performed relatively well. 81.1% of the smallmouth bass test data fell within the 0.1-0.9 quantile range. 10.0% of weights-at-length for smallmouth bass in the test data set were less than the expected value for the 0.1 quantile and 8.9% of weights-at-length were greater than the expected value for the 0.9 quantile. 76.7% of the northern pike test data fell within the 0.1-0.9 quantile range. 11.6% of weights-at-

length for northern pike in the test data set were less than the expected value for the 0.1 quantile and 11.7% of weights-at-length were greater than the expected value for the 0.9 quantile.

Discussion

Substantial ecological and environmental changes over the past 30 years have affected body condition of smallmouth bass and northern pike in the St. Lawrence River differently. The abiotic and biotic factors we examined were generally associated with increases in smallmouth bass body condition, but had mixed and competing associations with body condition of northern pike (e.g., presence of round goby was associated with increased body condition of northern pike, but higher water temperatures were associated with a decrease in body condition). The magnitude of changes across quantiles of body condition for smallmouth bass and northern pike were likely related to interactions between biological and environmental changes in the St. Lawrence River and each species' feeding and food preferences. The current ecological and environmental conditions in the St. Lawrence River are favorable for smallmouth bass growth and this was reflected in our body condition analyses. Clear water, abundant prey, and optimal water temperature during the summer growing season have resulted in substantial increases in weight-at-length for smallmouth bass across all quantiles of body condition. Recent environmental changes have been less beneficial to northern pike than smallmouth bass and this is likely due to its preference for cooler water temperatures and prey that occupy areas higher in the water column. Variable changes in northern pike weight-at-length across quantiles indicates that the best condition fish have benefitted from ecological changes, but the poorest condition fish have been negatively affected. Of the variables examined, presence of round goby and dreissenid mussels had the greatest effects on smallmouth bass body condition, and presence of

round goby, presence of dreissenid mussels, and conspecific abundance had the greatest effects on northern pike body condition. Round goby and dreissenid mussels have dramatically altered Great Lakes ecosystems in a relatively short time period (Hecky et al. 2004; Campbell et al. 2009; Farrell et al. 2010). Dreissenid mussel invasion has resulted in increased water clarity and decreased pelagic productivity in the Great Lakes (Mills et al. 2003; Farrell et al. 2010), and round gobies have provided predatory fishes with an abundant benthic food resource (Kornis et al. 2012).

Water clarity and productivity can directly and indirectly affect feeding success, food availability, and subsequently body condition of predatory fishes. Summer Secchi depths in the St. Lawrence River were about 3 m before invasion of dreissenid mussels, but now frequently exceed 7 m (McCullough and Gordon 2014); therefore, increased water clarity associated with dreissenid mussel invasion may have benefitted feeding efficiency of visual predators such as smallmouth bass and northern pike (Sweka and Hartman 2003; Pierce et al. 2012). Smallmouth bass reaction distance to prey increases with decreasing turbidity (Sweka and Hartman 2003). Craig and Babaluk (1989) found a positive relationship between summer Secchi depth and northern pike body condition in 37 central Canadian lakes and hypothesized that water clarity positively affected the feeding abilities of northern pike. Although increased water clarity benefits the feeding capabilities of both smallmouth bass and northern pike, restructuring of energy pathways, associated with dreissenid mussel invasion, has favored benthic over pelagic productivity (Mills et al. 2003; Farrell et al. 2010; Murry and Farrell 2014) and likely explains the varying body condition responses between smallmouth bass and northern pike. The preferred prey of smallmouth bass are benthic species, which may have benefitted from invasion of dreissenid mussels, while the preferred prey of northern pike occupy areas higher in the water

column and may have been negatively affected by decreased pelagic productivity. For example, abundances of yellow perch (*Perca flavescens*) and alewife (*Alosa pseudoharengus*) decreased substantially during the 1982-1992 time period and have remained at low levels since then (McCullough and Gordon 2014).

Increased condition of smallmouth bass and northern pike since 2005 illustrates a benefit of the non-native round goby. Dreissenid mussels are a primary prey item of round goby (French III and Jude 2001; Johnson et al. 2005; Taraborelli 2010) and round goby are heavily consumed by a variety predators in the Great Lakes-St. Lawrence River (Kornis et al. 2012), including smallmouth bass and northern pike (Reyjol 2010; Taraborelli 2010; Crane and Einhouse 2016). Therefore, invasion by round goby created an energy pathway that allowed for transfer of energy from dreissenid mussels to higher trophic levels; thus, reversing some of the negative effects of decreased pelagic productivity on predatory fishes such as northern pike. (Johnson et al. 2005). Crane et al. (2015) documented substantial increases in body condition of smallmouth bass and yellow perch (*Perca flavescens*) following invasions in Lakes Erie and Ontario by round goby, but concluded that availability of round goby as a new prey had minimal effects on burbot (*Lota lota*) and walleye (*Sander vitreus*) body condition. Crane et al. (2015) hypothesized that predator-prey habitat overlap, predator-prey size relationships, and feeding strategies explained among species differences in body condition responses. Although both northern pike and smallmouth bass experienced increases in weight-at-length following invasion of the St. Lawrence River by round goby, greater increases were observed for smallmouth bass. The smallmouth bass has a higher probability of encountering round goby compared to northern pike due to differences in feeding strategies between the species and sedentary nature of round goby (Kornis et al. 2012). Because the northern pike is a sit-and-wait predator, it less likely to

424 encounter the sedentary round goby compared to the smallmouth bass, which more actively
425 searches for prey.

426 Because density dependence in fishes is the result of competition (Diana 2004), changes
427 in prey availability following invasion of the St. Lawrence River by dreissenid mussels and
428 round goby likely altered any previously existing relationships between conspecific abundance
429 and body condition of smallmouth bass. For example, the availability of round goby as an
430 abundant food item likely limited competition for food and density dependent effects on body
431 condition of smallmouth bass during a time of increased abundance of smallmouth bass.
432 Smallmouth bass weight-at-length was greatest during 2005-2013 (post-dreissenid mussel, post-
433 round goby) despite average annual CPU increasing 90% between the 1993-2004 and 2005-2013
434 time periods (McCullough and Gordon 2014). Although the increase in CPU may partially be
435 attributed to increased catchability of faster growing smallmouth bass (McCullough and Gordon
436 2014), it is unlikely that the smallmouth bass population declined from the 1993-2004 to the
437 2005-2013 time period and allowed for compensatory growth. Round goby has limited density
438 dependent effects on body condition in other Great Lakes waters as well. Smallmouth bass and
439 yellow perch body condition and smallmouth bass growth increased after invasion of Lake Erie
440 by round goby, despite increased abundance of both species immediately following round goby
441 invasion (Crane et al. 2015; Crane and Einhouse 2016). In contrast to smallmouth bass, northern
442 pike weight-at-length was affected by conspecific abundance. Northern pike body condition was
443 lowest during 1993-2004 (post-dreissenid mussel, pre-round goby) despite decreased abundance
444 of conspecifics compared to the 1982-1992 time period (pre-dreissenid mussel, pre-round goby).
445 However, decreased abundance of northern pike during 1993-2004 may have prevented further
446 decreases in weight-at-length associated with dreissenid mussel invasion. Recent increases in

body condition may also be partially attributed to low northern pike abundance during 2005-2013. Staton et al. (2014) observed that body condition of yellow perch >150 mm (Saginaw Bay, Lake Huron) was significantly related to relative abundance of yellow perch, but because the relationship was weak the authors suggested that invasive species driven changes in the Saginaw Bay food web also affected body condition yellow perch.

Summer water temperature limited the body condition of northern pike, but not smallmouth bass in the St. Lawrence River. The northern pike is considered a coolwater species and body condition is inversely related to water temperature across its range (Doyon et al. 1988). Water temperature in the St. Lawrence River frequently exceeds the optimal temperature for growth in mass of northern pike (19 °C; Casselman 1978). The smallmouth bass is classified as a warmwater species and summer water temperature in the St. Lawrence frequently overlaps the optimal temperature for smallmouth bass growth (22 °C; Whitley et al. 2002). From 1993-2008 July monthly mean water temperature was >19 °C during 15 years and >20 °C during 8 years (mean = 20.3 °C; see National Oceanic Atmospheric Administration, Alexandria Bay, New York, U.S.A. Coastal-Marine Automated Network Station ABAN6; available online at: http://www.ndbc.noaa.gov/station_page.php?station=aban6 for water temperature data; accessed 7 April 2015). Additionally, summer water temperature in the St. Lawrence River generally peaks in August, and August water temperature averaged 21.9 °C during 1993 through 2008. Increasing summer water temperature associated with climate change in the Great Lakes Basin (Trumpickas et al. 2009) will result in increased physiological stress and limit body condition of northern pike. However, potential temperature related decreases in weight-at-length may be offset by prey availability because water temperature and ration interact to affect growth (Diana 2004). The 2005-2013 time period was the warmest time period in this study, but northern pike

weight-at-length was greater during 2005-2013, compared to the 1982-1992 and 1993-2004 time periods. High abundance of round goby and low abundance of northern pike may have mediated effects of recent warm water temperatures on northern pike body condition.

Previous research has suggested energetic costs to smallmouth bass associated with the presence of a new, highly abundant egg predator (Steinhardt et al. 2005); however, round goby did not affect the body condition of male nest guarding smallmouth bass in this study. Crane and Einhouse (2016) also found that changes in Lake Erie smallmouth bass growth following round goby invasion did not vary between males and females. Differences in the temporal proximity between nest-guarding and collection of fish may explain the discrepancy between our results and the findings of Steinhardt et al. (2005). Smallmouth bass in this study were collected 1-2 months after the spawning season; whereas, Steinhardt et al. (2005) collected fish while they were still guarding free-swimming juveniles. Energetic costs associated with nest-guarding in the presence of round goby are likely short-term, and the hyperabundance of round goby may allow for smallmouth bass to quickly recover depleted energy reserves. However, fish in this study were collected several weeks after nest-guarding finished; therefore, we were unable to account for any poor condition fish that died as the result of energetic costs associated with reproduction.

Rennie et al. (2009) suggested that simple before-after studies of the effects of aquatic invaders on fish condition may lead to spurious results if confounding variables are present. Although our analysis was more complex than a simple before-after study, additional limnological and prey abundance data would have improved our mechanistic understanding of the relationships between biological and environmental conditions and body condition of predatory fishes. Long-term data sets for basic limnological variables such as nutrient and chlorophyll concentrations are incomplete for the St. Lawrence River. Similarly, a long-term

continuous, single station water temperature data set was not available, which resulted in a need to model water temperature for 2003-2013. Unlike other areas of the Great Lakes, annual prey fish assessments are limited to seining and gill netting in the St. Lawrence River. Increased availability of data for basic limnological and biological variables will allow for a better understanding of how important sport fishes will respond to a changing ecosystem.

Acknowledgements

We would like to thank the many dedicated NYSDEC employees who were integral in collecting and maintaining the data used in this study. We especially thank Russell McCullough, David Gordon, and Rodger Klindt for providing the fish data and Irene Mazzocchi and Adam Bleau for providing the double-crested cormorant data. We also thank Yong Chen, Brian S. Cade, and two anonymous reviewers for their comments that improved this manuscript.

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Table 1. Sample sizes of male and female smallmouth bass and northern pike used for body condition analyses.

Species	Sex	1982-1992	1993-2004	2005-2013	Species total
Smallmouth bass	M	728	383	559	4499
	F	1110	690	1029	
Northern pike	M	518	270	176	2623
	F	803	589	267	

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Table 2. List of competing log₁₀ transformed median weight-length models used to investigate changes in body condition of smallmouth bass and northern pike during three ecologically different time periods in the Thousand Islands region of the St. Lawrence River. Candidate models included terms for length (TL), time period (time), sex, and one-way interactions between variables. Models were ranked using Bayesian information criterion (BIC), ΔBIC, and Schwartz weights (w_i), with the most likely model corresponding to the lowest BIC and greatest w_i .

Model	BIC	ΔBIC	w_i
<i>Smallmouth bass</i>			
log ₁₀ (TL), time, log ₁₀ (TL) x time	-15606.0	0.0	0.99
log ₁₀ (TL), time, sex, log ₁₀ (TL) x time	-15597.6	8.4	0.01
log ₁₀ (TL), time, sex, log ₁₀ (TL) x time, time x sex	-15586.2	19.8	<0.01
log ₁₀ (TL), time	-15575.1	30.9	<0.01
log ₁₀ (TL), time, sex	-15566.7	39.3	<0.01
log ₁₀ (TL)	-13433.2	2172.9	<0.01
log ₁₀ (TL), sex, log ₁₀ (TL) x sex	-13429.9	2176.1	<0.01
log ₁₀ (TL), sex	-13426.2	2179.8	<0.01
<i>Northern pike</i>			
log ₁₀ (TL), time, sex	-7709.6	0.0	0.98
log ₁₀ (TL), time	-7700.8	8.8	0.01
log ₁₀ (TL), time, sex, log ₁₀ (TL) x time	-7699.8	9.8	0.01
log ₁₀ (TL), time, log ₁₀ (TL) x time	-7690.9	18.8	<0.01
log ₁₀ (TL), time, sex, log ₁₀ (TL) x time, time x sex	-7685.3	24.4	<0.01
log ₁₀ (TL), sex	-7677.2	32.5	<0.01
log ₁₀ (TL), sex, log ₁₀ (TL) x sex	-7673.2	36.5	<0.01
log ₁₀ (TL)	-7670.4	39.2	<0.01

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Table 4. List of competing $\log_{10}$ transformed median weight-length models used to investigate the effects of biological and environmental variables on body condition of smallmouth bass and northern pike in the Thousand Islands region of the St. Lawrence River. Candidate models included terms for length (TL), presence of round goby (RG), presence of dreissenid mussels (DM), mean summer water temperature (temp), abundance of conspecifics (CPU), sex (northern pike only), and one-way interactions between variables. Models were ranked using Bayesian information criterion (BIC), Δ BIC, and Schwartz weights (w_i), with the most likely model corresponding to the lowest BIC and greatest w_i .

Model	BIC	Δ BIC	w_i
<i>Smallmouth bass</i>			
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{TL}) \times \text{DM}$	-12445.6	0.0	0.93
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{TL}) \times \text{DM}$	-12438.7	6.9	0.03
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{TL}) \times \text{DM}$	-12437.1	8.5	0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU}) + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{DM}$	-12437.1	8.5	0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU}) + \log_{10}(\text{TL}) \times \text{DM} + \log_{10}(\text{CPU}) \times \text{RG}$	-12436.8	8.8	0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU}) + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{TL}) \times \text{DM}$	-12430.9	14.7	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU}) + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{TL}) \times \text{DM} + \log_{10}(\text{CPU}) \times \text{RG}$	-12430.6	15.0	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM}$	-12409.8	35.8	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU}) + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{CPU}) \times \text{RG}$	-12403.8	41.8	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU}) + \log_{10}(\text{temp}) + \log_{10}(\text{CPU}) \times \text{RG}$	-12403.4	42.2	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU}) + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{CPU}) \times \text{RG}$	-12402.5	43.1	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU}) + \log_{10}(\text{temp})$	-12402.1	43.5	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \text{DM} + \log_{10}(\text{CPU})$	-12401.8	43.8	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \log_{10}(\text{CPU}) + \log_{10}(\text{CPU}) \times \text{RG}$	-12396.8	48.8	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \log_{10}(\text{CPU}) + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{CPU}) \times \text{RG}$	-12394.7	50.9	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \log_{10}(\text{CPU})$	-12383.8	61.8	<0.01
$\log_{10}(\text{TL}) + \text{RG}$	-12379.3	66.3	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \log_{10}(\text{TL}) \times \text{RG}$	-12377.8	67.8	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \log_{10}(\text{CPU}) + \log_{10}(\text{temp})$	-12376.6	68.9	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \log_{10}(\text{temp})$	-12374.0	71.6	<0.01
$\log_{10}(\text{TL}) + \text{RG} + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{RG}$	-12372.5	73.1	<0.01

$\log_{10}(\text{TL}) + \text{DM} + \log_{10}(\text{CPU})$	-11880.9	564.7	<0.01
$\log_{10}(\text{TL}) + \text{DM}$	-11575.3	870.3	<0.01
$\log_{10}(\text{TL}) + \log_{10}(\text{CPU})$	-10848.4	1597.2	<0.01
$\log_{10}(\text{TL})$	-10793.1	1652.5	<0.01

Northern Pike

$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{CPU})$	-5830.8	0.0	0.56
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{temp})$	-5829.1	1.6	0.25
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{CPU}) + \log_{10}(\text{CPU}) \times \text{RG}$	-5828.0	2.8	0.14
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{CPU}) + \log_{10}(\text{CPU}) \times \text{DM}$	-5824.0	6.7	0.02
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{RG}$	-5823.7	7.1	0.02
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{DM}$	-5822.9	7.9	0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{CPU}) + \log_{10}(\text{CPU}) \times \text{RG} + \log_{10}(\text{CPU}) \times \text{DM}$	-5820.5	10.3	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{TL}) \times \text{DM}$	-5816.7	14.1	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{CPU})$	-5815.4	15.4	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM}$	-5815.2	15.6	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{DM} + \log_{10}(\text{temp}) + \log_{10}(\text{CPU})$	-5812.6	18.1	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \log_{10}(\text{temp})$	-5810.1	20.6	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{TL}) \times \text{RG}$	-5808.8	22.0	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{TL}) \times \text{DM}$	-5808.7	22.1	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \log_{10}(\text{temp}) + \log_{10}(\text{CPU})$	-5808.2	22.6	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \log_{10}(\text{temp}) + \log_{10}(\text{TL}) \times \text{RG}$	-5804.0	26.8	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \text{DM} + \log_{10}(\text{TL}) \times \text{RG} + \log_{10}(\text{TL}) \times \text{DM}$	-5801.7	29.1	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG}$	-5797.1	33.6	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{RG} + \log_{10}(\text{TL}) \times \text{RG}$	-5790.9	39.8	<0.01
$\log_{10}(\text{TL}) + \text{sex}$	-5790.6	40.1	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{DM}$	-5790.5	40.3	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \log_{10}(\text{temp})$	-5790.1	40.6	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{DM} + \log_{10}(\text{temp})$	-5788.3	42.5	<0.01

$\log_{10}(\text{TL}) + \text{sex} + \log_{10}(\text{temp}) + \log_{10}(\text{CPU})$	-5783.6	47.2	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \text{DM} + \log_{10}(\text{TL}) \times \text{DM}$	-5783.2	47.6	<0.01
$\log_{10}(\text{TL}) + \text{sex} + \log_{10}(\text{CPU})$	-5783.1	47.7	<0.01

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Fig. 1. Map of the Thousand Islands region of the upper St. Lawrence River. Basemap from Esri Inc., 2014.

Fig. 2. Ecological variables incorporated in analyses of body condition of smallmouth bass and northern pike from the Thousand Islands region of the St. Lawrence River, NY. (A) Abundance of double-crested cormorant nesting pairs in the St. Lawrence River (Cape Vincent, NY to Morristown, NY) from 1982 through 2013. (B) Catch per unit effort (CPU) of smallmouth bass and northern pike in New York State Department of Environmental Conservation annual gillnet surveys of the Thousand Islands region of the St. Lawrence River (Cape Vincent, NY to Morristown, NY; 1982-2013). (C) Mean summer water temperature (May-July and June-July) for the St. Lawrence River near Maitland, ON. Water temperature data for 1982–2002 were based on observed data. Data for 2003–2013 were based on a modeled relationship between observed water temperature data and mean monthly air temperature at the Watertown International Airport in Watertown, New York. DM indicates growth and expansion of the dreissenid mussel population and RG indicates invasion by the round goby.

Fig. 3. Biological and environmental variable analysis - Parameter estimates (95% CI's) for quantile regression weight-length (log₁₀-transformed) models for northern pike collected in the Thousand Islands Region of the St. Lawrence River (1982-2013). Variables included in the final models were selected using Bayesian information criterion. Candidate models included terms for log₁₀ total length (TL), presence of round goby

(RG), presence of dreissenid mussels (DM), mean summer water temperature (temp), abundance of conspecifics (CPU), sex and one way interactions between variables.

Fig. 4. Observed versus predicted water temperature for the St. Lawrence River near Maitland, Ontario (1965-2002). Water temperatures for May-July (A) were used in analyses of northern pike body condition, and water temperatures for June-July (B) were used in analyses of smallmouth bass body condition. Predicted water temperature was based on an exponential model of observed mean monthly water temperature in the St. Lawrence River and mean monthly air temperature at the Watertown International Airport in Watertown, New York.

Fig. 5. Multiplicative changes (95% CI's) in smallmouth bass weight-at-length from the St. Lawrence River during three ecologically distinct time periods. Time period 1 = 1982-1992; time period 2 = 1993-2004; time period 3 = 2005-2013.

Fig. 6. Predicted weight-at-length (95% CI's) across quantiles 0.1-0.9 for specified length classes of smallmouth bass from the Thousand Islands region of the St. Lawrence River. Weight-at-length is displayed for three ecologically distinct time periods. Smallmouth bass weight-length models were based on a sample of 4499 fish collected during 1982-2013.

Fig. 7. Multiplicative changes (95% CI's) in northern pike weight-at-length from the St. Lawrence River during three ecologically distinct time periods. Although weight-at-

length differed between male and female northern pike, changes in weight-at-length between time periods were not dependent on sex. Therefore, the reported multiplicative changes in weight-at-length apply to male and female northern pike. Time period 1 = 1982-1992; time period 2 = 1993-2004; time period 3 = 2005-2013.

Fig. 8. Predicted weight-at-length (95% CI's) across quantiles 0.1-0.9 for specified length classes of male northern pike from the Thousand Islands region of the St. Lawrence River. Weight-at-length is displayed for three ecologically distinct time periods. Northern pike weight-length models were based on a sample of 2623 fish collected during 1982-2013.

Fig. 9. Predicted weight-at-length (95% CI's) across quantiles 0.1-0.9 for specified length classes of female northern pike from the Thousand Islands region of the St. Lawrence River. Weight-at-length is displayed for three ecologically distinct time periods. Northern pike weight-length models were based on a sample of 2623 fish collected during 1982-2013.

Fig.10. Time period analysis - Parameter estimates (95% CI's) for quantile regression weight-length ($\log_{10}$ -transformed) models for smallmouth bass collected in the Thousand Islands Region of the St. Lawrence River (1982-2013). Variables included in the final models were selected using Bayesian information criterion. Candidate models included terms for $\log_{10}$ length (TL), time period, sex, and one-way interactions. Time period 1 = 1982-1992; time period 2 = 1993-2004; time period 3 = 2005-2013.

Fig. 11. Time period analysis - Parameter estimates (95% CI's) for quantile regression weight-length ($\log_{10}$ -transformed) models for northern pike collected in the Thousand Islands Region of the St. Lawrence River (1982-2013). Variables included in the final models were selected using Bayesian information criterion. Candidate models included terms for $\log_{10}$ length (TL), time period, sex, and one-way interactions. Time period 1 = 1982-1992; time period 2 = 1993-2004; time period 3 = 2005-2013.

Fig. 12. Biological and environmental variable analysis - Parameter estimates (95% CI's) for quantile regression weight-length ($\log_{10}$ -transformed) models for smallmouth bass collected in the Thousand Islands Region of the St. Lawrence River (1982-2013). Variables included in the final models were selected using Bayesian information criterion. Candidate models included terms for $\log_{10}$ total length (TL), presence of round goby (RG), presence of dreissenid mussels (DM), mean summer water temperature (temp), abundance of conspecifics (CPU), and one way interactions between variables.

Fig. 13. Changes in median weight-at-length (%) of smallmouth bass following invasion of dreissenid mussels in the Thousand Islands region of the St. Lawrence River. The solid line represents the estimated change in weight-at-length and the dashed lines represent upper and lower 95% confidence limits.

Fig. 1. Map of the Thousand Islands region of the upper St. Lawrence River. Basemap from Esri Inc., 2014.

256x198mm (150 x 150 DPI)

254x190mm (96 x 96 DPI)

338x160mm (96 x 96 DPI)

338x121mm (96 x 96 DPI)

252x190mm (96 x 96 DPI)

243x190mm (96 x 96 DPI)

179x169mm (96 x 96 DPI)

241x190mm (96 x 96 DPI)

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