Impact of Introduced Chain Pickerel (*Esox niger*) on Lake Fish Communities in Nova Scotia, Canada

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ABSTRACT

The chain pickerel (*Esox niger*), an introduced species to Nova Scotia, has significant impacts on native lake fish communities. We evaluated the fish community structure in lakes with and without pickerel to assess the effect of the presence of this predator. Fifteen lakes were sampled for pickerel presence and fish community structure in East River, Pictou, the St. Mary's River, and Sutherland's River of northeastern Nova Scotia using gill net, fyke net and baited minnow traps. Sampling effort involved 1 572 trap-hours over 19 trap-nights. Chain pickerel were collected only in those lakes previously documented to contain them. Fish species richness and diversity appears to be higher in non-pickerel than in pickerel lakes, though unusual results from a single lake create some ambiguity for interpretation of statistical results. Mean Catch per Unit Effort was two orders of magnitude less in pickerel than in non-pickerel lakes. Distribution of fish sizes was greater in non-pickerel lakes than in pickerel lakes. Insects appear to dominate in the diet of pickerel sampled, with evidence of fish in stomach contents at low frequency. The effect of the pickerel on the native fish population is to: (1) simplify fish communities, (2) reduce overall fish abundance, and (3) truncate fish size distribution.

Introduction

The introduction of non-native species into aquatic ecosystems is known to potentially have dramatic effects on ecosystem structure and function. The chain pickerel (*Esox niger*) is an introduced fish species to Nova Scotia, initially planted in three lakes in 1945, whose distribution has spread to 95 known locations over time (Figure 1). All of these introductions have been through additional illegal movements of live fish and/or subsequent dispersal within watersheds following initial introductions, contingent on connectivity of adjoining or adjacent waterways. Unfortunately, as a relatively large predator, there is concern that the presence of chain pickerel may impact negatively on existing fish communities in lakes. There is evidence that introduction of littoral predators, such as chain pickerel, can change the fish assemblage structure of lakes, most notably the cyprinid community (Whittier et al., 1997; 1999). There is also concern that pickerel can displace native brook trout (*Salvelinus fontinalis*) populations (Alexander et al., 1986). Given the expanding distribution of chain pickerel in Nova Scotia, greater understanding of the ecological effects of pickerel on the fish communities of lakes is required. The purpose of the work described here was to compare fish community structure in lakes with and without chain pickerel.

Study Area

The East River, Pictou drains approximately 450 km^2 and in northeastern Nova Scotia, flowing into the Northumberland Strait at 45°37’14”N, 62°39’03”W. It is comprised of two branches (West Branch East River and main stem East River) and contains 36 lakes. Historically, three of these lakes (Black Lake, West Branch Lake and Speicht’s Lake) have been known to contain chain pickerel (estimated dates of introductions 1998, 2002, and 2007, respectively). Land use in the watershed is forestry with few dwellings on the lakes and relatively low road density, in the upper reaches, and agricultural and residential in the lower reaches, including cottages on lakes. In addition to sampling within the East River watershed, three lakes (Moose Lake and Perch Lake, St. Mary’s River watershed; Sutherland’s Lake; Sutherland’s River watershed) were sampled outside of this watershed as control lakes (known to be in a watersheds without pickerel). These lakes are in the headwaters of adjacent watersheds and those in the St. Mary's were selected for sampling due to being geographically near (2.5-5.0 km) the known pickerel lakes. Land use surrounding both the St. Mary's and Sutherland's River drainage lakes is forest harvesting and roading.

Methods

Fifteen lakes (man surface area 15.8 ha (SD 19.5 ha, N=15); mean depth 2.7 m (SD 0.8 m, N=8); mean pH 6.55 (SD=0.49, N=12)) were sampled between May 22 and October 31, 2010, 12 in the East River, Pictou system, 2 in the adjacent St. Mary's River system and 1 in Sutherland's River system. In 12 of the 15 lakes, the full complement of sampling gear (one variable mesh gill net, one fyke net, three minnow traps baited with roe) were set, while in three of the lakes (Drug Lake, Maple Lake, the MillPond), the gillnet and fyke net were not deployed due to concerns with bycatch of aquatic birds or mammals. In these lakes, only the three baited minnow traps were set. Two of the known pickerel lakes (Black Lake and West Branch Lake) were sampled on three occasions in the study period to try to detect other fish species at low abundance, resulting in a total of 19 lake-nights sampled. All other lakes were only sampled once. Gear was set overnight and targeted approximately 24 hour sets (mean soak time = 21.9 hours; SD=3.7 hours; N=19). Captured fish were identified to species and measured for body length. If large numbers of a species were caught a sample were measured and the remainder released with minimal handling. In three lakes (Hunters, Norman's, Sutherland's) fish measurement was limited. All chain pickerel were measured and retained (frozen) for stomach content analysis. This analysis was done by removing the stomach and intestine, squeezing contents into a petri dish and examining under a binocular dissecting microscope. Fish scales alone were not considered evidence of fish in the pickerel diet due to problems of contamination with scales, but rather fish bones in the stomach/intestine were necessary to unambiguously categorize as fish in the diet. Insects were classified to Order, where insect body integrity allowed. All data analyses were conducted at α=0.05, with procedures from Zar (1999).

Results

A total of 1,572 trap-hours were exerted over the period of study (mean = 98.25 trap-hours/lake SD=26.2). Chain pickerel were found in three of the lakes - Black Lake, West Branch Lake, and Speicht's Lake. The three lakes containing pickerel were populated by a maximum of two fish species (mean richness 2.0 species, SD=0.0 species); those being chain pickerel and white sucker (*Catastomus commersoni*) (Table 1). Mean Shannon-Weiner diversity in these lakes was 0.57 (SD=0.17). The non-pickerel lakes ranged considerably in fish species richness from 0 to 8 species captured. Three of these lakes, Drug Lake, Maple Lake, and MillPond were sampled only with minnow traps and they are not included in the following detailed richness and diversity analysis as sampling was not comparable with effort on other lakes. In the remaining 9 non-pickerel lakes mean species richness was 5.11 species (SD=2.0 species). Mean Shannon-Weiner diversity of non-pickerel lakes was almost double that of pickerel lakes, at 1.07 (SD=0.47). Calder Lake yielded only one individual of one species (a single stickleback) which resulted in a diversity index of 0; exclusion of this lake as an anomaly yielded mean Shannon Weiner diversity of 1.20 (SD=0.25) Fish species richness was statistically significantly lower (p=0.005; Student's t-test) in pickerel lakes than in non-pickerel lakes. Shannon-Weiner diversity was not significantly higher (p=0.07) in non-pickerel lakes than in pickerel lakes when all lakes considered, but exclusion of Calder Lake did yield significantly (p=0.02) greater diversity in non-pickerel lakes than pickerel lakes.

Comparison of non-pickerel lakes in East River, Pictou (n=6) with those in the St. Mary's and Sutherland's systems (n=3) are limited due to the unequal sample size. In general, mean species richness was higher in the St. Mary's/Sutherland's lakes (6.3 species; SD=0.58) than in East River Pictou (4.5 species; SD = 2.34). Shannon Weiner diversity was approximately equal between the two systems (mean H' 1.36, SD =0.23 in St. Mary's/Sutherland's; mean H' 0.92, SD =0.50 in East River Pictou). The high variability in East River was driven by Calder Lake resulting from a single individual captured despite intensive effort. Exclusion of this lake yields mean richness for lakes of East River of 5.20 species (SD = 1.8) and diversity of 1.10 (SD=0.24), which is more similar to the data from the St. Mary's lakes.

Catch per Unit Effort (CPUE) of total fish (Figure 2) was two orders of magnitude less in pickerel lakes (mean 0.047 fish/hour; SD = 0.032) than in non-pickerel lakes (mean 1.04 fish/hour; SD=1.14), with the differences being statistically significant (p=0.031; Student's t-test). CPUE was greatest in Moose Lake and Hunters Lake (2.59 and 3.32 fish/trap-hour, respectively); all other lakes had CPUE less than 1.0 fish/trap-hour. In Moose Lake the high CPUE was attributable to large abundance of golden shiner and yellow perch, while in Hunters Lake it was largely due to a very high catch of brown bullhead.

Distribution of body size of fishes was greater in non-pickerel lakes than in pickerel lakes (range among body size of all fish species in non-pickerel lakes 4.5 to 75 cm; pickerel lakes 15 to 47 cm) (Figure 3). Of particular note is the distribution of size of the white sucker, the only species common to both pickerel and non-pickerel lakes. In pickerel lakes, only large white sucker remained (range of size captured 32-47 cm; mean size captured 39.1 cm; SD=4.9; N=14) while in non-pickerel lakes there is a greater range of sizes (range of size captured 12.2-35.0 cm; mean size=21.8; SD=5.5; N=72). Mean size of white sucker in non-pickerel lakes is statistically significantly smaller ($p<0.0001$; Student's t-test) than in pickerel lakes. Mean size of pickerel was not different among the three lakes in which they were found ($p=0.61$; ANOVA). The largest pickerel (54 cm) was captured in West Branch Lake. Using the approximate size classes of Foote and Blake (1945) and Underhill (1949), these 17 sampled pickerel came from age classes age 2 (6 fish), age 3 (4), age 4 (4), age 5 (2), and age 6 (1).

Stomach contents from 17 pickerel were analyzed (5 from each of Black and West Branch lakes, 7 from Speicht's Lake). Of the 17, three (17.6%) had empty stomachs, two (11.7%) had evidence of fish as prey (vertebrae in stomach or intestine), two (11.7%) contained only unidentified digesta, and 10 (58.8%) contained insects. Insects in stomach contents were larvae of Ephemeropta (up to 11 individuals in a single stomach), and Odonata, as well as unidentified insects based on isolated body parts (legs, wings (if adult), cerci). Insects dominated the diet of chain pickerel during the sampling period.

Discussion

This comparison of fish communities among lakes with and without chain pickerel present shows that pickerel (1) simplify fish communities in lakes (significantly lower richness and diversity in pickerel versus non-pickerel lakes), (2) reduce overall fish abundance in lake (CPUE two orders of magnitude greater in non-pickerel lakes than in pickerel lakes), and (3) truncate fish size distribution in lake (absence of small bodied fishes in pickerel lakes). This fundamental ecological change in the fish community of a pickerel lake (loss of biomass, loss of small schooling fish species, retention of only large bodied fishes) may have significant trophic ramifications on avian and mammalian fish predators such as mergansers, cormorants, kingfishers, eagles, mink and otter. As examples, otter consume principally minnows, perch and sucker, with pickerel accounting for very little of their diet where the pickerel overlaps otter range (Lagler and Ostenson, 1942; Ryder, 1955; Sheldon and Toll, 1964). Indeed, the minnow community is thought to buffer otter predation from more socially valued sportfish (Lagler and Ostenson, 1942; Ryder, 1955). Bald eagles feed primarily (90%) on fish with the most common species in their diet being bullheads and suckers, though pickerel may form up to 20% of the diet where present (Dunston and Harper, 1975; Todd et al., 1982). Given the reliance of these, and other predators, on these other species, conceivably, pickerel lakes could be abandoned by these predators as the prey base is significantly diminished. Additionally, such a fundamental change in the fish community likely has significant effects on in-lake ecosystem functioning (nutrient cycling, phytoplankton/zooplankton production, etc.). These changes are likely to be permanent as long as the pickerel are present. The white sucker populations show zero recruitment with only the large adults being able to co-exist with the pickerel, suggesting that any small fish available will be consumed by the pickerel. Effectively, the pickerel have caused an negative ecological shift in lake food web complexity.

Though determining a date for an illegal introduction into a waterbody is very difficult, data from NS DFA suggests likely introductions and establishments of pickerel populations in Black

Lake in 1998, West Branch Lake in 2002, and Speicht's Lake in 2007. Black Lake, assumed to be the first location of pickerel in this watershed was an illegal introduction by people. While natural colonization of West Branch and Speicht's Lakes from this original introduction cannot be discounted, these latter three require pickerel from Black Lake to move downstream then proceed upstream (via the West Branch East River, Pictou) approximately 6 km. Pickerel are not known as strong swimmers in running water suggesting natural movement and colonization may not be likely. Further, we would anticipate colonization of waters downstream of the source (which was not apparent), rather than upstream. We believe it more likely that the pickerel arrived in all three lakes via illegal introductions. Of interest, if the approximate ageing of the pickerel is correct based on length, large pickerel from Speicht's Lake (38-41 cm) are about 5 years of age which would push back the introduction to 2004-2005 from the currently estimated 2007.

It is well established that younger (smaller) pickerel feed primarily on invertebrates, with insects, particularly dragonfly and mayfly nymphs being of great importance, while older (larger) pickerel are primarily piscivorous (Hunter and Rankin, 1939; Raney, 1942; Foote and Blake, 1945; Meyers and Muncy, 1962). The pickerel size at which this transition occurs appears to be in the range of 15-40 cm length (Foote and Blake, 1945), though Meyers and Muncy (1962) found pickerel >8cm began to show a predominance of fish over insects in the diet. The results here are consistent with this as the ten pickerel with insects in their stomachs were in the size range 14.5-38.5 cm.

Any sampling of fish using capture gear suffers from bias, capturing species of certain size, morphology and behaviour and not capturing others. Only with the use of multiple gear types will many of the species be captured (Jackson and Harvey, 1997; Whittier et al., 2000). Even so, however, using three gear types in this present study, it is highly probable that certain species were either not captured or are under-represented in the results. In particular, Alexander et al. (1986) notes that American eel, banded killifish and minnows are likely under-represented is using gill nets. The intensity of sampling in this survey, typical of reconnaissance surveys, of a single night, is low. Jackson and Harvey (1997) recommend multiple nights (generally >10 nights, dependent upon gear type) to accurately reflect fish community composition. Thus, the results of this sampling on the 15 lakes should not be considered definitive descriptions of the fish communities as not only accurate representation of number of individual species, but also entire members of the fish community, may not be well sampled.

Chain pickerel clearly have a profound impact on native fish communities on lakes in which they are introduced. These impacts are: (1) replacement of a traditionally highly valued recreational fishery with one of lesser value, (2) total loss of small bodied fish species, (3) truncating of fish body size distribution, leaving only larger white suckers, (4) likely change in lake functioning and (5) possible alteration to trophic food web complexity.

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Table 1: Results of fish sampling in 15 lakes of East River, Pictou, St. Mary's and Sutherland's rivers systems in 2010. Values for individual species are number of individuals captured. Note: Black Lake and West Branch Lake were sampled three times in period and these data reflect three sampling intervals.

	Pickerel Lakes			Non-Pickerel Lakes											
	Black Lake	Speicht's Lake	West Branch Lake	Calder Lake	Drug Lake	Forbes Lake	Grant's Lake	Hunters Lake	MacPherson Lake	Maple Lake	Mill Pond	Moose Lake [a]	Norman's Lake	Perch Lake [a]	Sutherland's Lake [a]
Soak time (hrs)	65	19	69.5	21	15	24	15	20	23.5	24	19	25	27.5	22	25
Chain pickerel	5	7	6												
White sucker	6	1	11			27	2	42				1	32	3	14
Brook trout			1			2	4	2	11			8	3	1	1
Yellow perch						47		5				96		27	
Golden shiner						40	32	20				157	7	17	12
Brown bullhead							11	259				5		41	17
American eel								3						1	
Common shiner						2						56			
Banded killifish												1	14		7
Northern redbelly dace							4		4						
Northern creek chub								1	1		12				
Threespine stickleback				1							3				
White perch								19							
Blacknose dace [b]													5		16
"Unidentified" cyprinid [c]						8									
Total number of individuals	11	8	18	1	0	126	53	351	16	0	15	324	56	90	67
Species Richness	2	2	3	1	0	5	5	8	3	0	2	7	5	6	6
Shannon Weiner Diversity Index	0.689	0.376	0.649	0	--	1.368	1.144	0.946	0.777	--	--	1.206	1.277	1.247	1.623

[a] = Moose Lake and Perch Lake are in St. Mary's River drainage and Sutherland's Lake in Sutherland's River system; all others in East River Pictou
[b] = Identification of fish as blacknose dace (*Rhinichthys atratulus*) is questionable as Gilhen and Hebda (2002) report this species not in Nova Scotia east of the Cobequid Mountains.
[c] = Unidentified cyprinid likely lake chub (*Couesius plumbeus*) based on Scott and Crossman (1973), but confidence in identification is not high.

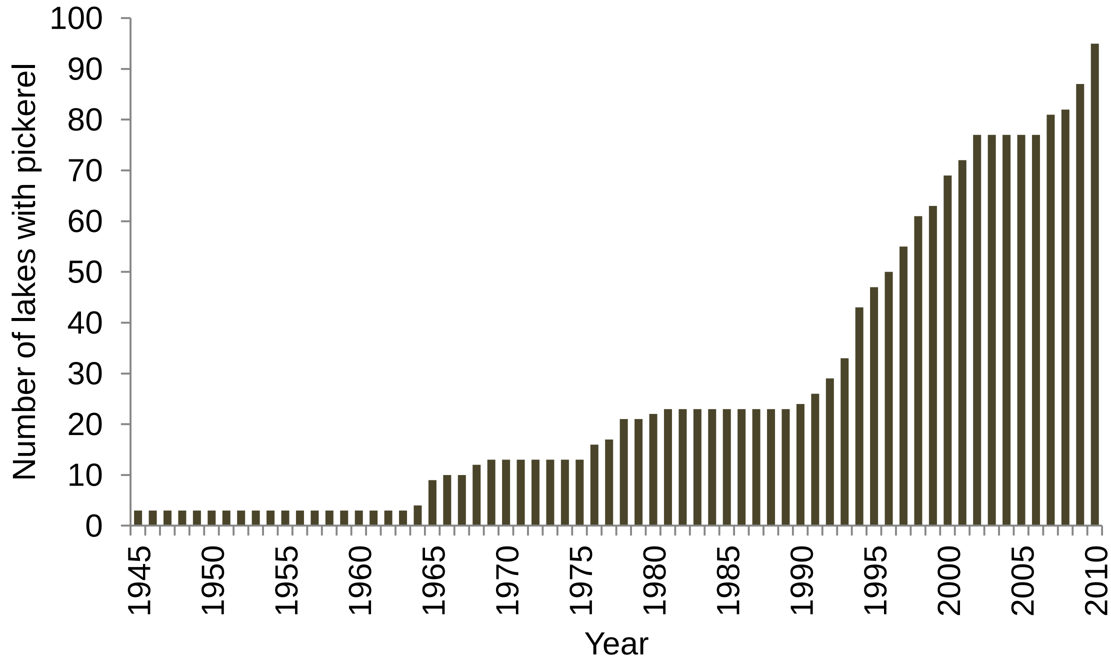
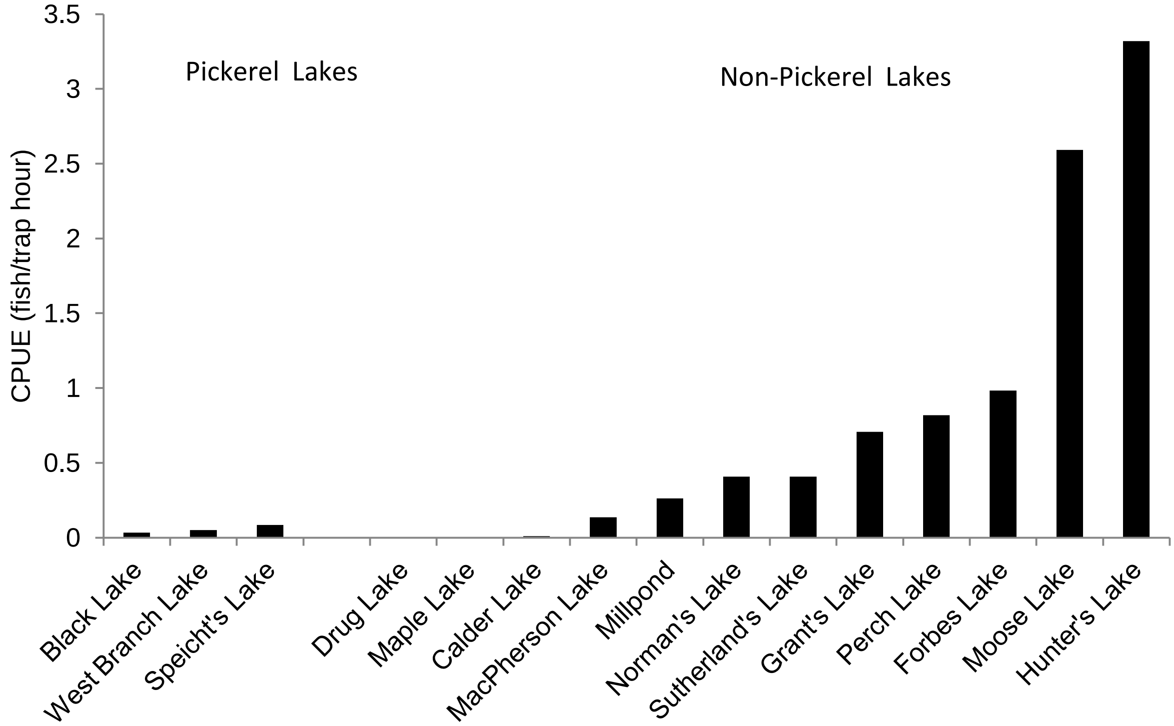


Figure 1: Cumulative distribution of number of lakes in Nova Scotia documented to contain chain pickerel each year, 1945-2010. Total number of lakes known to contain pickerel in 2010 = 95. Data from Nova Scotia Department of Fisheries and Aquaculture.



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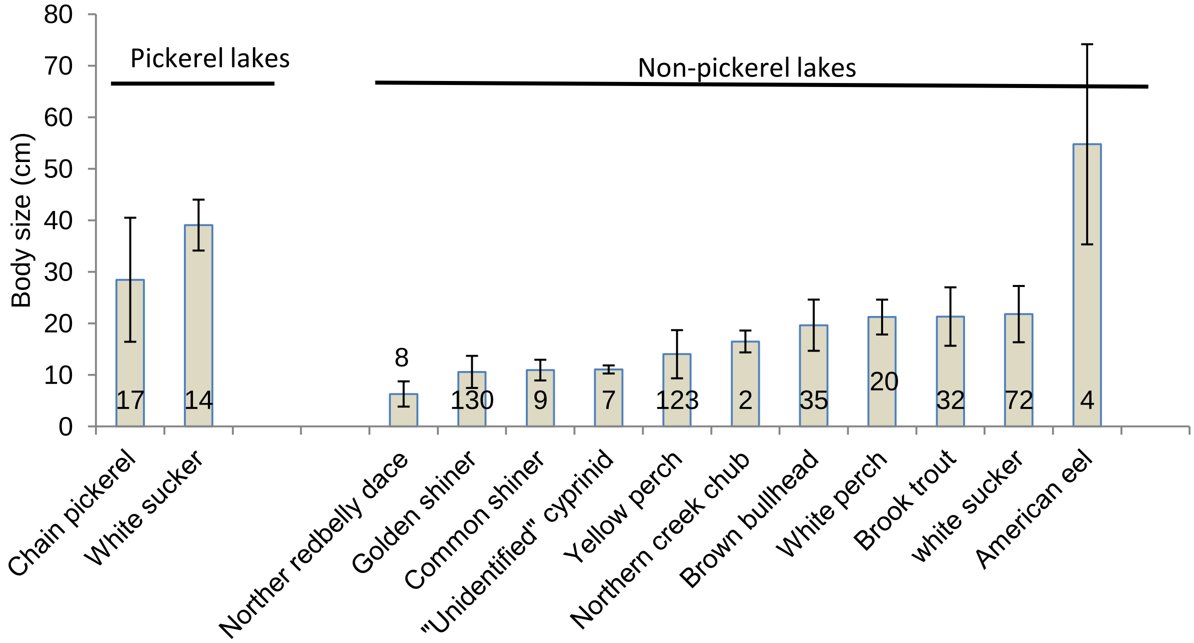

Figure 3: Mean body size of fish captured during pickerel sampling, 2010. Error bars are SD. Numbers indicate number of fish measured.