Potential Importance of Competition, Predation, and Prey on Yellow Perch Growth from Two Dissimilar Population Types

Casey W. Schoenebeck
South Dakota State University

Michael L. Brown
South Dakota State University

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CASEY W. SCHOENEBECK[1] AND MICHAEL L. BROWN

Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007, USA (CWS, MLB)

ABSTRACT Our objective was to describe the influence of population dynamics, inter- and intra-specific competition, predation, prey abundance, and prey size structure on yellow perch (*Perca flavescens*) growth for two perch population types (high-quality and low-quality) commonly found in South Dakota glacial lakes. We selected Lake Cochrane as a low quality yellow perch population and Lake Madison as a high quality perch population. Sunfish (*Lepomis* spp.) relative abundance was greater ($P < 0.05$) in Lake Cochrane than Lake Madison, suggesting interspecific competition may have a large influence on yellow perch growth. Indices of available sizes and densities of zooplankton were lower ($P < 0.05$) in Lake Cochrane than Lake Madison, suggesting that increased competition for large zooplankton may have reduced zooplankton size structure and density. Zooplankton may be a limiting resource in South Dakota glacial lakes when both yellow perch and sunfish are feeding primarily on zooplankton which may explain differences in perch growth rates between population types.

KEYWORDS competition, growth, *Perca flavescens*, sunfish, yellow perch, zooplankton size structure

Yellow perch (*Perca flavescens*) are an important component of recreational fisheries in the upper Midwest (VanDeValk et al. 2002, Radomski 2003, Zhenming et al. 2007) and are the most sought-after panfish species in South Dakota (Gigliotti 2004). Yellow perch growth can be influenced by many factors, including inter- and intraspecific competition, predation, prey abundance, and prey size structure (Lucchesi 1991, Lott et al. 1996, 1998, Paukert et al. 2002, Tomcko and Pierce 2005).

Growth can be impacted by population density through intraspecific competition (Hanson and Leggett 1985, Lucchesi 1991, Lott et al. 1996). High density yellow perch populations were found to exhibit slower growth than low density populations in six South Dakota lakes suggesting that high perch densities may lead to intraspecific competition for food resources (Lott et al. 1996). Similarly, a negative relationship existed between yellow perch growth and perch relative abundance in five South Dakota lakes (Lucchesi 1991).

Population recruitment and mortality also may influence growth. High quality yellow perch populations often are characterized by fast growth, high recruitment variability, large size structure, and high total annual mortality (Lott et al. 1996, Paukert et al. 2002). Conversely, low quality populations are characterized by slow growth, low recruitment variability, small size structure, and low total annual mortality (Lott et al. 1996, Paukert et al. 2002).

Interspecific competition among fishes (particularly sunfish; *Lepomis* spp.) for food resources may influence yellow perch growth rates (Hanson and Leggett 1985, 1986, Guy and Willis 1991). Sunfish and yellow perch prey on zooplankton and macroinvertebrates, creating the potential for competition under prey limited conditions (Laarman and Schneider 1972, Werner and Hall 1977, Lott et al. 1996, Radabaugh 2006). Interspecific competition with abundant sunfish may reduce yellow perch growth (Hanson and Leggett 1985, Fullhart et al. 2002). In small impoundments and natural lakes, increased predator abundance has reduced density-dependent effects of intraspecific competition and thus increased growth rates of yellow perch (Guy and Willis 1991, Paukert et al. 2002) and bluegill (*L. macrochirus*; Paukert et al. 2002, Tomcko and Pierce 2005).

Prey density and size structure may influence yellow perch growth (Laarman and Schneider 1972). Size structure of available zooplankton has been shown to influence yellow perch growth (Laarman and Schneider 1972, Mills and Schiavone 1982, Lott et al. 1998). For instance, previous researchers reported that mean length of available zooplankton and percent of *Daphnia* spp. > 1.3 mm was correlated with yellow perch growth in six South Dakota lakes (Lott et al. 1998) and eight New York lakes (Mills and Schiavone 1982).

Previous studies have investigated differences in yellow perch growth rates between fishery types by evaluating potential influences of predation (Guy and Willis 1991) or food habits (Lott et al. 1998). However, these and other factors may collectively influence yellow perch growth. Therefore, our objective was to describe the influence of population dynamics, inter- and intra-specific competition, predation, prey abundance, and prey size structure on yellow perch growth for two perch population types commonly found in South Dakota glacial lakes.

[1] Present address: Department of Biology, 905 W 25th Street, University of Nebraska at Kearney, Kearney, NE 68849, USA.
Corresponding author email address: schoenebeccw@unk.edu

STUDY AREA

We selected study populations to represent two yellow perch population types, low-quality and high-quality fisheries, common to eastern South Dakota (Lott et al. 1996). Lake Cochrane (Deuel County) was selected to represent a low-quality fishery due to its relatively slow yellow perch growth and small population size structure, high submerged vegetation coverage (31.0%) and low productivity (total phosphorus 0.03 ppm). We selected Lake Madison (Lake County) to represent a high-quality fishery due to its relatively fast yellow perch growth and large population size structure, low submerged vegetation coverage (<0.1%) and high productivity (total phosphorus 0.27 ppm). Lake Cochrane had a maximum depth of 7.3 m, mean depth of 4.0 m, and surface area of 144 ha (Stukel 2003). Lake Madison had a maximum depth of 4.9 m, mean depth of 2.4 m, and surface area of 1,069 ha (Stukel 2003). The fish community in Lake Cochrane was dominated by slow growing populations of yellow perch, bluegill, and hybrid (bluegill × green sunfish; *L. cyanellus*) sunfish. Black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), walleye (*Sander vitreus*), northern pike (*Esox lucius*), white sucker (*Catostomus commersonii*), and common carp (*Cyprinus carpio*) also were present. The Lake Madison sport fish community was primarily comprised of walleye and yellow perch but black crappie, smallmouth bass (*M. dolomieu*), and northern pike also were present. Lake Madison contained a higher abundance of white sucker, common carp and largemouth buffalo (*Ictiobus cyprinellus*) than Lake Cochrane.

METHODS

Fish Community Sampling

We surveyed the fish community in both study lakes using experimental gill nets and trap nets during midsummer from 2005 through 2007. Gill nets were composed of 6 equal sized panels (1.8 x 7.6 m) of mesh sizes 13, 19, 25, 32, 38, and 51 mm (bar measure) for Lake Cochrane (2005, 2007) and 19, 25, 32, 38, 51, and 64 mm (bar measure) for Lake Cochrane (2006) and Lake Madison (2005–2007). Both sets of experimental gill nets contained mesh sizes (i.e., 19, 25, and 38 mm) that efficiently sampled the size and age distribution of yellow perch present in these lakes (Lott and Willis 1991). We used gill net catch per unit effort (CPUE) to index the relative abundance of yellow perch and walleye. We measured yellow perch and walleye captured in gill nets for total length (mm), sex, and subsampled aging structures (otoliths) from 5 fish per 10-mm length group. We calculated sex ratios as the ratio of female to male yellow perch. We used catch per unit effort of double frame trap nets (19-mm bar mesh, 1.2 x 1.5-m frames) to index sunfish relative abundance.

Population Dynamics Analysis

We used mean length at capture of age-3 yellow perch as an index to growth because this age group is commonly used for perch growth assessments (Lott et al. 1996, 1998, Isermann et al. 2007) and this age group was present during all years in both lakes. We modeled recruitment stability using the recruitment coefficient of determination (RCD), derived from age frequency data with a minimum of three year classes represented (Isermann et al. 2002). We included year classes with less than two fish in the RCD analysis only when subsequent year classes included more than two fish or subsequent year classes were not represented in the sample (Isermann et al. 2002). We estimated yellow perch total annual mortality using catch curve analysis (Ricker 1975, Miranda and Bettoli 2007).

Invertebrate Community Sampling

We surveyed invertebrate prey communities in both study lakes during August 2005–2007. We conducted zooplankton sampling during August because correlations between yellow perch growth and mean zooplankton length have previously been documented during this month (Mills and Schiavone 1982, Lott et al. 1998). We sampled zooplankton and benthic macroinvertebrates at 16 sites per lake, using 3 replicate samples per site to account for within site variability; sites were divided equally into offshore (>50 m offshore) and inshore (<50 m offshore). We sampled zooplankton using a 2-m column sampler (7.3-cm inside diameter) and filtered zooplankton samples through a 153-µm Nitex mesh catch net. We preserved zooplankton samples using 10% Lugol's solution (Pennak 1989), pending analysis. We collected benthic samples with an Ekman grab (0.023 m^2), filtered samples with a number 30 mesh sieve, and preserved the filtrate in 70% ethanol pending analysis.

We subsampled zooplankton samples exceeding 200 zooplankton/50 ml using a Hansen-Stemple pipette to measure three separate, 1-ml aliquots; otherwise total counts were made (Livings et al. 2010). We identified zooplankton to genus while macroinvertebrates were identified to family (Pennak 1989). We calculated the ratio of *Daphnia* spp. density (n/L) to total zooplankton density and macroinvertebrate density (n/m^2) for each year across all sites. For both zooplankton and macroinvertebrate samples, we recorded the first 20 lengths (total length, mm) of randomly selected individuals for each taxon and calculated mean length from individuals obtained across all sample sites (Livings et al. 2010). We compared yellow perch population dynamics, sunfish relative abundance, and invertebrate prey community indices between study lakes using t-tests with the level of significance set at 0.05 (Sheskin 1997)

RESULTS

Yellow perch CPUE was variable among years and mean perch CPUE did not differ (t_4 = 0.16, P = 0.88) between Lake Cochrane (60 fish per net night; Table 1) and Lake Madison (55 fish per net night; Table 2). Mean gillnet walleye CPUE in Lake Cochrane (5 fish per net night) was lower (t_3 = −3.29, P = 0.05) than in Lake Madison (14 fish per net night). Mean trap net sunfish CPUE in Lake Cochrane (64 fish per net night) was greater (t_3 = 8.81, P < 0.01) than Lake Madison (5 fish per net night). Mean length at capture of age-3 yellow perch at Lake Cochrane (185 mm) was less (t_4 = −15.66, P < 0.01) than the Lake Madison population (237 mm). However, mean total annual mortality (t_3 = −0.67, P = 0.55), mean RCD (t_4 = 0.88, P = 0.43), and sex ratio (t_4 = 1.05, P = 0.36) did not differ between the two study populations (Table 1, 2).

Mean zooplankton length in Lake Cochrane (0.52 mm) was lower (t_4 = −5.22, P < 0.01) than in Lake Madison (0.79 mm). Mean zooplankton density in Lake Cochrane (3.5 n/L) was lower (t_4 = −3.20, P = 0.03) than in Lake Madison (10.4 n/L). In addition, mean *Daphnia* spp. length in Lake Cochrane (1.13 mm) was lower (t_3 = −3.10, P = 0.05) than in Lake Madison (1.57 mm). Mean *Daphnia* spp. density in Lake Cochrane (1.6 n/L) also was lower (t_4 = −3.68, P = 0.02) than in Lake Madison (18.9 n/L). The ratio of *Daphnia* spp. to total zooplankton density in Lake Cochrane (0.03) was lower (t_4 = −3.79, P = 0.02) than in Lake Madison (0.31). Chironomidae composed an average of 82% and 97% of all benthic macroinvertebrate families collected in Lake Cochrane and Lake Madison, respectively. Mean Chironomidae length in Lake Cochrane (8.1 mm) was not different (t_4 = 0.94, P = 0.40) from Lake Madison (6.8 mm). Mean Chironomidae density in Lake Cochrane (543.2 n/m^2) was not different (t_4 = −0.45, P = 0.68) from Lake Madison (706.4 n/m^2).

Table 1. Means and (standard errors) of independent variables for yellow perch from Lake Cochrane, South Dakota, 2005–2007.

Variables[a]	2005	2006	2007
YEP length (mm)	187 (4)	183 (4)	186 (2)
YEP RCD	0.38	0.49	0.84
YEP mortality	0.45	0.28	0.41
YEP sex	3.2	1.5	1.8
WAE CPUE		7 (2)	4 (2)
YEP CPUE	90 (8)	70 (7)	22 (4)
SUN CPUE		55 (6)	72 (15)
Daphnia ratio	0.00	0.09	0.01
Daphnia spp. density (n/L)	0.0	4.6 (0.4)	0.2 (0.0)
Chironomidae density (n/m^2)	581.6 (219.3)	457.8 (101.5)	590.2 (7.9)
Zooplankton length (mm)	0.44 (0.02)	0.60 (0.03)	0.54 (0.03)
Daphnia spp. length (mm)		1.14 (0.06)	1.12 (0.06)
Chironomidae length (mm)	10.5 (0.9)	7.6 (0.6)	6.1 (0.9)

[a] YEP length= yellow perch total length at age 3, YEP RCD = yellow perch recruitment coefficient of determination, YEP mortality = yellow perch total annual mortality, YEP sex = yellow perch sex ratio. Predation was indexed as walleye relative abundance (number of fish per net night; WAE CPUE), intraspecific competition was indexed as yellow perch relative abundance (YEP CPUE) and interspecific competition was indexed using sunfish relative abundance (SUN CPUE). Prey abundance and size structure metrics represented are the ratio of *Daphnia* spp. density to the total zooplankton density (Daphnia ratio), *Daphnia* spp. and Chironomidae density, and zooplankton, *Daphnia* spp., and Chironomidae length. Blank cells represent no data.

Table 2. Means and (standard errors) of independent variables for yellow perch from Lake Madison, South Dakota, 2005–2007.

Variables[a]	2005	2006	2007
YEP length (mm)	238 (6)	242 (8)	232 (6)
YEP RCD	0.17	0.29	0.7
YEP mortality		0.31	0.64
YEP sex	1.1	1.0	2.3
WAE CPUE	11 (5)	14 (8)	17 (6)
YEP CPUE	31 (9)	18 (9)	115 (22)
SUN CPUE	5 (1)	8 (4)	2 (1)
Daphnia ratio	0.17	0.38	0.36
Daphnia spp. density (*n*/L)	10.0 (1.6)	23.1 (3.6)	23.5 (2.5)
Chironomidae density (*n*/m^2)	564.7 (79.1)	1386.5 (396.5)	168.1 (37.8)
Zooplankton length (mm)	0.77 (0.05)	0.77 (0.06)	0.82 (0.06)
Daphnia spp. length (mm)	1.35 (0.04)	1.68 (0.03)	1.68 (0.04)
Chironomidae length (mm)	7.8 (0.6)	6.3 (0.3)	6.1 (0.8)

[a] YEP length= yellow perch total length at age 3, YEP RCD = yellow perch recruitment coefficient of determination, YEP mortality = yellow perch total annual mortality, YEP sex = yellow perch sex ratio. Predation was indexed as walleye relative abundance (number of fish per net night; WAE CPUE), intraspecific competition was indexed as yellow perch relative abundance (YEP CPUE) and interspecific competition was indexed using sunfish relative abundance (SUN CPUE). Prey abundance and size structure metrics represented are the ratio of *Daphnia* spp. density to the total zooplankton density (Daphnia ratio), *Daphnia* spp. and Chironomidae density, and zooplankton, *Daphnia* spp., and Chironomidae length. Blank cells represent no data.

DISCUSSION

Sunfish relative abundance was greater in Lake Cochrane suggesting that interspecific competition may have a large influence on yellow perch growth in the two study lakes. Alternatively, sunfish may provide an alternative prey source for predators, thereby indirectly influencing yellow perch density. Interspecific competition seems a more likely explanation because walleye and largemouth bass in north temperate lakes have shown feeding preferences for yellow perch over sunfish (Reed and Parsons 1996, Starostka et al. 1996). Furthermore, differences in zooplankton size and density between Lakes Cochrane and Madison suggests that predation on yellow perch or bluegill was insufficient to reduce inter- or intraspecific competition for large (and presumably more desirable) zooplankton. Differences in diet preference between yellow perch populations in our study lakes may possibly influence the level of interspecific competition. Lott et al. (1996) observed that the relative importance of zooplankton in diets of low quality South Dakota yellow perch populations was higher than in high quality populations. This could potentially lead to competition for large zooplankton between yellow perch and sunfish in low quality yellow perch populations (Lott et al. 1996). Interspecific competition for zooplankton is likely reduced in high quality yellow perch populations where the relative importance of macroinvertebrates in the diet may be greater than zooplankton (Lott et al. 1996). Mean Chironomidae lengths and density did not differ between our study populations, suggesting that benthic macroinvertebrates may not be a limiting prey resource in South Dakota glacial lakes during August. Though we were unable to document direct evidence of competition between yellow perch and sunfish during our study, we do provide strong supporting indirect evidence suggesting that zooplankton may be a limiting resource in South Dakota glacial lakes if both yellow perch and sunfish are feeding primarily on zooplankton.

Zooplankton abundance and size structure were lower in Lake Cochrane suggesting that there may be competition for large, more desirable zooplankton (e.g., *Daphnia* spp). We suggest the relationship between zooplankton size structure and density and yellow perch growth may be influenced, in part, by increased interspecific competition with abundant sunfish for large zooplankton in low quality yellow perch populations that occur with abundant sunfish populations. Relative importance of zooplankton was lower in diets of high quality yellow perch populations thus possibly decreasing interspecific competition for large zooplankton (Lott et al. 1996). Large cladocerans (> 1.3 mm) were more abundant in two Michigan lakes containing high quality, fast growing yellow perch and bluegill populations than in two low quality, slow growing populations (Laarman and Schneider 1972). Conversely, slow growing yellow perch populations may prey disproportionately more on zooplankton (Lott et al. 1996) and may compete with sunfish for larger, more desirable zooplankton such as *Daphnia* spp., decreasing the size structure of the zooplankton community. Decreases in zooplankton size structure were found as the abundance of planktivorous fish increased in 35 New York lakes (Mills et al. 1987). Zooplankton density and size structure both increased following a decrease in a planktivorous fish community (Syväranta and Jones 2008). However, fish density was not related to zooplankton size structure in 30 Nebraska Sandhill lakes possibly due to reduced feeding efficiency caused by dense stands of vegetation or alternatively, high densities of *Daphnia* spp. (Paukert and Willis 2003). Average *Daphnia* spp. density (sampled during July) was higher in the Nebraska Sandhill lakes than either Lake Cochrane or Lake Madison and therefore changes in zooplankton size structure may not be as detectable as in lakes containing lower zooplankton densities (Paukert and Willis 2003).

MANAGEMENT IMPLICATIONS

Our findings suggest that improvements in yellow perch growth may be best accomplished through reductions in competition with sunfish by decreasing overabundant planktivores. For low-quality yellow perch populations in South Dakota, a reduction in the abundance of sunfish would reduce interspecific competition and allow yellow perch to consume larger, more desirable zooplankton and therefore increase yellow perch growth rates. An alternative management strategy would simply be to focus management efforts directed at producing faster growing, higher quality yellow perch populations to lakes containing a low abundance of sunfish. Lakes with low sunfish abundance would have reduced interspecific competition with yellow perch and therefore the potential for fast yellow perch growth.

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