

Articles

Population Characteristics of Yellow Perch in a Central Appalachia Hydropower Reservoir

Corbin D. Hilling,* Nate D. Taylor, Stuart A. Welsh, Dustin M. Smith

C.D. Hilling

Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University, 310 West Campus Drive, Cheatham Hall, Room 106 (MC 0321), Blacksburg, Virginia 24061

N.D. Taylor

West Virginia Division of Natural Resources, 2311 Ohio Avenue, Parkersburg, West Virginia 26101

S.A. Welsh

U.S. Geological Survey, West Virginia Cooperative Fish and Wildlife Research Unit, West Virginia University, 313 Percival Hall, Morgantown, West Virginia 26506

D.M. Smith

West Virginia Division of Natural Resources, 1110 Railroad Street, P.O. Box 99, Farmington, West Virginia 26571

Abstract

Estimates of population characteristics of sport fishes inform fisheries management decisions and provide feedback on management strategies. Cheat Lake provides an unusual fishery in West Virginia because the hydropower reservoir supports a Yellow Perch *Perca flavescens* population. We estimated age structure, size structure, condition, total instantaneous mortality, growth, and summer diet for Cheat Lake Yellow Perch based on electrofishing collections in 2012. From 302 individuals, we observed a maximum age of 9 y. Maximum age, average size, and growth of females in the sample exceeded those of males. Cheat Lake Yellow Perch scored low on the relative weight index, but generally exhibited faster growth than other populations, even when compared by sex. Estimated annual survival was 0.63 (95% CI = 0.51–0.78), which is comparable to other exploited populations. These data support the presence of an ontogenetic diet shift from consumption of zooplankton to macroinvertebrates and fishes as Yellow Perch age. This study is the first evaluation we are aware of on Yellow Perch population characteristics in West Virginia, providing baseline data to enhance management decisions and direct future studies.

Keywords: condition; diet; growth; mortality; *Perca flavescens*; sex

Received: March 12, 2018; Accepted: August 7, 2018; Published Online Early: August 2018; Published: December 2018

Citation: Hilling CD, Taylor ND, Welsh SA, Smith DM. 2018. Population characteristics of Yellow Perch in a central Appalachia hydropower reservoir. *Journal of Fish and Wildlife Management* 9(2):486–495; e1944–687X. doi:10.3996/012018-JFWM-007

Copyright: All material appearing in the *Journal of Fish and Wildlife Management* is in the public domain and may be reproduced or copied without permission unless specifically noted with the copyright symbol ©. Citation of the source, as given above, is requested.

The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

* Corresponding Author: hillingc5@gmail.com

Introduction

Population characteristics, such as individual growth, survival, and longevity, are important to understanding

the status of fisheries (Babcock et al. 2013). These life-history traits can provide useful inputs in population dynamic models and inform management plans for exploited populations (Cortés 1998). In addition, inte-



grating multiple population characteristics can describe how quickly individuals reach sizes conducive to harvest, the number of recruits susceptible to fisheries, and likelihood of individuals reaching trophy sizes (Allen and Hightower 2010). Further, population characteristics can be integrated into biological reference points to set fishing limits (Zhou et al. 2012). These traits can vary among populations (Colby and Nepszy 1981; Shuter et al. 1998); therefore, assuming homogeneity of population characteristics across a species' range may be inappropriate (Gray 2015).

The Yellow Perch *Perca flavescens* is an economically important game species with a broad native distribution in North America (Hushak et al. 1988). Yellow Perch naturally inhabit lakes and rivers from the Northwest Territories to Quebec in Canada and south to Georgia along the Atlantic Coast, including the Great Lakes and Mississippi River basin north of the confluence with the Ohio River, with uncertainty owing to historical introductions (Boschung and Mayden 2004; Stepien et al. 2015). Population characteristics can be influenced by both biotic and abiotic conditions (DiCenzo et al. 1996), so Yellow Perch growth rates vary among populations. Differences in growth rates among populations of Yellow Perch have been attributed to several factors: density-dependence (Headley and Lauer 2008), interspecific competition (Boisclair and Leggett 1989a, 1989b, 1989c; Schoenebeck and Brown 2009), predator abundance (Dembkowski et al. 2017), and prey quality (Lott et al. 1996; Fullhart et al. 2002). Further, age structure, maturation rates, and growth rates of Yellow Perch populations tend to vary across a latitudinal gradient with increased longevity, slower growth, and slower maturation rates in northern populations (Craig 2000; Brown et al. 2009). Thermal influences likely contribute to latitudinal variability among populations (Power and van den Heuvel 1999). Variable environmental conditions dictate the need for region-specific research to fill information gaps present within the literature.

In West Virginia, populations of Yellow Perch are present in many large rivers and reservoirs, but rarely support productive fisheries. Thus, opportunities for recreational anglers to target large Yellow Perch are uncommon throughout much of the state. However, one exception is a reservoir in northern West Virginia (Cheat Lake) that supports a productive Yellow Perch fishery. The lake is the only water body in the state where Yellow Perch harvest is regulated (15-fish daily creel limit) in response to concerns of declines in prevalence of large Yellow Perch and suspected overharvest in the mid-2000s. However, data on the fishery are limited to catch per unit effort and size structure from fishery-independent surveys. Information on population characteristics is needed to provide feedback on the aforementioned creel limit and support adaptive management of this recreational fishery.

The primary goal of this study was to improve understanding of population characteristics for a Yellow Perch fishery subject to harvest regulations. We provided estimates of population characteristics and summer diet for the species in the east-central portion of its range,

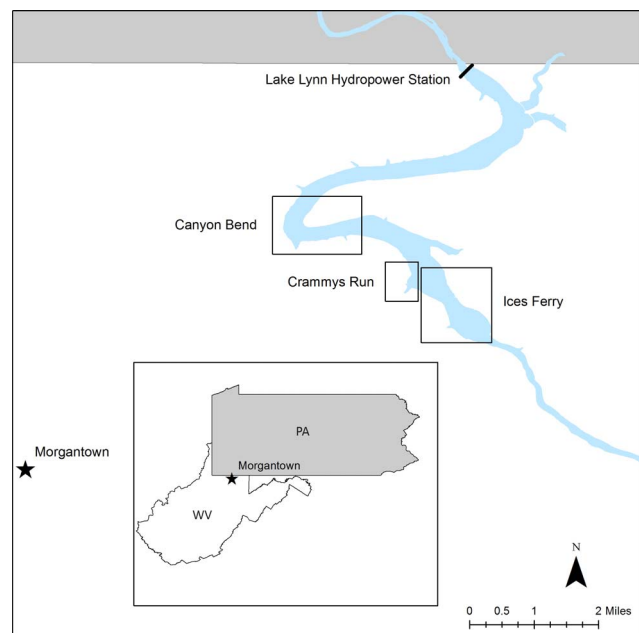


Figure 1. Cheat Lake and the Cheat River in relation to Morgantown, West Virginia (indicated by star), and the West Virginia–Pennsylvania state border. Areas sampled using boat electrofishing from 9 July to 4 September 2012 for Yellow Perch *Perca flavescens* (boxes) and the Lake Lynn Hydropower Station (dark bar) are also presented.

incorporating sex-specific consideration of growth and condition. This study represents the first investigation we are aware of on Yellow Perch in West Virginia, establishing baseline information for Cheat Lake. Natural resource managers may use this baseline information for comparison with similar data from subsequent studies, where differences in parameter estimates between or among time periods will inform management decisions for the fishery.

Study Site

Cheat Lake (originally Lake Lynn) is a 700-ha reservoir on the Cheat River in Monongalia County, West Virginia (Figure 1). Established in 1926 for hydropower generation, the impoundment is 21 km in length with a maximum depth of approximately 25 m near the outflow at the Lake Lynn Hydropower Station. Drawdowns are regulated to maintain lake elevation in three periods May–October (264.6–265.2 m), November–March (261.2–265.2 m), and April (263–265.2 m) to promote recreational opportunities, maximize power generation, and promote Walleye *Sander vitreus* and Yellow Perch spawning success, respectively. Cheat Lake is a temperate, dimictic reservoir, experiencing seasonal stratification in temperature and dissolved oxygen concentration. Historically, water quality of Cheat Lake was degraded by acid precipitation (Welsh and Perry 1997) and run-off from abandoned mining operations (Freund and Petty 2007; Merovich et al. 2007) throughout much of the Cheat River watershed. However, mitigation efforts

within the Cheat River watershed (McClurg et al. 2007) have contributed to recent improvements in water quality in Cheat Lake, which currently supports a diverse assemblage of temperate sport and nongame fishes (D.M. Smith, unpublished data).

Methods

We sampled Cheat Lake for Yellow Perch from 9 July to 4 September 2012 using night-time boat electrofishing (5.0 GPP; Smith-Root, Inc., Vancouver, WA) with a typical output of 60 pulses/s and 4–6 amps. Night-time electrofishing provided an effective means for sampling that avoided interference from daytime recreational boating and concerns about potential mortality of Cheat Lake's recovering Walleye population in passive gears. Based on unpublished reports from previous nontarget fisheries surveys, densities of Yellow Perch in Cheat Lake during summer are highest in the middle section of the lake from Canyon Bend to Ices Ferry (Figure 1). Other areas of the lake were also sampled for Yellow Perch. However, lower densities of Yellow Perch were observed in these areas, further confirming our knowledge about the species' distribution within the reservoir. We targeted shallow depths (<3 m) owing to the limitations of our sampling gear. We omitted from analysis data from sampling sites yielding small sample sizes of Yellow Perch, because we collected the majority of individuals from the area of known higher concentrations. We measured total length (mm) and weight (g) for all Yellow Perch. We initially used a size-based subsampling procedure—10 individuals/25-mm size group—for collection procedures. However, after the release of 31 individuals collected during two July sampling events, we determined that improved sample sizes would be advantageous for validating sex, determining age, and evaluating stomach contents. Consequently, we kept all Yellow Perch collected after this change in protocol. We placed retained individuals in their own labelled plastic bag to ensure regurgitated food items were accurately attributed to stomach contents from that specific fish. We then placed retained fish on ice to prevent regurgitation and reduce further digestion of stomach contents (Doxtater 1963; Garvey and Chipps 2012).

We extracted sagittal otoliths in the laboratory to determine ages of Cheat Lake Yellow Perch. Black modeling clay provided a convenient medium to hold otoliths in place and provided contrast for annulus interpretation. We submerged otoliths in a small volume of water to reduce glare and viewed them whole through the ventral surface using a dissecting microscope (\times tg 20–40) and reflected light source. Two readers independently assigned ages to otoliths and resolved disagreements via mutual examination. Annulus formation typically occurs later in larger Yellow Perch (Blackwell and Kaufman 2012), and we considered incremental measurements from marginal annuli during age determination. We assigned ages to released fish using an age-length key in Fisheries Analyses and Modeling Simulator 1.64 using 1-cm length groups (Slipke and Maceina 2014). Yellow Perch exhibit sexual

dimorphisms with respect to size because females typically grow faster and achieve larger maximum sizes than males (Brofka and Marsden 1993; Purchase et al. 2005). We determined sex via gonadal inspection for individuals >100 mm in length. We were unable to determine sex for released fish because of limited confidence in discernibility of external sex characters, despite reported success in other studies with captive and wild Yellow Perch (Malison et al. 2011; Shepherd et al. 2013; Dub et al. 2017).

We constructed a length-frequency histogram (1-cm bins), to assess the contribution of females and males to the size structure. We also examined age structure using an age-frequency plot displaying contributions of females and males for each age. Both length- and age-frequency plots included the released fish for which sex was undetermined. We examined condition using the relative weight index (W_r) for individuals exceeding 100 mm total length (Wege and Anderson 1978; Willis et al. 1991; Anderson and Neumann 1996). We calculated mean W_r for males and females separately and within Gabelhouse (1984) length classes to account for possible sex- and length-specific trends in condition (Murphy et al. 1991).

We calculated total instantaneous mortality (Z) for Cheat Lake Yellow Perch using catch-curve regression fitted using a least-squares estimator. We used all ages after and including the most commonly collected age to fit the catch-curve, assuming this was the first age that fully recruited to the electrofishing gear. We calculated 95% confidence intervals around the slope of the regression line to provide estimates of uncertainty surrounding estimates of Z . Using our estimates of Z and uncertainty, we calculated total annual survival (S) and its 95% confidence interval using the relationship $S = e^{-Z}$.

We examined Yellow Perch growth in Cheat Lake using the von Bertalanffy growth model. We tested for differences in growth between sexes using analysis of residual sum of squares (Chen et al. 1992). We fit the von Bertalanffy model to otolith-derived length-at-age data from males, females, and both sexes pooled for fish age ≥ 1 y. We compared the residual sum of squares of the pooled model with the sum of the residual sum of squares for the sex-specific models using an F -test. We compared Cheat Lake Yellow Perch growth by sex to range-wide averages using the relative growth index (RGI) and the standard length equation developed by Jackson et al. (2008).

We extracted whole stomachs from Yellow Perch specimens and fixed them in a 10% formalin solution for a minimum of 2 d, followed by preservation in 70% ethanol. We removed stomach contents via dissection and identified to the lowest practical taxonomic level. We omitted from dietary analyses any individuals with empty stomachs and those containing unidentifiable prey items. To evaluate dietary overlap and the partitioning of prey resources by size, we grouped Yellow Perch into three age categories: age-0, age-1, and age-2+. We used frequency of occurrence (O_i), mean percent by number (MN_i), and prey-specific abundance



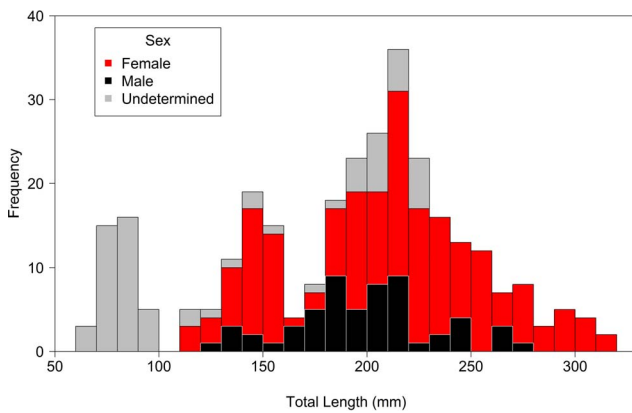


Figure 2. Length-frequency distribution of Yellow Perch *Perca flavescens* collected using boat electrofishing from 9 July to 4 September 2012 from Cheat Lake, West Virginia ($n = 302$), by sex using 10-mm bins. Fish were sexed via dissection and sex was undetermined for fish <100 mm and released fish.

(P_i) to describe the summer diet composition among the three age categories for Cheat Lake Yellow Perch (Amundsen et al. 1996; Garvey and Chipps 2012). We conducted all statistical analyses in R 3.1.3 (R Core Team 2015).

Results

We collected 302 Yellow Perch during six sampling events from 9 July to 4 September 2012 in 511 min of electrofishing (mean catch per unit effort = 35 fish/h; Data S1, *Supplemental Material*). Yellow Perch ranged in size from 66 to 320 mm (mean total length $[\overline{TL}] \pm SD = 190 \pm 60$ mm). Females ($n = 175$) were more prevalent than males ($n = 57$). Also, females were generally larger than males, with females ranging from 115 to 320 mm ($\overline{TL} \pm SD = 212 \pm 49$ mm) and males ranging in size from 128 to 280 mm ($\overline{TL} \pm SD = 199 \pm 35$ mm). We collected 39 young-of-the-year, with a mean length ($\pm SD$) of 81 ± 7 mm. We released 31 fish, with a mean length of 192 ± 34 mm. The length-frequency distribution showed smaller individuals normally distributed around distinct peaks, representing age-0 and age-1 individuals (Figure 2). However, distinction between age classes diminished among larger individuals.

We assigned ages to 271 fish using sagittal otoliths and 31 fish using an age-length key. The two otolith readers had an agreement rate of 96.3% during age estimation with agreement ± 1 y of 100%. Readers reached a consensus on all examined otoliths. Otolith-aged individuals ranged in age from age 0 ($n = 39$) to age 9 ($n = 2$). The oldest individuals collected were two age-9 females (total length = 277 and 316 mm). Age-frequency distributions suggest an underrepresentation of age-0 and age-1 individuals within the sample (Figure 3). The most abundant age-class (including age-length-key-aged fish) was age-2 ($n = 91$), suggesting a strong 2010 year-class or that age-0 and age-1 Yellow Perch were not fully susceptible to boat electrofishing. Age-7 Yellow Perch ($n = 13$) were more abundant than both

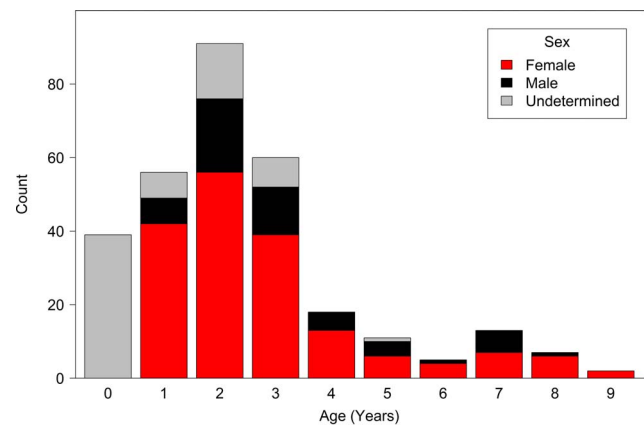


Figure 3. Bar-plot representing sex-specific distribution of ages among 302 Yellow Perch *Perca flavescens* collected from Cheat Lake, West Virginia, using boat electrofishing from 9 July to 4 September 2012. Fish were sexed via dissection and sex was undetermined for fish <100 mm and released fish. Ages were assigned by counting annular rings on otoliths or an age-length key for released fish.

age-5 ($n = 11$) and age-6 ($n = 5$) individuals. Males and females were present among all year-classes collected, with exception to the oldest age group (age-9) consisted of two female Yellow Perch.

We calculated relative weight (W_r) for 263 Yellow Perch from 100 to 320 mm (Table 1). Mean W_r for the sample was 74 ($SD = 7$). Mean W_r for males was 75 ($SD = 6$) and 74 for females ($SD = 7$) when calculated separately. In addition, there was little variability in mean W_r by size class, except for fish smaller than stock size (Sub-stock, <130 mm). Separating W_r into size-based groupings by sex yielded similar estimates to broader categories (Table 1).

We estimated total instantaneous mortality as $Z = 0.47$ (95% CI = 0.25–0.68) using catch-curve regression from ages 2 to 9. Consequently, the annual survival rate was calculated as $S = 0.63$ (95% CI = 0.51–0.78). Examination of residual plots revealed heterogeneity of variance, indicating that one or more of the assumptions of catch curve analysis were not met.

We used the von Bertalanffy growth model and analysis of residual sum of squares to determine growth of males and females was statistically different ($F = 33.77$; $df = 3, 226$; $P < 0.001$). Predicted length-at-age was greater for females than males, where females reached preferred length (250 mm) in half the time required for males (Figure 4). Parameter estimates ($\pm SE$) from the von Bertalanffy model for females were $L_\infty = 299 \pm 5$ mm, $k = 0.40 \pm 0.02/y$, $t_0 = -0.75 \pm 0.05$ y and $L_\infty = 252 \pm 6$ mm, $k = 0.44 \pm 0.04/y$, $t_0 = -0.88 \pm 0.07$ y for males.

Based on the RGI for ages 1–6, this population exhibits fast growth (mean RGI = 143). Of the ages with growth percentiles available, Cheat Lake Yellow Perch were commonly in the 75th percentile or greater (Table 2). Females grow faster than males, so female RGI values were always at or above the 75th percentile; whereas, males were at or above the 50th percentile for most ages considered. Cheat Lake Yellow Perch RGI values were at

Table 1. Relative weight (W_r) by sex and total length group with standard deviation (in parentheses) for Cheat Lake, West Virginia, Yellow Perch *Perca flavescens* collected using boat electrofishing from 9 July to 4 September 2012. Length intervals are as follows: substock (100–129 mm), stock (130–199 mm), quality (200–249 mm), preferred (250–299 mm), and memorable (>300 mm). The pooled row features fish with sex undetermined. Sample sizes within groups are indicated by n .

	Substock	Stock	Quality	Preferred	Memorable	Total
Pooled						
n	8	98	115	36	6	263
W_r	80 (10)	74 (7)	74 (6)	74 (6)	74 (8)	74 (7)
Male						
n	1	27	25	4	0	57
W_r	68	75 (7)	75 (4)	72 (10)	—	75 (6)
Female						
n	4	62	71	32	6	175
W_r	78 (11)	74 (7)	73 (6)	74 (6)	74 (8)	74 (7)

least at the 95th percentile for ages 1 and 2 for both sexes.

We evaluated summer diet composition for 266 Yellow Perch. We grouped individuals into three age categories: age-0 ($n = 37$), age-1 ($n = 47$), and age-2+ ($n = 182$). We excluded from the diet analysis any individuals with empty stomachs and those including unidentifiable prey items ($n = 76$). Thus, we included 191 individuals in diet analyses: age-0 ($n = 19$), age-1 ($n = 41$), and age-2+ ($n = 131$). Percent frequency of occurrence (O_i), mean percent by number (MN_i), and prey-specific abundance (P_i) among the three age groups are presented in Table 3.

Zooplankton (primarily Copepods) were present among all age-0 individuals, on average accounting for 85.3% of all prey types consumed. Trichoptera were also commonly consumed by age-0 Yellow Perch, occurring in 21.1% of stomachs and accounting for 46.7% of all prey items identified from fish that had Trichoptera in their stomachs. Diptera (mostly *Chaoborus* spp.) were present among 10.5% of all age-0 individuals and comprised 45.5% of all prey items where present. However, Trichoptera and Diptera accounted for <10% of the diet when considering the numerical abundance of prey types among age-0 individuals.

Trichoptera were found in 63.4% of age-1 Yellow Perch, accounting for 43.4% of the diet and comprising 74.6% of the diets of Yellow Perch in which they were identified. Diptera (primarily Chironomidae) were found in 61.0% of all age-1 individuals, and accounted for 20.8% of all prey items consumed by age-1 individuals. Bivalvia were present in 17.1% of age-1 Yellow Perch; and among the individuals that had consumed them, Bivalvia comprised 10.8% of the diet on average.

The diet composition of age-2+ individuals was more diverse than younger age groups. Fishes were found in the stomach contents of 41.5% of age-2+ individuals and numerically accounted for 30.7% of all prey items consumed. Trichoptera were identified from 33.1% of all age-2+ Yellow Perch and accounted for 73.0% of the prey items found in the stomachs of individuals that had consumed Trichoptera. Diptera (mostly Chironomidae) were consumed by 36.2% of age-2+ Yellow Perch, and

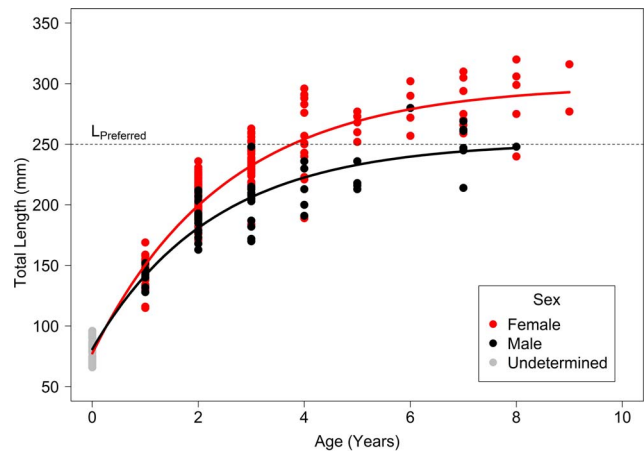


Figure 4. Comparison of male and female Yellow Perch *Perca flavescens* growth in Cheat Lake, West Virginia, in relation to preferred length ($L_{\text{Preferred}} = 250$ mm) from Gabelhouse (1984). Points denote length-at-age observations from otoliths, while lines are sex-specific fitted von Bertalanffy growth models. Fish were collected from 9 July to 4 September 2012 using boat electrofishing.

comprised 12.1% of all prey items and 22.0% of all prey items present in the stomachs of individuals that had consumed Diptera. Megaloptera (Sialidae) were also commonly consumed by age-2+ individuals, numerically accounting for 53.0% of all prey items in the stomachs of age-2+ individuals that had consumed them. Zooplankton (mostly Cladocerans and Ostracods) were only found in 1.5% of age-2+ Yellow Perch. However, zooplankton accounted for 70.0% of the stomach contents for the few individuals in which zooplankton were identified.

Discussion

Yellow Perch provide commercial and recreational fisheries across a wide geographic range (Stepien et al. 2015). However, research on this species has often focused on the Great Lakes and upper Midwest regions, leaving knowledge gaps for portions of its range. Specifically, West Virginia offers limited opportunities for Yellow Perch fisheries, and therefore no known published works have examined population characteristics of Yellow Perch within the state. Cheat Lake supports an important Yellow Perch fishery and provided an opportunity to learn more about Yellow Perch within the east-central portion of its range. Further, regulation changes in response to population declines from suspected overharvest provided an opportunity to gather information on the population’s response to support adaptive management strategies. These data will support management of this population by providing inputs for simulation studies and identifying data gaps. Using these data in range-wide meta-analyses could help enhance understanding of Yellow Perch population dynamics by providing information in a relatively understudied region.

Cheat Lake Yellow Perch condition was low compared with other populations using the relative weight index.

Table 2. Relative Growth Index (*RGI*) by sex (F = Female, M = Male) with standard deviation (in parentheses) for Yellow Perch *Perca flavescens* from Cheat Lake, West Virginia, collected using boat electrofishing from 9 July to 4 September 2012. L_5 and *Percentile* indicate the standard length-at-age (total length, mm) and minimum percentile derived by Jackson et al. (2008), respectively. Sample sizes are indicated by *n*.

Age	<i>n</i> (F, M)	L_5	RGI_F	RGI_M	Percentile (F, M)
1	42, 7	81	176 (15)	171 (11)	95, 95
2	58, 20	138	150 (11)	136 (10)	95, 95
3	39, 13	178	131 (10)	114 (12)	90, 50
4	13, 5	207	123 (15)	103 (9)	90, 50
5	6, 4	228	116 (4)	97 (5)	75, 25
6	4, 1	243	116 (8)	115 (NA)	75, 75

When developing the standard weight equation for Yellow Perch, Willis et al. (1991) acknowledged a geographic trend in W_r values among populations. Apart from Oneida Lake in New York, eastern populations had a consistently lower W_r than populations located in the plains regions. Willis et al. (1991) suggested agricultural production in midwestern states may be partially responsible for this geographic variability, and a mean W_r of 84 (63–109) was determined for the nine populations from Ohio, Pennsylvania, and Virginia incorporated in their analyses. Additionally, Willis et al.

(1991) noted low W_r in Georgia, indicating the southern portion of the range may have lower condition. Willis et al. (1991) also noted their samples came from different seasons. Seasonal variability in condition among individual fish is apparent in somatic changes occurring in female fishes during egg development.

We estimated an annual survival rate of 63% for the population from catch-curve regression. Our survival estimate for Cheat Lake, although slightly higher, was similar to other studies that included exploited ($S = 0.614$) and unexploited populations ($S = 0.48–0.53$;

Table 3. Quantitative description of summer diet composition for three age groups (Age-0, -1, and -2+) of Yellow Perch *Perca flavescens* from Cheat Lake, West Virginia, collected using boat electrofishing from 9 July to 4 September 2012. Data are reported as frequency of occurrence (O_i), mean percent by number (MN_i), and prey-specific abundance (P_i). Prey items not encountered for age groups are denoted by “—”.

Prey type	O_i			MN_i			P_i		
	Age-0	Age-1	Age-2+	Age-0	Age-1	Age-2+	Age-0	Age-1	Age-2+
Zooplankton	100.0	7.3	1.5	85.3	1.4	0.9	99.0	21.6	70.0
Amphipoda	15.8	4.9	—	4.0	0.7	—	25.6	14.3	—
Cladocera	36.8	4.9	0.8	10.0	0.6	0.7	4.9	12.0	85.7
Copepoda	68.4	2.4	—	67.3	0.2	—	99.6	6.3	—
Ostracoda	10.5	—	0.8	4.0	—	0.3	29.4	—	33.3
Annelida	—	—	1.5	—	—	0.2	—	—	4.3
Hirudinea	—	—	0.8	—	—	0.0	—	—	2.3
Oligochaeta	—	—	0.8	—	—	0.2	—	—	25.0
Bivalvia	—	17.1	15.4	—	3.8	5.4	—	10.8	24.3
Corbiculidae	—	9.8	0.8	—	0.6	0.6	—	3.6	83.3
Sphaeriidae	—	12.2	14.6	—	3.2	4.8	—	16.1	23.6
Coleoptera	—	—	3.1	—	—	0.9	—	—	25.0
Decapoda	—	—	10.0	—	—	7.1	—	—	58.1
Diptera	10.5	61.0	36.2	5.1	20.8	12.1	45.5	20.6	22.0
<i>Chaoborus</i> spp.	10.5	14.6	1.5	4.0	6.4	0.3	36.4	35.5	5.5
Chironomidae	5.3	56.1	34.6	1.1	13.4	11.7	20.0	13.7	21.9
Culicidae	—	4.9	0.8	—	0.7	0.0	—	7.3	2.7
Tipulidae	—	4.9	2.3	—	0.4	0.1	—	4.2	4.8
Ephemeroptera	5.3	—	8.5	0.4	—	3.1	8.3	—	8.3
Fishes	—	19.5	41.5	—	9.1	30.7	—	5.4	22.0
Gastropoda	—	17.1	3.1	—	6.5	0.4	—	15.9	7.9
Physidae	—	7.3	0.8	—	0.4	0.0	—	7.1	1.9
Planorbidae	—	14.6	2.3	—	6.0	0.3	—	9.3	9.4
Lepidoptera	—	—	0.8	—	—	0.4	—	—	50.0
Nematomorpha	—	14.6	2.3	—	1.9	2.2	—	6.2	90.0
Odonata	5.3	14.6	9.2	0.4	12.5	3.7	7.1	72.7	21.7
Anisoptera	—	14.6	7.7	—	12.5	3.4	—	72.7	23.9
Zygoptera	5.3	—	2.3	0.4	—	0.3	7.1	—	9.1
Megaloptera	—	12.2	24.6	—	0.7	12.6	—	4.6	53.0
Sialidae	—	12.2	24.6	—	0.7	12.6	—	4.6	53.0
Trichoptera	21.1	63.4	33.1	8.9	43.4	20.3	46.7	74.6	73.0

Paukert and Willis 2001). However, variability among residuals of the fitted linear model suggests one or more assumption violations associated with catch-curve analysis. Inconsistencies between residuals often result from nonconstant rates of recruitment and year-class strength (Maceina 1997). Henderson (1985) reported Yellow Perch recruitment variation in Lake Huron was related to water levels. Yellow Perch recruitment may experience increased variability in Cheat Lake as a result of water-level fluctuations from hydropower operations. Female Yellow Perch lay strands of eggs on woody structures, vegetation, *Chara* spp., or the lake bottom in shallow water (<1.6 m in depth, Echo 1955; Craig 2000). We observed dewatered fish eggs draped over formerly submerged trees during spring surveys following a drawdown event. The timing and duration of these drawdown events could contribute to variability in recruitment and may explain one possible violation of the assumptions of catch-curve regression.

We observed sexually dimorphic and fast growth for Yellow Perch in Cheat Lake. Females grew faster and achieved larger maximum sizes than males, a trend well-documented among populations of Yellow Perch (Headley and Lauer 2008; Uphoff and Schoenebeck 2012). Cheat Lake is in the east-central portion of the Yellow Perch native range, and latitude-driven temperature differences may contribute to faster growth than more northern populations (Power and van den Heuvel 1999). Further, Cheat Lake features several predatory sportfishes including three *Micropterus* species, Walleye, and a developing Muskellunge *Esox masquinongy* population that may contribute to faster growth (Olson et al. 2001; Dembkowski et al. 2017). Although diet studies on these potential predators are limited, Yellow Perch do seem to comprise a large proportion of Walleye diets in Cheat Lake (D.M. Smith, unpublished data) and predation may reduce densities, promoting faster growth (Henderson 1985; Post and McQueen 1994; Headley and Lauer 2008; Irwin et al. 2009). Studies also support that prey quality and abundance contribute to Yellow Perch growth, where robust benthic invertebrate communities promote faster growth than situations where fish rely on zooplankton (Lott et al. 1996; Tyus and Knight 2001). Further, growth studies on other species (Channel Catfish *Ictalurus punctatus* and Walleye) have also observed fast growth (Hilling et al. 2016; D.M. Smith, unpublished data), indicating additional unknown factors may facilitate rapid growth of fishes in Cheat Lake.

Diet indices provided evidence suggesting partitioning of prey resources by three age groups of Yellow Perch, indicative of ontogenetic changes in diet composition. Zooplankton was the most important prey item for age-0 individuals. Some dietary overlap occurred between age-1 and age-2+ individuals. However, fishes were identified from stomach contents of 41.5% of all age-2+ individuals. Gape limitation is likely responsible for reduced piscivory observed among age-1 individuals. Authors have suggested Chironomidae larvae as a fundamental component of Yellow Perch diet among populations (Paxton and Stevenson 1978; Lott et al. 1996; Fullhart et al. 2002). Although Chironomidae

occurred among the diets of Cheat Lake Yellow Perch, larger macroinvertebrate preys (*Bivalvia*, *Sialidae*, and *Trichoptera*) were also frequently identified from stomach contents.

This study is limited by several factors. First, fish collections took place solely during the summer of 2012. Consequently, we only provide a snapshot of the population during one point in time. Growth and mortality information are limited to a single year, which may not provide estimates that can be extrapolated over time because of heterogeneity in growth, inconsistent recruitment and year-class strength, and changes in angler behavior. In addition, summer sampling limited our diet analysis to a single season and leaves a knowledge gap for seasonal variability in diet composition. We collected otoliths during the growing season and length-at-age data are likely biased as a result of varying amounts of new growth throughout the sampling period. Also, we are unable to interpret our condition data in a seasonal context to understand bioenergetic processes and how W_r fits into range-wide standards generated from data collected in multiple seasons. This study is also limited because of a skewed sex ratio, making population inferences difficult. Females were much more prevalent in the sample than males, leading to assumptions in population characteristics that estimates derived from a female-biased sample are representative of both sexes. In addition, a large proportion of fish collected in this sample were from one area of Cheat Lake because of low densities in other portions of the lake. Most of the fish in the sample examined here were collected within the transitional zone of the lake where shallower depths occur and bathymetry is relatively flat.

This study provides useful baseline data for future studies examining management of Cheat Lake Yellow Perch. However, information regarding recruitment, angler harvest rates, and human dimensions are still needed. Understanding how anthropogenic activities influence the recruitment of this species would provide important information on how habitat and water levels can be manipulated to maintain or improve this and other fisheries. Further, we currently lack information on exploitation of this population and need to improve our understanding of angling effort and harvest rates. Human dimensions data could also provide insight into angler interests that could shape management objectives and promote positive angler–agency relationships.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Data S1. Biological and stomach content data from Yellow Perch *Perca flavescens* collected from 9 July to 4 September 2012 from Cheat Lake, West Virginia, using boat-electrofishing. Data are organized as three sheets within a single Microsoft Excel file. Sheet 1 features



biological information (length, weight, age), collection information (date, fish identification number, and location), and a diet table used to calculate diet indices. Sheet 2 contains biological (length, weight, age, sex) and collection (date, fish identification number, location, and whether the fish was released or not) information. Sheet 3 contains metadata explaining the components of the other two sheets.

Found at DOI: <https://doi.org/10.3996/012018-JFWM-007.S1> (43 KB XLSX).

Acknowledgments

We would like to thank K. J. Hartman and D. I. Wellman for comments that improved a previous version of this manuscript. In addition, we thank G. T. Merovich for his advice regarding statistical analyses and D. L. Hartman for her assistance with macroinvertebrate identification. We also thank three anonymous reviewers and the Associate Editor for their thoughtful reviews. This study was performed under the auspices of West Virginia University IACUC protocol 10-0403.

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References

- Allen MS, Hightower JE. 2010. Fish population dynamics: mortality, growth, and recruitment. Pages 43–79 in Hubert WA, Quist MC, editors. *Inland fisheries management in North America*. 3rd edition. Bethesda, Maryland: American Fisheries Society.
- Amundsen, PA, Gabler HM, Staldvik FJ. 1996. A new approach to graphical analysis of feeding strategy from stomach contents data—modification of the Costello method. *Journal of Fish Biology* 48:607–614.
- Anderson RO, Neumann RM. 1996. Length, weight, and associated structural indices. Pages 447–482 in Murphy BR, Willis DW, editors. *Fisheries techniques*. 2nd edition. Bethesda, Maryland: American Fisheries Society.
- Babcock EA, Coleman R, Karnauskas M, Gibson J. 2013. Length-based indicators of fishery and ecosystem status: Glover's Reef Marine Reserve, Belize. *Fisheries Research* 147:434–445.
- Blackwell BG, Kaufman TM. 2012. Timing of yellow perch otolith annulus formation and relationship between fish and otolith lengths. *North American Journal of Fisheries Management* 32:239–248.
- Boisclair D, Leggett WC. 1989a. Among population variability of fish growth, I. Influence of quantity of food consumed. *Canadian Journal of Fisheries and Aquatic Sciences* 46:457–467.
- Boisclair D, Leggett WC. 1989b. Among population variability of fish growth, II. Influence of prey type. *Canadian Journal of Fisheries and Aquatic Sciences* 46:468–482.
- Boisclair D, Leggett WC. 1989c. Among population variability of fish growth, III. Influence of fish community. *Canadian Journal of Fisheries and Aquatic Sciences* 46:1539–1550.
- Boschung HT Jr, Mayden RL. 2004. *Fishes of Alabama*. Washington, D.C.: The Smithsonian Institution.
- Brofka WA, Marsden J. 1993. A survey of sport fishing in the Illinois portion of Lake Michigan. Annual Report to the Illinois Department of Conservation, Aquatic Ecology Technical Report 93/4, Champaign.
- Brown T, Runciman B, Bradford M, Pollard S. 2009. A biological synopsis of yellow perch (*Perca flavescens*). Canadian Manuscript Report of Fisheries and Aquatic Sciences 2883:v–28.
- Chen Y, Jackson DA, and Harvey HH. 1992. A comparison of von Bertalanffy and polynomial functions in modelling growth data. *Canadian Journal of Fisheries and Aquatic Sciences* 49:1228–1235.
- Colby PJ, Nepszy SJ. 1981. Variation among stocks of walleye (*Stizostedion vitreum vitreum*): management implications. *Canadian Journal of Fisheries and Aquatic Sciences* 38:1814–1831.
- Cortés E. 1998. Demographic analysis as an aid in shark stock assessment and management. 39:199–208.
- Craig JF. 2000. *Percid fishes: systematics, ecology and exploitation*. Oxford, United Kingdom: Blackwell Science.
- Dembkowski, DJ, Weber, MJ, Wuellner MR. 2017. Factors influencing recruitment and growth of age-0 yellow perch in eastern South Dakota glacial lakes. *Fisheries Management and Ecology* 24:372–381.
- DiCenzo VJ, Maceina MJ, Stimpert MR. 1996. Relations between reservoir trophic state and gizzard shad population characteristics in Alabama reservoirs. *North American Journal of Fisheries Management* 16:888–895.
- Doxtater GD. 1963. Use of ice water to prevent regurgitation of stomach contents of fish. *Transactions of the American Fisheries Society* 92:68–69.
- Dub JD, Roswell CR, Czesny S. 2017. Utilizing external features and a consensus field-based approach to determine sex of Lake Michigan yellow perch. *North American Journal of Fisheries Management* 37:1107–1111.
- Echo JB. 1955. Some ecological relationships between yellow perch and cutthroat trout in Thompson Lakes, Montana. *Transactions of the American Fisheries Society* 84:239–248.
- Freund JG, Petty JT. 2007. Response of fish and macroinvertebrate bioassessment indices to water chemistry in a mined Appalachian watershed. *Environmental Management* 39:707–720.
- Fullhart HG, Parsons BG, Willis DW, Reed JR. 2002. Yellow perch piscivory and its possible role in structuring littoral zone fish communities in small Minnesota lakes. *Journal of Freshwater Ecology* 17:37–43.
- Gabelhouse DW Jr. 1984. A length-categorization system to assess fish stocks. *North American Journal of Fisheries Management* 4:273–285.



- Garvey JE, Chipps SR. 2012. Diets and energy flow. Pages 733–779 in Zale AV, Parrish DL, Sutton TM, editors. Fisheries techniques. 3rd edition. Bethesda, Maryland: American Fisheries Society.
- Gray CA. 2015. Spatial variation in demography of an estuarine teleost: implications for population and fishery assessments. *Aquatic Biology* 23:209–223.
- Headley HC, Lauer TE. 2008. Density-dependent growth of yellow perch in southern Lake Michigan, 1984–2004. *North American Journal of Fisheries Management* 28:57–69.
- Henderson BA. 1985. Factors affecting growth and recruitment of yellow perch, *Perca flavescens* Mitchell, in South Bay, Lake Huron. *Journal of Fish Biology* 26:449–458.
- Hilling CD, Welsh SA, Smith DM. 2016. Age, growth, and fall diet of channel catfish in Cheat Lake, West Virginia. *Journal of Fish and Wildlife Management* 7:304–314.
- Hushak LJ, Winslow JM, Dutta N. 1988. Economic value of Great Lakes sportfishing: the case of private-boat fishing in Ohio's Lake Erie. *Transactions of the American Fisheries Society* 117:363–373.
- Irwin BJ, Rudstam LG, Jackson JR, Van De Valk AJ, Forney JL, Fitzgerald DG. 2009. Depensatory mortality, density-dependent growth, and delayed compensation: disentangling the interplay of mortality, growth, and density during early life stages of yellow perch. *Transactions of the American Fisheries Society* 138:99–110.
- Jackson ZJ, Quist MC, Larscheid JG. 2008. Growth standards for nine North American fish species. *Fisheries Management and Ecology* 15:107–118.
- Lott JP, Willis DW, Lucchesi DO. 1996. Relationship of food habits to yellow perch growth and population structure in South Dakota lakes. *Journal of Freshwater Ecology* 11:27–37.
- Maceina MJ. 1997. Simple application of using residuals from catch-curve regression to assess year-class strength in fish. *Fisheries Research* 32:115–121.
- Malison JA, Held JA, Kaatz SE. 2011. Sex determination of yellow perch by external morphology. *North American Journal of Aquaculture* 73:285–287.
- McClurg SE, Petty JT, Mazik PM, Clayton JL. 2007. Stream ecosystem response to limestone treatment in acid impacted watersheds of the Allegheny Plateau. *Ecological Applications* 17:1087–1104.
- Merovick GT, Stiles JM, Petty JT, Fulton J, Ziemkiewicz PF. 2007. Water chemistry based classification of streams and implications for restoring mined Appalachian watersheds. *Environmental Toxicology and Chemistry* 26:1361–1369.
- Murphy BR, Willis DW, Spring TA. 1991. The relative weight index in fisheries management: status and needs. *Fisheries* 16:30–38.
- Olson MH, Green DM, Rudstam LG. 2001. Changes in yellow perch (*Perca flavescens*) growth associated with the establishment of a walleye (*Stizostedion vitreum*) population in Canadarango Lake, New York (USA). *Ecology of Freshwater Fish* 10:11–20.
- Paukert CP, Willis DW. 2001. Comparison of exploited and unexploited yellow perch *Perca flavescens* (Mitchell) populations in Nebraska Sandhill lakes. *Fisheries Management and Ecology* 8:533–542.
- Paxton KO, Stevenson F. 1978. Food, growth, and exploitation of percids in Ohio upground reservoirs. *American Fisheries Society Special Publication* 11:270–277.
- Post JR, McQueen DJ. 1994. Variability in first-year growth of yellow perch (*Perca flavescens*): predictions from a simple model, observations, and an experiment. *Canadian Journal of Fisheries and Aquatic Sciences* 51:2501–2512.
- Power M, van den Heuvel MR. 1999. Age-0 yellow perch growth and its relationship to temperature. *Transactions of the American Fisheries Society* 128:687–700.
- Purchase CF, Collins NC, Morgan GE, Shuter BJ. 2005. Predicting life history traits of yellow perch from environmental characteristics of lakes. *Transactions of the American Fisheries Society* 134:1369–1381.
- R Core Team. 2015. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. Available: <http://www.R-project.org/> (July 2017).
- Schoenebeck CW, Brown ML. 2009. Potential importance of competition, predation, and prey on yellow perch growth from two dissimilar population types. *The Prairie Naturalist* 42:32–37.
- Shepherd BS, Rees CB, Sepulveda-Villet OJ, Palmquist DE, Binkowski FP. 2013. Identification of gender in yellow perch by external morphology: validation in four geographic strains and effects of estradiol. *North American Journal of Aquaculture* 75:361–372.
- Shuter BJ, Jones ML, Korver RM, Lester NP. 1998. A general, life history based model for regional management of fish stocks: the inland lake trout (*Salvelinus namaycush*) fisheries of Ontario. *Canadian Journal of Fisheries and Aquatic Sciences* 55:2161–2177.
- Slipke JW, Maceina MJ. 2014. Fisheries analyses and modeling simulator (FAMS 1.64). Bethesda, Maryland: American Fisheries Society.
- Stepien CA, Behrmann-Godel J, Bernatchez L. 2015. Evolutionary relationships, population genetics, and ecological and genomic adaptations of perch (*Perca*). Pages 7–46 in Couture P, Pyle G, editors. *Biology of perch*. Boca Raton, Florida: CRC Press.
- Tyus JT, Knight RL. 2001. Response of yellow perch to changes in the benthic invertebrate community of western Lake Erie. *Transactions of the American Fisheries Society* 130:766–782.
- Uphoff CS, Schoenebeck CW. 2012. Quantifying inter-population variability in yellow perch sexual size dimorphism. *Journal of Freshwater Ecology* 27:507–516.
- Wege GJ, Anderson RO. 1978. Relative weight (W_r): a new index of condition for largemouth bass. Pages 79–91



- in Novinger GD, Dillard JG, editors. New approaches to the management of small impoundments. Bethesda, Maryland: American Fisheries Society, North Central Division. Special Publication 5.
- Welsh SA, Perry SA. 1997. Acidification and fish occurrence in the upper Cheat River drainage, West Virginia. *Journal of the American Water Resources Association* 33:432–429.
- Willis DW, Guy CS, Murphy BR. 1991. Development and evaluation of a standard weight (W_s) equation for yellow perch. *North American Journal of Fisheries Management* 11:374–380.
- Zhou S, Yin S, Thorson JT, Smith ADM, Fuller M. 2012. Linking fishing mortality reference points to life history traits: an empirical study. *Canadian Journal of Fisheries and Aquatic Science* 69:1292–1301.

