Population Characteristics of Black Bullhead *Ameiurus melas* in Two Small Oklahoma Close to Home Fishing Ponds.

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Abstract: Black Bullheads have both native and introduced populations throughout North America and introduced populations in Europe. Research of Black Bullhead populations has increased in recent years due to their native and introduced ranges having potential detrimental effects on fish communities. Black Bullheads are common throughout Oklahoma and are found in many Close to Home Fishing Ponds (CTHFP), however research in these small impoundments is limited. Therefore, our objective was to estimate abundance and describe population characteristics for two Black Bullhead populations in two Oklahoma CTHFP. We sampled two CTHFP in El Reno, Oklahoma within Canadian County, Southern Hills North (SHN) and Southern Hills South (SHS) with tandem baited hoop nets in June of 2022. To estimate population size, we used the K-pass depletion method. Lapilli otoliths were extracted from fish from each pond, but age and growth statistical analysis were only completed for SHS due to insufficient numbers of fish prohibiting analysis. Black Bullheads from SHS had a fish density estimate of 810 fish/ha, slow growth, ages ranging from 2-7, relatively low mortality ($Z = 0.39$), and was dominated by stock-sized individuals. The SHN pond had a lower fish density estimate (110 fish/ha) than SHS, fish ages ranging from 1-7, and was dominated by quality-sized individuals. Additional research should focus on understanding angler dynamics, variables that attribute to overabundant populations, and variability of Black Bullhead growth in CTHFP to allow for more effective fisheries management of native and invasive populations.

Introduction

Black Bullheads (*Ameiurus melas*) have native and invasive populations throughout North America and introduced populations throughout Europe (Rutkayová et al. 2013, Copp et al. 2016). They can tolerate poor water quality (i.e., high turbidity, low oxygen quality, high nutrient concentrations, high temperatures) which has aided in their expansion (Copp et al. 2016, Sikora et al. 2022). Black Bullheads are omnivorous and can outcompete native fish assemblages through direct competition, predation, or by negatively impacting water quality (Copp et al. 2016, Snow et al. 2017, Sikora et al. 2021, Montague et al. 2021). Their wide niche-breadth combined with a flexible maturity schedule allows them to attain high population densities, dominate the biomass where they reside, and establish populations outside of their native range (Stuber 1982, Copp et al. 2016, Sikora et al. 2022). Due to Black Bullhead's extensive native range, invasive populations, and robust population characteristics, interest has increased from managers to research their life history and population characteristics (Novomeská and Kovác. 2009, Copp et al. 2016, Sikora et al. 2021, Montague et al. 2021, Montague et al. *in review*). However, research on life history and population characteristics is still lacking compared to other ictalurid species (Channel Catfish [*Ictalurus punctatus*], Blue Catfish [*Ictalurus furcatus*], and Flathead Catfish [*Pylodictis olivaris*]) despite their potential negative effects on fish assemblages and water quality. Therefore, additional research on Black Bullhead populations is critical for managers to better understand how to manage them in both native and introduced ranges.

The Oklahoma Department of Wildlife Conservation (ODWC) manages Close to Home Fishing Ponds (CTHFP; small impoundments < 8.1 ha in size) to provide local-and-accessible fishing opportunities for urban anglers and "R^3" purposes (i.e., recruitment, retention, reactivation; Hinrichs et al. 2020). While most anglers utilizing Oklahoma's CTHFP target Channel Catfish, Crappie (*Poxomis spp*), Largemouth Bass (*Micropterus salmoides*) and sunfish (*Lepomis*) species (Balsman and Shoup 2008, York 2019), Black Bullhead are also commonly found in these ponds throughout the state (OFAA 2022). Black Bullheads inhabiting small impoundments can have a negative effect on sportfish assemblages if not managed, by altering biomass due to their low age-at-maturity, relatively high fecundity, parental care, and ability to alter water quality (Mork et al. 2009, Sikora et al. 2021). Therefore, it is imperative that biologists monitor and manage their populations in CTHFP to prevent their potential negative effects. Furthermore, population dynamics of Black Bullheads in small impoundments are poorly understood, limiting the ability of managers to manipulate populations for the benefit of other sportfish. Researchers must first determine Black Bullhead population characteristics (i.e., demographics and vital rates) to determine the applicability of potential management approaches in small impoundments.

During an electrofishing sampling assessment of sportfish populations on Southern Hills South (SHS) CTHFP in El Reno, Oklahoma, ODWC biologists observed high densities of Black Bullheads. Preliminary age and growth analysis of this population suggested that Black Bullheads in SHS consisted of primarily old fish (up to age-7) at small lengths (≤ 230 mm), which is characteristic of a stunted population (unpublished data, ODWC). This prompted further sampling efforts to better understand the Black Bullhead population in SHS. Biologists also sampled the Southern Hills North (SHN) Black Bullhead population. SHN is a CTHFP adjacently located (< 100 yards away), to compare population characteristics between ponds. Therefore, our objectives were to 1. estimate abundance and fish density (fish/ha) and 2. describe population characteristics (proportional size distribution, growth trajectories, length-weight relationships, length at maturity, mortality of two Black Bullhead populations in two Oklahoma CTHFP (Southern Hills North and South).

Methods

Study Area

Southern Hills South is a 0.3 ha impoundment with 0.32 km of shoreline located in El Reno, Oklahoma in Canadian County (latitude: 35.506520, longitude: -97.960830). Southern Hills North is a 0.81 ha impoundment with 0.4 km of shoreline located in El Reno, Oklahoma in Canadian County (latitude: 35.506520, longitude: -97.960830). Both ponds serve as CTHFP that are managed by the ODWC and support popular sportfish species such as Channel Catfish, Largemouth Bass, and Sunfish.

Study Design

Black Bullheads were collected using tandemly baited hoop nets (25-mm mesh) from both SHN and SHS in June 2022 (typically correlates with Black Bullhead spawning season in Oklahoma, [Montague et al. 2021]). Tandem, baited (Sportsman's Choice Trophy Fish Feed, Multi-species Formula, Cargill Animal Nutrition, Minneapolis, MN) hoop nets were rigged following ODWC standardized Channel Catfish sampling protocols. Specifically, three tandem hoop net sets were fished parallel to shore at depths of 1–3 m for a total of 72 hours, checked, and reset every 24 hours. Each net set consisted of three 3.4-m-long hoop nets (25-mm bar mesh; Miller Net Company, Inc., Memphis, Tennessee) containing seven fiberglass hoops, with the first hoop being roughly 0.8 m in diameter and each following hoop slightly decreasing in diameter toward the cod end. Every net included a throat on the second hoop and a restricted throat on the fourth hoop. Temperature (°C) and dissolved oxygen concentration (mg/L) were recorded with a YSI meter (model Pro 2030, Yellow Springs Instruments, Yellow Springs, OH) just above the bottom at each net set to ensure that dissolved oxygen was ≥ 4 mg/L. Due to the proximity of SHN and SHS being so close, water temperatures (range from 26.9 - 28.4), dissolved oxygen (ranging from 6.3 – 7.4), and secchi depth (2.1 – 2.7 m) measurements overlapped showing no difference between the two ponds.

All fish caught were measured for total length (TL; mm) and weighed (g). Our goal was to collect 20 fish per 10-mm TL grouping for age estimation and sex determination. Every fish was removed from each net 24, 48, and 72 hours after setting to generate a population estimate using the depletion method. Fish kept for age estimation and sex determination were euthanized with a 1:1 ice water slurry (Blessing et al. 2010), placed on ice, and transported to the Oklahoma Fishery Research Laboratory in Norman to be processed. Fish were then re-measured, weighed, sex was determined, and the lapilli otoliths were removed for age estimation. Fish were assigned a maturity status (immature or mature) following methods of Davis and Posey (1958) and Perry and Carver (1972). Mature females were classified if they had developed ovaries that contained eggs (yellow or white in color) or their ovaries were spent (the eggs deposited). Mature males were classified if their testes were enlarged and white in color. Immature Black Bullhead showed no signs of gonadal development and their ovaries and/or testes were barely distinguishable or are readily distinguishable but not developed.

After extraction, both pairs of lapilli otoliths are placed into a uniquely numbered envelope (Montague et al. 2021, Montague et al. *in review*). The otoliths were dried for ≥ 24 hours prior to processing (Secor et al. 1992) and processed similarly to methods of Buckmeier et al. (2002) and Montague et al. (2021). After processing, otoliths were viewed using a stereo microscope (capable of 130x magnification) with a fiber optic filament attached to an external light source to illuminate annuli (Buckmeier et al. 2002, Montague et al. 2021). Two readers estimated the age of the otolith in concert read, however, if the readers disagreed on the estimated age, that otolith was reevaluated at a different time (Hoff et al. 1997). The second otolith's age was estimated if the first otolith's age was unreadable. If both otoliths were unreadable, the fish was removed from the age analysis. Each otolith was read randomly with no reference to length, weight, or sex (Hoff et al. 1997).

Analysis

Black Bullhead population estimates and

probability of capture (p) were determined for both ponds with the K-pass depletion method using the removal() function in the FSA package in R (Ogle 2022). Black Bullhead population size structure in both ponds were described with a length frequency histogram (10-mm length bins) of all fish captured. A Fisher's exact test (fisher.test() function, R Core Team 2022, version 1.4.1103) was used to determine if length frequencies from each pond differed ($P \leq 0.05$). Additionally, proportional size distribution (PSD; PSD-stock ≥ 150 mm, PSD-quality ≥ 230 mm, PSD-preferred ≥ 300 mm; Gabelhouse 1984) was calculated using the psdcalc() function in Ogle's Fisheries Stock analysis (FSA) package (2022) in R (R Core Team 2022) to describe each pond's size structure. A simple linear regression was used to describe the relationship between $\log_{10}$(weight):$\log_{10}$(length). The relationship of Black Bullhead length to weight was also used to evaluate fish condition by calculating relative weight (Wr) using the wrAdd() function in the FSA package (Ogle 2022) in R (R Core Team 2022).

Age and growth statistical analysis was only completed for SHS because the SHN had insufficient numbers of fish caught, prohibiting age and growth analysis. Therefore, the remaining analysis was completed for only SHS. A logistic regression model was used to determine the relationship between maturity at age for male and female Black Bullhead using binary variables (0 = immature, 1 = mature). Mean length at age was calculated for male and female Black Bullhead. These data were then log transformed to linearize the relationship, and differences in growth between sexes were tested using analysis of covariance (ANCOVA) with the aov() function in R (R Core Team 2022). Because prior analysis of growth between sexes was similar ($F_{1,108} = 1.29$, $P = 0.26$), all fish were combined to estimate growth rates using a von Bertalanffy growth model.

Growth trajectories and instantaneous mortality rates (Z) for Black Bullheads were estimated using a von Bertalanffy growth model fit to total length and age estimates using the Fisheries Stock Analysis R package (Ogle 2022, R Core Team 2022). Instantaneous mortality rates and annual survival (S) were estimated using the Chapman-Robson method with the chapmanRobson() function in the FSA package (Ogle 2022) in R (R Core Team 2022, version 1.4.1103). Black Bullhead < age-2 were not fully recruited to the sampling gear, so they were removed from mortality analysis.

Results

Southern Hills South

A total of 237 Black Bullhead were collected from SHS, with a high fish density estimate of 810 fish/ha. (Table 1). Of the fish collected, 165 fish were kept for age estimation and population assessment. Fish used for age analysis ranged from age-2 to age-7 and 149 - 247 mm TL. More male (55.9%) than female (44.1%) fish were represented in the sample. Both female and male Black Bullhead reached 100% maturity by age-7 (Figure 1). The earliest that

Table 1. Population estimates (95% CI) using the K-Pass depletion method for Black Bullheads caught with tandem, baited hoop nets in Southern Hills South and Southern Hills North Ponds in El Reno, Oklahoma. Fish density (fish/ha) estimates (95% CI) and capture probability (p; 95% CI) for tandem, baited hoop nets fished for 72 hours (checked and fish removed every 24 hours) are also shown.

System	Size (ha)	Population Estimate	Density (fish/ ha)	Capture probability
Southern Hills South	0.3	243 (236 - 250)	810 (787 - 833)	0.7 (0.64 - 0.77)
Southern Hills North	0.81	89 (74 - 104)	110 (91 - 128)	0.48 (0.32 - 0.64)

a Black Bullhead reached maturity was age-2, and 50% of all fish reached maturity by age-5. By age-7, 100% of all male fish have reached maturity. The earliest that a female reached maturity was age-2, 50% of all female fish reached maturity by age-4, and 100% by age-7.

Length frequencies derived from the catch rates of SHS and SHN differed significantly (Fisher's exact *P* value ≤ 0.01, Figure 2). The SHS Black Bullhead population was dominated by stock sized (≥ 150 mm) fish (Table 2; Figure 2). As a result, PSD was low (PSD = 4), and no fish reached PSD-Q size (< 300 mm). Stock length fish had a mean age of 3.83, and quality length fish had a mean age of 5 (Table 1). The weight-length relationship ($\log_{10}(W) = 2.73(\log_{10}(TL)) - 4.26$) was significant ($r^2 = 0.84$, $P < 0.01$) resulting in a mean Wr of 84.3 (Figure 3, Table 2).

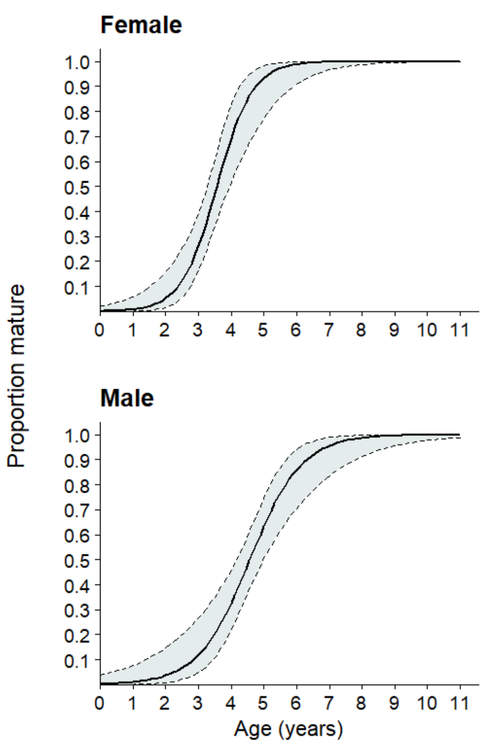

Figure 1. Results of logistic regression analysis displaying the proportion of mature female (top) and male (bottom) Black Bullheads by age caught from Southern Hills South Pond, El Reno, Oklahoma using tandem baited hoop nets. Grey dashed lines represent 95% confidence intervals.

The Von Bertalanffy growth model indicated that Black Bullhead approach L_∞ (L_∞ = 224.5 mm TL; predicted maximum total length) slowly (k = 0.377; Figure 4). The estimated instantaneous mortality was 0.39 (0.32 - 0.47) and the annual survival rate was 67.5%.

Southern Hills North

A total of 78 Black Bullheads were collected from SHN with a lower fish density estimate (110 fish/ha) than SHS (Table 1). Of the fish collected, 35 were kept for age estimation and population assessment. Fish used for age analysis ranged from age-1 to age-7 and 130 - 311 mm TL. More male (54.2%) than female (45.8%) fish were represented in the sample.

This population was dominated by quality sized (≥ 230 mm) Black Bullhead (Table 2; Figure 2). As a result, PSD was higher than SHS (PSD = 72), and some fish reached PSD-P size (8; ≥ 300 mm). Stock length fish had a mean age of 3.83, and quality length fish had a mean age of 5 (Table 2). The weight-length relationship ($\log_{10}(W) = 2.69(\log_{10}(TL)) - 4.12$) was significant ($r^2 = 0.96$, $P < 0.01$;) resulting in a mean W_r of 85 (Figure 3, Table 2).

Discussion

Southern Hills South had a high abundance of Black Bullheads (810 fish/ha) with a fish density estimate nearly 8 times the estimate at SHN (110 fish/ha). Our results from the SHS population reflect similarly to other studies showing that Black Bullheads can have high abundances in small impoundments (Sikora et al. 2021, Sikora et al. 2022). The high densities in SHN may be the result of density-dependent factors such as interspecific competition over resources, lack of predators, or various environmental factors such as poor water quality (Shelley and Modde 1982, Anderson et al. 2016, Copp et al. 2016). Identifying and understanding the environmental and biological

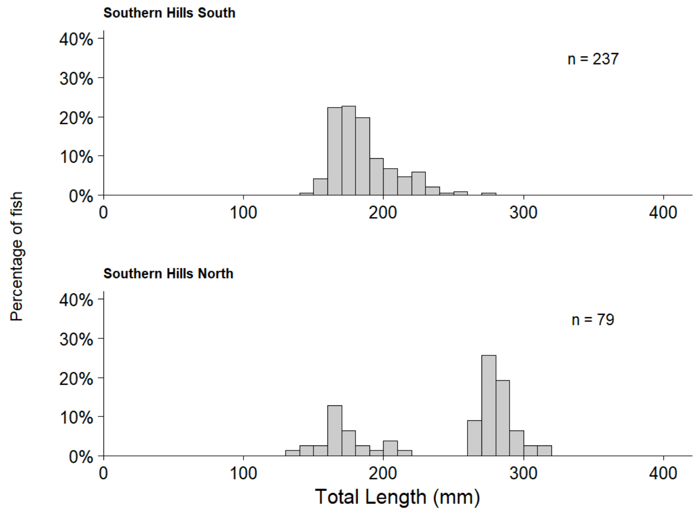

Figure 2. Length Frequency histogram (10-mm bins) of Black Bullheads caught using tandem, baited hoop nets from Southern Hills South and Southern Hills North Ponds, El Reno, Oklahoma.

factors that lead to overabundant Black Bullhead populations in small impoundments, specifically CTHFP, is warranted and will allow biologists to better manage this species and the specific system. Future research should examine the effects of Black Bullhead removal to aid in the management of overabundant populations in CTHFP as Black Bullhead removal has been shown to benefit native fish assemblages. For example, Barabe (2021) found that removal efforts of Black Bullhead in a California stream improved the abundance and recruitment of Coastal Rainbow Trout *Oncorhynchus mykiss irideus*. Sikora et al. (2021) found that Black Bullhead removal in Wisconsin lakes resulted in an increased abundance of Walleye *Sander vitreus* and Yellow Perch *Perca flavescens* and increased the diversity of the fish community. Additional research should also examine appropriate removal target rates to have the desired positive effect on the fish community. Further understanding of how Black Bullhead removal impacts the ecosystem in small impoundments will be essential to managing their overabundant populations.

Black Bullheads in SHS had slow growth, stunted population characteristics, and a different size structure compared to Black Bullheads in SHN. Due to insufficient sample

Table 2. Proportional size distribution (PSD, 95% CI), mean age (range), and mean relative weight (W_r; 95% CI) of Black Bullheads by size class from Southern Hills South and Southern Hills North Ponds in El Reno, Oklahoma.

System	Size Category	*n*	PSD Value	Mean Age	Wr
Southern Hills South	Sub-Stock (< 150 mm)	1	N/A	1.88 (1 - 3)	78.2
	Stock (≥ 150 mm)	227	96 (93- 98)	3.83 (2 -7)	84.5 (82.9 - 86.1)
	Quality (≥ 230 mm)	9	4 (2 – 7)	5 (5 - 5)	80.1 (75.3 - 84.9)
	Overall	237	-	3.59 (1 -7)	84.3 (82.8 - 85.8)
Southern Hills North	Sub-Stock (< 150 mm)	3	N/A	1 (1 - 1)	131 (88.6 - 173.4)
	Stock (≥ 150 mm)	24	28 (18 - 40)	1.75 (1 - 3)	91.4 (86.8 - 96)
	Quality (≥ 230 mm)	47	72 (60 - 82)	5.1 (4 - 6)	80 (77.1 - 82.9)
	Preferred (≥ 300 mm)	6	8 (3- 17)	6. 25 (6 - 7)	79.5 (64.9 - 94.1)
	Overall	78	-	4.55 (1 - 7)	85 (81.6 - 88.4)

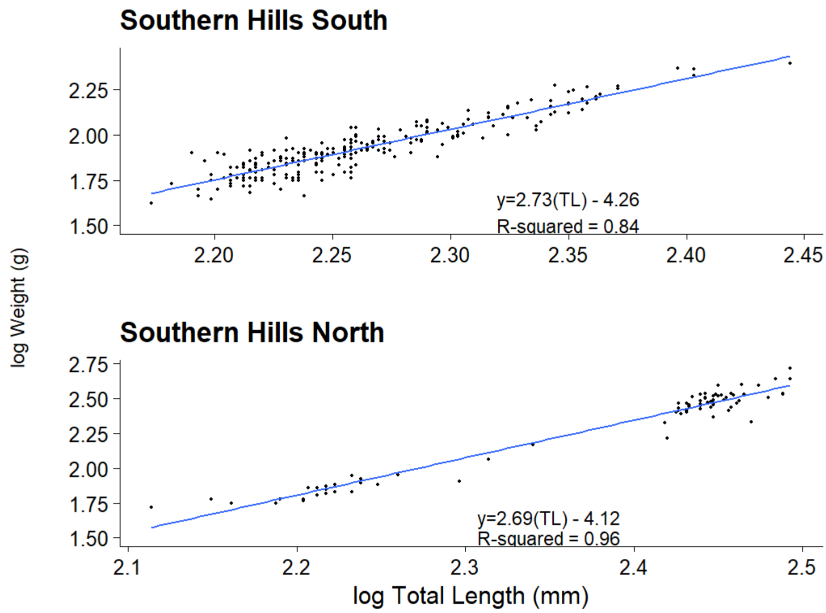

Figure 3. Weight-length relationship for Black Bullheads collected from Southern Hills South and Southern Hills North Ponds in El Reno, Oklahoma. The logarithmically transformed weight-length equations are shown for each pond.

size for age and growth analysis, we were unable to quantify age and growth (i.e., Von Bertalanffy growth curve) for SHN, however, the length frequencies were significantly different between ponds. Furthermore, the mean length at various PSD size categories at SHS suggests they had dissimilar growth rates. Our results depict the variability of Black Bullhead growth amongst populations and are consistent with what has been documented in the literature. For example, Mork (2009) found that Black Bullhead populations in Iowa varied and hypothesized that fish in poorer water quality (high nutrient concentrations and low water clarity) had higher growth rates than those with better water quality. In South Dakota Lakes, Hanchin (2002a) found that Black Bullhead growth was highly variable, and fish were more likely to overpopulate in shallow, productive lakes, resulting in slow growth. Hanchin (2002a) also found that growth was inversely related to size structure of predators suggesting a predator effect on Black Bullhead growth. Similarly, Sikora et al. (2022) found in Howell Lake, Wisconsin Black Bullheads exhibited fast growth rates due to the size structure of predators. Additionally, their initial analyses do not support the common ideology that black bullheads are suppressing sport fish populations through direct predation, but possibly diet overlap (Sikora et al. 2022). Black Bullhead typically grow faster where they are introduced in European countries compared to their native populations in North America (Copp et al. 2016). Future research should examine the statewide growth of Black Bullhead populations and how environmental and biological characteristics (e.g., lake size, productivity, predators) may impact growth rates.

Tandem baited hoop nets efficiently sampled and provided population density information for managing Black Bullhead in both CTHFP in our study. However, studies that examined the use of tandem, baited hoop nets with 25-mm mesh while sampling Channel Catfish suggest this gear may underrepresent smaller size classes of catfish, suggesting that juvenile Channel Catfish may not be fully recruited to the gear. (Montague et al. *in-press*, Tyszko 2021). If we assume this bias is true for Black Bullheads, then tandem baited hoop nets with 25-mm mesh may

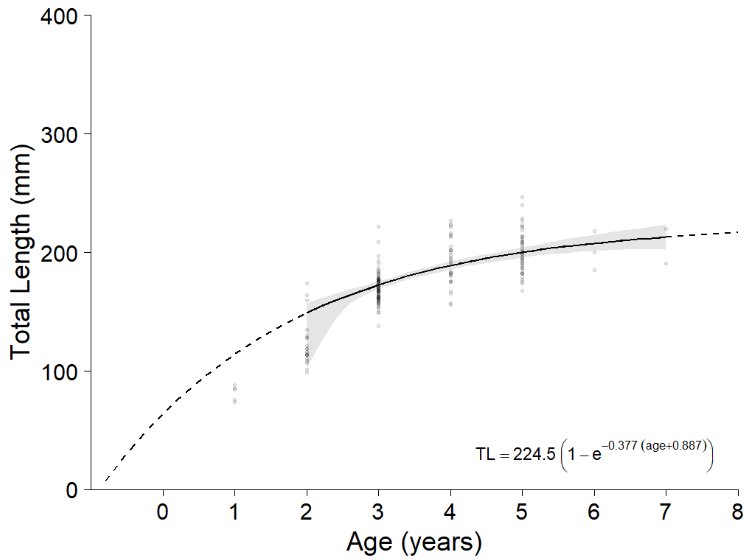

Figure 4. Von Bertalaffy growth curve calculated from 165 lapilli otolith age estimates for Black Bullheads collected using tandem, baited hoop nets from Southern Hills South Pond, El Reno, Oklahoma.

not effectively sample juvenile fish. Sampling juvenile Black Bullheads would be important for gaining information on recruitment and aiding in their overall management. Additionally, past research has sampled Black Bullhead populations with a variety of gears including fyke nets, trap nets, gill nets, hoop nets, and electrofishing (Hacnhin et al. 2002, Cucherousset et al. 2006, Mork et al. 2009, Snow et al. 2017, Sikora et al. 2021). Hacnhin et al. (2002) found that trap nets and experimental gill nets provided similar population size structure indices, however, trap nets may provide a better index of relative abundance for population monitoring. Cucherousset et al. (2006) found significant differences in length frequencies between trap nets and electrofishing for Black Bullheads, indicating a potential size bias between gears. Due to the discrepancies in which gear to use to sample Black Bullheads accurately, precisely, and efficiently, future research should evaluate the various gear types. This will allow managers to develop a standardized sampling protocol that most effectively and accurately evaluates these populations and allow for the use of catch-per-unit effort (CPUE) as a density index in reservoirs, increasing our understanding of population variation between reservoirs.

Close to Home Fishing Ponds are important for anglers in Oklahoma, providing fishing opportunities to urban areas and facilitating angler recruitment and reactivation in the face of declining license sales (Balsman and Shoup 2008). However, Black Bullhead populations can have detrimental effects on small impoundments and our results depict that the overcrowded and stunted population in SHS could potentially have a negative effect on sportfish populations and water quality in ODWC CTHFP. Therefore, management of CTHFP, especially in urban areas is needed. This study provides information on the population characteristics of two contrasting Black Bullhead populations and provides insights into future Black Bullhead research in CTHFP. Additional work should focus on understanding angler dynamics in CTHFP as this will be beneficial to managers trying to develop strategies that match angler preference, in turn providing quality fishing experiences to Oklahoman anglers. Lastly, identifying and understanding variables that attribute to overabundance and growth variability within and between Black Bullhead populations will allow for more effective fisheries management of both native and invasive populations in small impoundments.

Acknowledgments

We thank Amy Webb, Keith Thomas, and Alexis Whiles for assisting with field sampling and lab work for this project. We thank Austin Griffin and Jory Bartnicki for reviewing an earlier draft of this manuscript. We also thank Dr. Mostafa Elshahed and anonymous reviewers for providing edits that improved this manuscript. Financial support for this publication was provided by the Sport Fish Restoration Program grant [F-50-R-25] and [F-86-D-1] to the Oklahoma Department of Wildlife Conservation.

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Submitted September 3, 2022 Accepted October 22, 2022