Population Dynamics of White Crappie Occurring in a Small Georgia Impoundment Stocked with Female-only Largemouth Bass

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Abstract: Crappies (*Pomoxis spp.*) are popular sportfish, but can be difficult to manage due to erratic recruitment and variable growth. In this study, we document the population dynamics of a white crappie (*P. annularis*) population in a small impoundment characterized by low predator density and abundant populations of several forage species. White crappies ($n = 301$) were collected by electrofishing in October 2012. Relative abundance as indexed by electrofishing catch per unit effort of crappie was high (103.3 fish $h^{-1} \pm 18.7$ SD). A sub-sample was aged ($n = 153$) and growth was described by a von Bertalanffy growth curve as total length (TL) = $379.6\,(1 - e^{-0.341[\text{age} + 0.769]})$. Growth was considered medium to fast with crappie reaching 254 mm TL in 2.5 yrs. Mean TL of age-2 crappie was 231 mm TL, but lengths ranged from 85 to 365 mm TL. The age distribution revealed that age-2 fish comprised 93% of the population and several year-classes were completely absent from the age distribution. Aging revealed that both stunting and rapid growth were apparent in the same year-class. Crappie populations stocked in a female-only bass fishery can exhibit a high dispersion of lengths within age-classes, which can be a challenge to characterize with traditional population dynamic assessment tools. Future research and management efforts in this small impoundment should be allocated towards a creel survey that assesses angler exploitation and age demographics of the catch, as well as dietary preferences of the white crappie.

Key words: crappie, growth, recruitment variability

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Black crappie (*Pomoxis nigromaculatus*) and white crappie (*P. annularis*) provide important recreational fisheries, comprising 21% of total freshwater anglers in Georgia alone, ranking only behind black bass and catfish fisheries (USFWS and USBOC 2011). However, crappie population dynamics can vary greatly compared to other sportfish species, which creates challenges for fishery managers (Mitzner 1984, Hooe 1991, Boxrucker and Irwin 2002, Michaletz 2013). In particular, crappie populations are known to exhibit erratic or variable recruitment that can limit the effectiveness of traditional management activities (Hooe 1991, Allen and Miranda 1998, Dockendorf and Allen 2005). Crappie populations often exhibit cyclic recruitment patterns, with a strong year-class occurring every 3 to 5 years (Swingle and Swingle 1967, Guy and Willis 1995). These unpredictable recruitment patterns have a great influence on population dynamics modeling (Allen and Miranda 1998, Slipke and Maceina 2000).

Quality crappie fisheries are often hard to achieve and maintain in small impoundments, and this management option has been discouraged by managers in the past (Wright and Kraft 2012). Crappie populations are known to overpopulate when introduced into small impoundments, which leads to intraspecific competition for food resulting in poor growth or stunting (Swingle 1952, Goodson 1966, Mitzner 1984, Boxrucker 1987). Erratic recruitment may contribute to crappies stunting because a single large year class can dominate the population for several years (Goodson 1966). In an attempt to improve growth rate and decrease abundance of crappie in small impoundments, bottom-up (i.e., forage stockings) and top-down (i.e., predator stockings) approaches have been used with varying degrees of success (Boxrucker and Irwin 2002). The stocking of alternative forage entails a strong risk component due to potentially negative competitive effects on non-target species or early life stages of angler targeted species (Li et al. 1976, Ney 1990, DeVries et al. 1991). Threadfin shad (*Dorosoma petenense*) stockings have increased crappie growth rates and population structure in some systems (McConnel and Gerdes 1964, Range 1972, Mosher 1984), but not others (Boxrucker 1992, Hale 1996). Alternately, several studies have shown that predation on crappie by largemouth bass (*Micropterus salmoides*) has been linked to desirable crappie populations in small impoundments (Cichra et al. 1981, Gabelhouse 1984a, Boxrucker 1987). As a result of these studies, there is evidence that stocking predators in small impoundments decreases crappie abundance, which in turn increases crappie growth rates.

Management of small impoundment fisheries can benefit from new approaches to exceptional and unique fishing opportunities that may attract and retain future anglers (Schramm and Willis 2012). One such example is the stocking of all female largemouth bass at a low density to produce trophy fishing opportunities a strategy which has been recently implemented in several private ponds in the southern United States (Willis et al. 2010, Schramm and Willis, 2012). However, the effects of this new management paradigm on a concurrent crappie population are unknown. To our knowledge, there is no published study that has examined the population dynamics of white crappie within a managed low-density predator environment. In this study we document the age structure, condition, growth, and relative abundance of white crappie in a small impoundment containing a low-density population of female-only largemouth bass and several abundant forage species.

Methods

Ocmulgee Public Fishing Area (OPFA) (3222N, 8329W) is a 42.9-ha reservoir owned by the Georgia Department of Natural Resources Wildlife Resources Division (GADNR) and located on the Bleckley/Pulaski county line near Cochran, Georgia. Following impoundment in 2004, the reservoir was intensively managed, including regular fertilization. Due to high amounts of limestone bedrock throughout the basin, the water alkalinity was naturally high (>50 ppm; J. Miller, GADNR, personal communication), so liming was unnecessary. Mean depth was 4.0 m with the deepest locations exceeding 9.0 m and secchi-depth managed for a range between 0.5 and 1.1 m. In theory, anglers should expect lower catch rates of largemouth bass in systems like this (Maceina and Sammons 2015). White crappies were stocked into this impoundment to develop an alternative fishery with higher catch rates for anglers. Since impoundment regulations for the largemouth bass were catch and release, the white crappie were managed under the statewide regulation of 30 fish per person per day, no minimum size limit.

Forage species were stocked as OPFA initially filled in 2004 and included bluegill (*Lepomis macrochirus*), redear sunfish (*L. microlophus*), and threadfin shad (Table 1). Channel catfish (*Ictalurus punctatus*) and white crappie (4.2 fish ha^{-1}) were stocked in fall 2005. Forage was supplemented in future years by stocking lake chubsucker (*Erimyzon sucetta*), golden shiner (*Notemigonus crysoleucas*), and goldfish (*Carassius auratus*) (Table 1). In an effort to create a trophy largemouth bass fishery at OPFA, only female largemouth bass were stocked to eliminate recruitment and maintain a low density of largemouth bass. The initial stocking of female largemouth bass in 2005 was 12.8 fish ha^{-1}, and subsequent stockings varied between 0 and 12.8 fish ha-1 from 2006 to 2012 (Table 2). Male largemouth bass were found in the impoundment beginning in 2009, but largemouth bass densities were likely never >40 fish ha^{-1} during the study, and mean catch-per-effort from 2006–2012 was 19.5 fish h^{-1} (SD = 13).

Table 1. Stocking history of forage, including species, years stocked, total number of stockings, number stocked, per–hectare (ha) stocking mean, mean total length (TL) stocked, minimum (Min) TL stocked, and maximum (Max) TL stocked. N/A = minimum, maximum, and mean TL data for one or more of the stocking events was not taken.

Species	Years stocked	Total stockings	Number stocked	Per-ha stocking mean	Mean TL	Min TL	Max TL
Bluegill	2004, 2011 & 2012	3	100,223	778.7	N/A	N/A	N/A
Channel catfish	2005–2011	4	77,000	448.7	25	201	N/A
Golden shiners	2005	1	4,500	104.9	N/A	N/A	N/A
Goldfish	2004–2011	21	701,121	778.2	127	25	350
Lake chubsuckers	2008–2012	9	117,065	303.2	178	88	380
Redear	2004, 2011 & 2012	3	25,035	194.5	N/A	N/A	N/A
Threadfin shad	2005	1	1,500	35	N/A	N/A	N/A
White crappie	2005	1	181	4.2	N/A	N/A	N/A
Totals		41	1, 026,625	583.7	N/A	N/A	N/A

Table 2. Stocking history including year-class, age, number stocked, per-ha stocked, mean total length (TL) stocked, minimum (Min) TL stocked, maximum (Max) TL stocked, and brood origin. N/A = Not available or not measured, or minimum, maximum, and mean TL data for this stocking event was lost.

Year-class	Age	Number stocked	Per-ha stocked	Mean TL	Min TL	Max TL	Brood origin
2005	8	550	12.8	273	141	340	American Sportfish
2006	7	550	12.8	240	185	351	American Sportfish
2008	5	53	1.3	317	227	443	Dodge County (PFA) (Flat Creek PFA)
2009	4	100	2.3	N/A	N/A	N/A	Dodge County (PFA)
	N/A	6		455	421	480	Ocmulgee PFA Reproduction
2010	3	334	7.8	204	146	312	Dodge County (PFA)
	N/A	7		441	300	528	Ocmulgee PFA Reproduction
2012	1	81	1.9	256	229	287	Ocmulgee PFA Broods
	N/A	3		477	390	541	Ocmulgee PFA Reproduction

A unique stocking strategy was adapted at OPFA. Our goal was to stock the maximum-sized prey that could be utilized by memorable-sized largemouth bass (i.e., >510 mm TL; Gabelhouse 1984b). Juvenile and adult largemouth bass typically can eat up to 50% of their TL (Lawrence 1957, Johnson and Post 1996). Our target stocking for prey size varied from 60 to 300 mm TL, based on a maximum predator size of 625 mm TL. In 2010, average prey size was skewed towards the smaller end of the forage target size, with sunfish at 112 mm TL, golden shiner at 128 mm TL, threadfin shad at 113 mm TL, and lake chubsucker at 192 mm TL. There was evidence of severe stunting in the forage. Therefore, supplemental forage was provided at sizes and in numbers that would provide the most noticeable benefit in terms of increasing biomass of the trophy largemouth bass (Table 1).

White crappie were collected from OPFA using a boat electrofisher with a 5000-W generator and a Smith-Root Model VII-V pulsator (Smith-Root, Inc., Vancouver, Washington); electrical output ranged from 4 to 6 A of pulsed DC. Sampling occurred between 16 and 22 October 2012. All white crappie captured in the field were immediately measured to the nearest mm for total length (TL), and weight g. An aged sub-sample of five fish per cm group was kept up to 30 cm TL and 10 fish per cm group >30 cm TL. Fish sex was determined at the lab and the sagittal otoliths were removed for aging via annuli (Hoyer et al. 1985, Maceina and Betstill 1987, Bonvechio et al. 2008). As described in Bonvechio et al. (2008), otoliths were processed and sectioned, and age was determined by two experienced readers, or three in the case of any discrepancies. Ages from the subsample were extrapolated to all fish collected using an age-length key (Ricker 1975). If less than three fish were present in the whole sample for any age group, then that age group was not included in the analysis. We attempted to determine the instantaneous total mortality slope (Z) and total annual mortality ($A = 1 - e^{-z}$) from a catch-curve (Ricker 1975).

To describe growth, a von Bertalanffy (1938) curve was fit to the mean TL at age using FAST (Slipke and Maceina 2000) and then compared to Allen and Miranda's (1995) comprehensive white crappie growth analysis from 23 different estimates across the southern and midwestern United States. To assess size structure, a length-frequency distribution was created and proportional size distribution for quality-size fish (PSD), preferred-size fish (PSD-*P*), and memorable-size fish (PSD-*M*) were calculated using length categories found in Gabelhouse (1984b). Fish condition, as indexed by relative weight (W_r), was assessed for fish larger than 100 mm TL using the standard weight equation found in Neumann and Murphy (1991). Mean W_r was compared among standard size groups [stock (130–199 mm TL), quality (200–249 mm TL), preferred (250–299 mm TL), and memorable (300–379 mm TL)] using an analysis of variance. Means were separated using the LSMEANS procedure (SAS Institute 2011), and a Type I error rate of 0.05 was used for all analyses.

Results

A total of 310 white crappies were collected from four 2700-s transects. Catch rates were considered high (mean = 103.3 fish h^{-1}, SD = 18.7). Sampled white crappie exhibited a bimodal distribution with lengths varying from 80 to 375 mm TL and the PSD was 70, PSD-*P* was 61, and the PSD-*M* was 40 (Figure 1). Mean relative weight (W_r) increased with size (ANOVA, $F = 24.73$, $P < 0.001$, Figure 2). Mean relative weight of stock-sized fish was significantly less than quality- and preferred-size fish (LSMEANS, $t = 3.434$ to 4.872, $P < 0.001$), and means for all three were less than memorable (LSMEANS, $t = 2.591$ to 8.577, $P < 0.035$) (Figure 2).

Age was estimated for 153 white crappies and between-reader agreement of the age estimates was 95%. The seven aging discrepancies were resolved by a third independent reader. Gender was evenly split (57 males and 56 females), but gender could not be determined for 40 individuals between 85 and 200 mm TL due

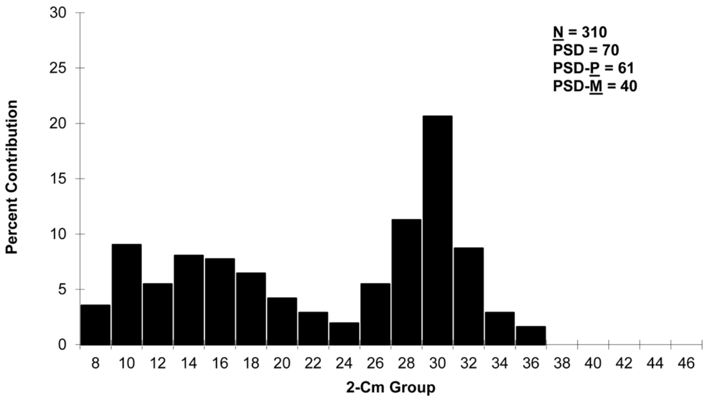

Figure 1. Graph depicting the length-frequency distribution (2-cm group, dark shaded bars) of white crappie collected at Ocmulgee Public Fishing Area with electrofishing from 16 October and 22 October 2012. Total lengths (TL) are presented in terms of 2-cm groupings (e.g., 8 = 8.00-9.99 cm). Proportional size distribution (PSD), preferred-size fish (PSD-*P*) and memorable fish (PSD-*M*) were calculated using 130 mm TL as stock size, 200 mm TL as quality size, 250 mm TL as preferred size, and 300 mm TL as memorable size (Gabelhouse 1984b). No trophy size individuals were obtained (≥380 mm TL).

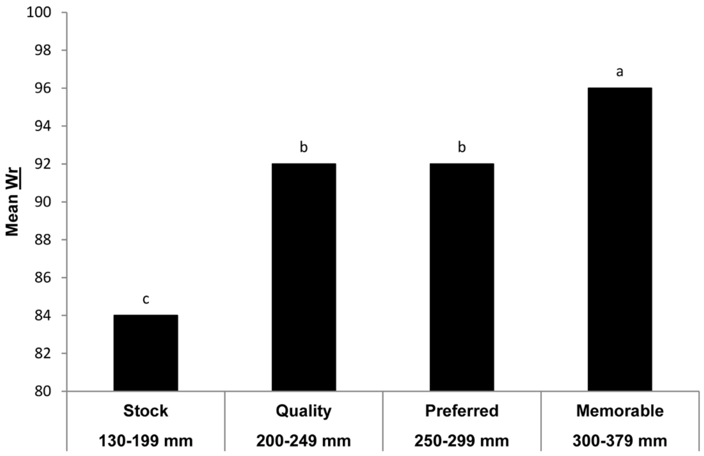

Figure 2. Graph representing mean relative weight (W_r) for each Gabelhouse (1984b) PSD size group (mm) and the associated significant similarities and differences among the groups are depicted with letters.

to lack of gonadal development, most of which (90%) were slow-growing age-2 fish. Age of white crappie in OPFA varied between 1 and 9 years, but 93% were age-2 (Table 3). Several year-classes were completely missing from the age distribution, and no age-0 fish were collected. Due to the lack of successive age-classes present, a reliable catch-curve (mortality estimate) could not be calculated. Wide variations in lengths at age were observed for age-1 and age-2 fish (Table 3). Age-7 fish represented the oldest naturally-spawned white crappie in the lake, thus the age-9 fish collected were likely remnants of the adult white crappie that were stocked as 2-year-old fish in 2005. Growth of white crappie was described with the von Bertalanffy growth curve as $TL = 379.6\,(1 - e^{-0.341[age + 0.769]})$, and was considered moderate to fast in comparison to rates reported by Allen and Miranda (1995), taking only 2.5 years to reach 254 mm TL and 4.0 years to reach 305 mm TL (Figure 3).

Table 3. Estimated total length (TL) and associated standard deviation (SD) at age for white crappie collected at Ocmulgee Public Fishing Area. Missing values indicate that no fish were collected for that age. (n) is the number of fish assigned at each age and percent (%) is the composition of the age-frequency distribution. Minimum (Min) and maximum (Max) size fish for each age are given. No standard deviation (SD) could be determined for age-3 fish due to low sample size.

Age	TL	SD	n	%	Min	Max
1	172	34	10	3.2	82	200
2	232	81	288	92.6	85	360
3	365	–	1	0.3	–	–
4	–	–	–	–	–	–
5	–	–	–	–	–	–
6	–	–	–	–	–	–
7	353	15	9	2.9	337	375
8	–	–	–	–	–	–
9	366	13	3	1.0	357	375

Discussion

An age-length key was impossible to perform with our data given the large length overlap between age-1 and age-2 fish. Age and growth studies on crappies in the past have applied similar age and growth protocols as the current study (Bonvechio et al. 2008). Despite collecting five fish per cm group up to 30 cm and 10 fish per cm group >30 cm, several year-classes were completely missing from the age distribution, and the majority of the sample was age-2 fish. Although sample size was not believed to be an issue, when field sampling concluded, larger sample sizes similar to those recommended by Coggins et al. (2013) may need to be collected on systems characterized by extremely variable recruitment. Accuracy and precision of growth and mortality parameter estimates are likely influenced by life history and exploitation history of the stock in question (Coggins et al. 2013). The variable growth and erratic recruitment (i.e., missing year-classes) demonstrated in this

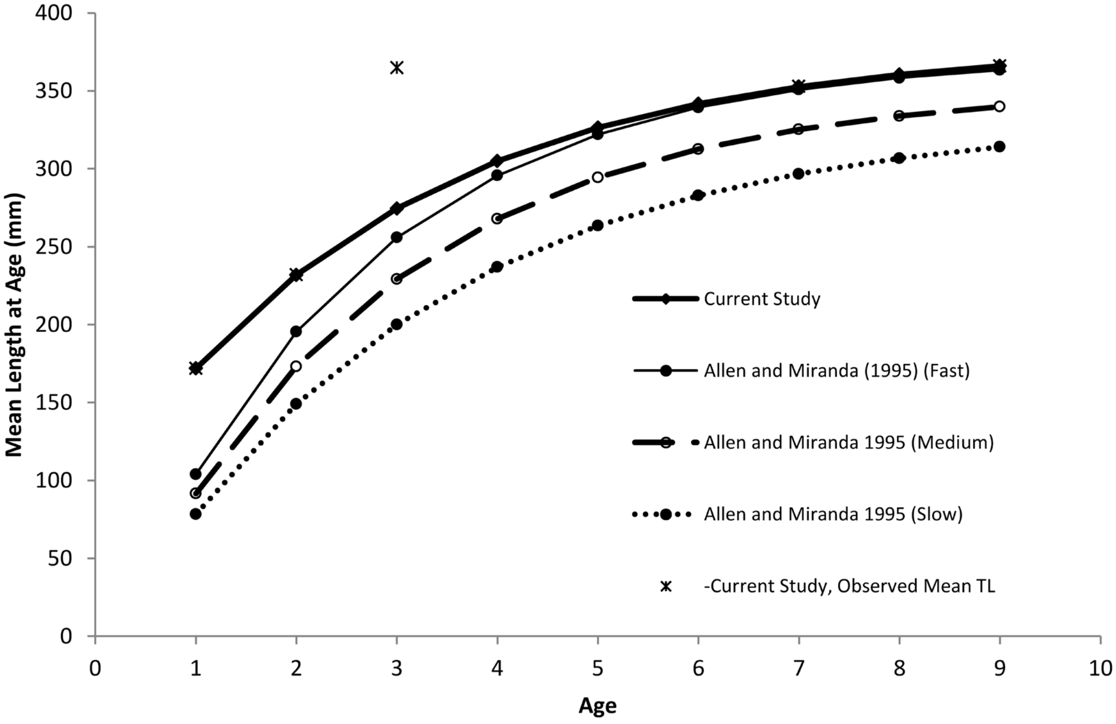

Figure 3. The von Bertalanffy growth curves obtained from predicated mean total length (TL) at-age estimates (Current Study) and observed mean TL estimates for the current study, compared to fast, medium and slow growth rates from Allen and Miranda (1995).

study likely affected the precision surrounding the parameter estimates (Allen 1997, Allen and Miranda 1998). Substantial overlap in lengths among age-classes has been noted in crappie populations in Kansas and Tennessee (Gabelhouse 1991, Sammons et al. 2000). Similarly, Sammons and Maceina (2009) observed broad overlapping lengths within each age-class of sunfish in a suite of Georgia rivers and concluded that managers working with sunfish need to obtain a large sample for age and growth analysis to reduce the chance of bias. Short-lived fish such as sunfish and crappies may be more likely to exhibit high length overlap at age, and thus biologists working with these species should be concerned with the accuracy and precision of parameter estimates informed by age composition in the age-length key (Coggins et al. 2013).

Competition for zooplankton between age-0 shad and white crappies in OPFA may have facilitated the high length dispersion of age-2 crappie and year-class strength (DeVries et al. 1991, Slipke et al. 1998). A network of diffusers is used in OPFA to prevent stratification and avoid low oxygen problems. However, aeration diffusers can reduce crustacean zooplankton levels on a short term basis (Cowell et al. 1987) and can cause higher levels of turbidity in a prolonged situation over multiple years (Thomforde and Boyd 1991) thus resulting in potential food competition between threadfin shad and age-0 white crappie. Guest et al. (1990) found that density and biomass of age-0 white crappie decreased in the presence of gizzard shad or threadfin shad in small ponds. They suggested that competition for food between crappie and shad larvae was partially responsible for that decline.

Large growth variations may be linked to a forage transition to piscivory, which has been documented for other species (Phillips et al. 1995, Olson 1996, Braband 2001). White crappie generally switch to piscivory when they attain 200 mm TL (Ellison 1984, and O'Brien et al. 1984). In contrast, Heidinger (1977) found that this shift did not occur until crappies reached 240 mm TL in Illinois impoundments. Although diet analysis was not conducted in this study, we believe the large abundance of threadfin shad and other forage species present may have been a contributing factor to the wide range of lengths observed in each age-class.

Condition (i.e., W_r) of white crappie in OPFA improved as length group increased, notably after 200 mm TL. The majority of the fish that lacked detectable gonads were found to be slow-growing age-2 fish, which were ≤200 mm TL. This size matches what Bunnell et al. (2007) reported for white crappie in Ohio reservoirs, where well-fed fish invested more energy into ovary development than less-fed individuals. Therefore, the bimodal length frequency distribution in OPFA may represent two groups of crappie: faster growing individuals that quickly transitioned to piscivory and slower growing individuals that exhibited compensatory growth by continuing to feed on zooplankton (Guest et al. 1990, Pope and DeVries 1994). Similar to others (Gabelhouse 1991, Neumann and Murphy 1991), we found that W_r was higher during the fall sample for adult white crappie than juveniles. As a result, changes in W_r may have simply been related to the season of when our sample took place and not related to dietary preferences.

The growth of white crappie in OPFA was faster than Allen and Miranda (1995) reported from 23 different estimates across the southern and midwestern United States. Despite almost half the population demonstrating stunting at an early age, growth estimates for the overall population were more than acceptable from a management standpoint. White crappie growth rates in the first couple of years of life can be density dependent (Pope et al. 2004). Similar to our study, Cichra et al. (1981) found that adult white crappie were exhibiting fast growth and stunting in Texas lakes where the conditions were conducive for rapid growth of largemouth bass. Typically, systems without adequate densities of predators cause overpopulation of crappie to occur (Cichra et al. 1981, Gabelhouse 1984a, Summers et al. 1994). As a result of the low predators, some stunting was occurring in OPFA.

Despite the low density of predatory fish in OPFA, white crappie W_r was still better than those in an unfished Colorado lake where northern pike were present (Willis et al. 1984). However, the effects of angling mortality on the strong age-2 year-class remain unknown. Ricker (1975) coined the term recruitment by platoon, which occurs when fish of the recruited platoon of any age are of larger size than the unrecruited ones, yet there is often a broad overlap of sizes at the same age. Platoon recruitment is typical when fishing targets a population during a breeding migration and non-maturing fish do not mingle with the maturing ones or when faster-growing fish reach harvestable size quicker than slower-growing counterparts. This situation has been theorized to occur in crappie populations in Tennessee reservoirs that experience high angling pressure (Sammons et al. 2000). If this is the case for the strong age-2 year-class, it is apparent that fish ≤200 mm TL were less susceptible to angling than fish >200 mm TL. However, the angling component of the crappie fishery in OPFA was never addressed with a concurrent creel survey due to manpower limitations. Had exploitation been measured or fish carcasses been intercepted for sagittal otolith removal, we may have had a better idea of what to expect when the population dynamics were examined. Undoubtedly, the lack of older age-classes present in the age structure sample of our study may indicate the stock may be heavily exploited by anglers (Pope et al. 2004, Coggins et al. 2013). Pope et al. (2004) speculated that white crappie become acceptable to keep in Texas Reservoirs during their third or fourth year of life. Similarly, we observed little to no age representation for ages 3 to

6 in OPFA, thus angling could be another important component affecting the age structure.

Hatch dates of white crappies were related to timing of water-level rise during the spring in Normandy Reservoir, Tennessee (Sammons et al. 2001). Also, Several studies indicate that reproductive success of crappie is greater during higher water levels before, during, and after the spawn (McDonough and Buchanan 1991, Beam 1983, Mitzner 1991, Sammons and Bettoli 2000, Sammons et al. 2002, Maceina 2003). Annual water levels in OPFA fluctuated frequently during our study. Water level was 1.2 to 2.4 m below full pool in 2009 and 2011, but 2010 was a relatively wet year resulting in full pool in spring and fall 2010 (i.e., corresponding to the strong year-class produced in 2010). Thus, the extended low water periods experienced in OPFA may have also contributed to several missing year-classes in the age sample.

Here, we documented a case study which evaluated the population metrics of white crappie in a low predator environment with an abundance of forage species. The stocking of all female largemouth bass at a low density to produce trophy opportunities is something, which has been recently implemented in small impoundments in the southern United States (Willis et al. 2010). It is anticipated that the strategy of stocking female-only largemouth bass at a low density in small impoundments will involve lower angler catch rates. Crappies can be stocked in predator-poor impoundments to create an alternative fishery, yielding much higher catch rates than the primary trophy largemouth bass fishery. This study provides a depiction of what managers could experience when stocking crappies in a female-only largemouth bass impoundment. In an effort to further understand the erratic recruitment and variable growth rates examined, future studies on these unique systems should focus on the angler harvest to determine how many year-classes are potentially driving the fishery (i.e., obtaining otoliths from carcasses), as well as determining trophic overlap among crappies and prey species. Managers should also be aware that crappie populations stocked in a female-only largemouth bass fishery can exhibit a high dispersion of lengths within age-classes, proving to be a challenge to characterize with traditional population dynamic assessment tools.

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