Diet and Population Characteristics of Stocked Age-0 Saugeye in an Oklahoma Reservoir

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Abstract: Fish growth early in life typically affects recruitment to adulthood. For this reason, fisheries managers stock fish of varying sizes (e.g., fingerling or advanced fingerling rather than fry, which are less expensive to produce) hoping that an initial size advantage results in improved survival. Saugeye (*Sander vitreus x S. canadensis*) are hatchery-produced hybrids that are stocked into many Midwestern and southern U.S. reservoirs to create sportfishing opportunities. A saugeye stocking program was initiated at Arcadia Reservoir, Oklahoma, in 2017 when 38,110 fingerlings were stocked. In 2018, 146,086 fry were stocked into Arcadia Reservoir. This provided us the opportunity to compare differences in diet, growth, and mortality between two year-classes of age-0 saugeye stocked at different sizes. Age-0 saugeye (184 in 2017 [stocked as fingerlings], 198 in 2018 [stocked as fry]) were collected across 14 sampling events during July 2017–May 2019 using boat electrofishing to analyze diets and population characteristics. Gizzard shad (*Dorosoma cepedianum*) were the most important identifiable prey item found in juvenile saugeye diets for both stocked cohorts, but inland silversides (*Menidia beryllina*) and centrarchids contributed substantially to age-0 saugeye diets. Mean TL of age-0 saugeye were similar between the two cohorts by late summer. However, saugeye stocked as fingerlings in 2017 were larger than those stocked as fry in 2018 by their first spring. Daily mortality estimates were significantly higher for saugeye stocked as fingerlings in 2017 than fry stocked in 2018. Fisheries managers should stock fingerlings to capitalize on improved growth rates, which allows for creation of recreational saugeye fisheries more rapidly; however, abundance of forage may mediate growth and survival of stocked fish regardless of their size at stocking.

Key words: food habits, growth, daily mortality, early life history, *Sander canadensis*

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Growth during the early life of fishes often drives recruitment to adulthood (Goodgame and Miranda 1993, Ludsin and DeVries 1997). Fish that attain larger sizes early in life can consume larger prey items, transition to piscivory sooner, and avoid predation by exceeding gape limits of predators, giving them a competitive advantage over smaller fish of the same cohort and increasing the odds of survival to adulthood (Goodgame and Miranda 1993, Santucci and Wahl 1993, Ludsin and DeVries 1997, Mesing et al. 2008). Survival through the first winter is a critical threshold in the early life history of fish that typically affects recruitment to adult populations. Therefore, fish that grow to larger sizes during the first growing season have an advantage entering winter that translates into increased survival and ultimate year-class strength (Ludsin and DeVries 1997).

Many fisheries are managed using hatchery-produced fish, and their growth post-stocking can influence survival and eventual recruitment to adulthood (Santucci and Wahl 1993, Kampa and Hatzenbeler 2009). Early growth is dictated by the ability of hatchery-produced fishes to acclimate to conditions in their new environment (Cowx 1999). Because early fish growth is so important to stocking success, fisheries managers typically stock larger fish (fingerling or advanced fingerling stages) in lieu of fry that are cheaper to produce, hoping that an initial size advantage will increase survival (Santucci and Wahl 1993, Pope et al. 1996, Kampa and Hatzenbeler 2009). Because fish growth can have a major effect on the overall success of a stocking program, evaluation of growth rates is an important post-stocking performance measure (Stewart and Long 2015).

Saugeye are hybrids of female walleye (*Sander vitreus*) and male sauger (*S. canadensis*) that are produced in hatcheries and stocked into many midwestern and southern U.S. reservoirs to create sportfishing opportunities (Leeds 1988, Fiss et al. 1997, Hale et al. 2008). Rapid growth rates, likely related to heterosis (i.e., “hybrid vigor”), allow saugeye to reach a catchable size (300 mm TL) in one year in some systems (Humphreys et al 1984, Leeds and Summers 1987). However, early growth of saugeye may be impeded by a foraging reduction caused by increased water temperatures if fish are stocked during summer in Oklahoma (Snow et al. 2018). In 2017, the Oklahoma Department of Wildlife Conservation (ODWC) stocked fingerling saugeye into Arcadia Reservoir for the first time to create additional sportfishing opportunities. In 2018, saugeye were stocked into Arcadia Reservoir as fry due to hatchery pond space limitations that occurred that year. Because the ability of young saugeye to forage effectively in their new environment can affect growth and survival, and ultimately stocking success, our objective was to compare differences in diet, growth, and mortality between saugeye that were stocked into Arcadia Reservoir at different sizes over two years.

Methods

Arcadia Reservoir is a 678-ha impoundment located in central Oklahoma. Sportfish common to Arcadia Reservoir include blue catfish (*Ictalurus furcatus*), channel catfish (*I. punctatus*), flathead catfish (*Pylodictus olivaris*), largemouth bass (*Micropterus salmoides*), white bass (*Morone chrysops*), and white crappie (*Pomoxis annularis*). Bluegill (*Lepomis macrochirus*), gizzard shad (*Dorosoma cepedianum*), green sunfish (*L. cyanellus*), inland silverside (*Menidia beryllina*), longear sunfish (*L. megalotis*), orangespotted sunfish (*L. humilus*), red shiner (*Cyprinella lutrensis*), and redear sunfish (*L. microlophus*) are also common in the reservoir and may be utilized by sportfish as forage. Saugeye were stocked into Arcadia Reservoir for the first time on 2 May 2017 when 38,110 fingerlings (56 fish ha^{-1}) averaging 38 mm TL were stocked. Saugeye were stocked again on 17 April 2018, when 146,086 fry (215 fish ha^{-1}) ranging 5–8 mm TL were stocked.

Saugeye stocked as fingerlings in May 2017 were collected during eight sampling events (six in July–September 2017 and two in May–June 2018; Table 1). Saugeye stocked as fry in April 2018 were collected during six sampling events (four in July–October 2018 and two in April–May 2019). All age-0 saugeye were sampled using boat electrofishing (pulsed DC, high voltage, 7.5 GPP, Smith-Root, Inc., Vancouver, Washington), which is an accurate method for estimating fingerling walleye abundance (Serns 1982) and has been commonly used to sample age-0 saugeye (Pope et al. 1996, Galinat et al. 2002). Electrofishing sites were selected to ensure that all available habitat types were sampled. Saugeye were collected primarily during nighttime hours, but occasionally collections ran into daylight hours when sampling could not be completed before sunrise. All saugeye encountered were netted and held in a 114-L livewell and CPUE was expressed as fish h^{-1}. Because year-class strength of age-0 walleye is typically evaluated during August–December (Borkholder and Parsons 2001), we considered age-0 saugeye CPUE on 29 August 2017 and 29 August 2018 to represent an index of year-class strength. Also, samples taken in the following May each year were considered to index over-winter recruitment of each cohort. In both cases, differences in CPUE between cohorts were assessed using a two-sample *t*-test.

Table 1. Summary statistics of two age-0 saugeye year-classes (YC) sampled using boat electrofishing at Arcadia Reservoir, Oklahoma, during September 2017–May 2019.

YC	Date	*n*	Mean TL, mm range)	Sites (*n*)	Effort (h)	CPUE (SE)
2017	7 Jul 2017	49	147 (126–166)	9	1.6	31.05 (6.55)
	13 Jul 2017	33	158 (135–172)	5	0.8	43.83 (9.57)
	28 Jul 2017	24	171 (157–188)	7	1.1	22.89 (6.36)
	18 Aug 2017	13	190 (165–211)	7	1.2	11.12 (3.04)
	29 Aug 2017	28	203 (176–234)	8	1.3	21.17 (6.32)
	6 Sep 2017	14	221 (207–245)	10	1.7	7.81 (2.26)
	17 May 2018	19	314 (262–344)	8	1.4	13.66 (3.93)
	14 Jun 2018	4	330 (314–338)	13	2.3	2.57 (1.63)
2018	24 Jul 2018	46	157 (125–176)	7	1.1	42.74 (13.92)
	16 Aug 2018	21	183 (168–200)	7	1.2	17.41 (4.19)
	29 Aug 2018	35	201 (171–238)	5	0.9	40.58 (8.76)
	22 Oct 2018	36	250 (208–280)	4	0.6	61.46 (2.85)
	25 Apr 2019	30	279 (242–307)	9	1.5	20.37 (4.72)
	16 May 2019	30	275 (235–326)	6	0.9	33.95 (26.00)

Following capture, each fish was measured (mm, TL) and stomach contents were removed from each age-0 saugeye using pulsed gastric lavage (PGL), which has been used to remove stomach contents from age-0 walleye (Blankman et al. 2018). The device used for PGL consisted of clear plastic tubing constricted three times (19.1-mm internal diameter [30.5 cm long] to 12.7-mm internal diameter [152.4 cm long] to 6.4-mm internal diameter [106.7 cm long]) and attached to a 568-L h^{-1} livewell pump to control the flow rate to 46.94 ml sec^{-1} (SD = 1.54). Stomach contents were removed from each fish by inserting the plastic tubing into the esophagus and water was pumped briefly until stomach contents were evacuated into a wooden trough (Fowler and Morris 2008). The contents were then emptied from the trough into individually numbered plastic bags and stored on ice until returned to the Oklahoma Fishery Research Laboratory in Norman, Oklahoma, to be frozen or processed. A subsample of 17 age-0 saugeye (Mean TL = 148 mm TL; SD = 9) was sacrificed on the first night of sampling to evaluate stomach content evacuation rates using PGL. Following dissection, we determined that 100% of stomach contents were removed using pulsed gastric lavage in the field, so we were confident that this method would allow for a comprehensive view of age-0 saugeye diets in subsequent samples. In the laboratory, saugeye stomach contents were identified to the lowest taxonomic level possible (order or family for invertebrates and species for fish unless remains were unidentifiable) and enumerated. Following Bowen (1996), saugeye

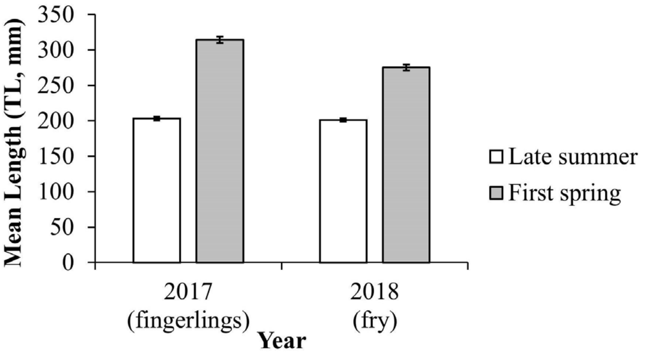

Figure 1. Comparison of mean TL, mm of 135- to 136-day-old and 396-day-old saugeye stocked as fingerlings in 2017 and fry in 2018. Error bars represent standard error of the mean.

diets were described in three ways: percent occurrence, percent composition by number, and percent weight.

The Robson and Chapman method (Robson and Chapman 1961, Miranda and Bettoli 2007) was used to estimate daily mortality (%) using age-0 saugeye CPUE data. The mortality estimates were considered significantly different if the 95% CL did not overlap. Saugeye were collected at similar times in both years at 135- to 136-d post-hatch (29 August in both years) and 396 d post-hatch (16 May 2018 and 17 May 2019), so we used length data from those dates and performed a two-sample *t*-test on the observed mean lengths to compare growth between the two stocked year classes. The outcomes of the *t*-tests were considered significant at $P < 0.05$.

Results

Catch Statistics

A total of 184 age-0 saugeye (126–344 mm TL) from the May 2017 fingerling stocking was collected across eight sampling events during July–September 2017 and May–June 2018 (Table 1). Sample size varied from 4 to 49 fish per sampling trip. Mean CPUE also varied from 2.57–43.83 fish h^{-1}. A total of 198 age-0 saugeye (125–326 mm TL) stocked as fry in April 2018 was collected during July–October 2018 and April–May 2019 (Table 1). Sample size ranged from 21 to 46 fish per sampling trip, which resulted in mean CPUEs from 17.41–61.46 fish h^{-1}. In general, CPUE was greater for saugeye stocked as fry in April 2018 than those stocked as fingerlings in May 2017, but year-class strength (i.e., CPUE on 29 August in both years) did not differ between the stocked cohorts ($t = -1.80$, df = 8, $P = 0.11$; Table 1). Similarly, the CPUE in the first spring (May in both years) did not differ between the stocked cohorts ($t = -0.77$, df = 5, $P = 0.48$), suggesting there was no differential over-winter mortality.

Population Characteristics

The daily mortality rate of age-0 saugeye was 4.6% (95% CL = 3.5%–5.7%) in 2017 and 2.5% (95% CL = 2.0%–2.9%) in 2018, and the 95% CL of these estimates did not overlap suggesting that these estimates are significantly different. Mean TL of 135- to 136-d post-hatch saugeye did not differ between the two cohorts in late summer ($t = 0.57$, df = 57, $P = 0.57$; Figure 1). However, mean TL of 396-d-old saugeye collected in May 2018 (2017 fingerlings) were significantly larger than those collected in May 2019 (2018 fry; Figure 1; $t = 6.33$, df = 43, $P < 0.05$).

2017 Fingerling Saugeye Diets

A total of 184 age-0 saugeye collected during eight sampling events was used for diet analysis. Of the 184 fish collected for diet analysis, 64 had empty stomachs (35%). Saugeye collected in 2017 consumed 14 different prey types (Table 2). Age-0 saugeye were primarily piscivorous, as fishes dominated diets (≥99%) by number and weight. Unidentified fish remains (38%) contributed most to 2017 saugeye diets by percent occurrence, followed by gizzard shad (29%), inland silversides (15%), and bluegill (13%). All other prey items contributed <7% by occurrence. For percent by number, unidentified fish remains comprised the largest percent (33%), followed by gizzard shad (27%), centrarchids (sunfish and white crappie; 25%), and inland silversides (12%). All other fish represented <2% by total number. When combined, centrarchids (sunfish and white crappie) contributed the most to saugeye diets by total weight (31%), followed by gizzard shad (29%), and inland silversides (27%). All other fishes represented <7% by total weight.

2018 Fry Saugeye Diets

A total of 198 age-0 saugeye collected during six sampling events was used for diet analysis. Of the 198 fish collected for diet analysis, 47 had empty stomachs (24%). Saugeye collected in 2018 consumed 15 different prey types (Table 2). Age-0 saugeye were primarily piscivorous, as fishes dominated the diets (≥95%) by number and weight. Gizzard shad (40%) dominated 2018 saugeye diets by percent occurrence, followed by unidentified fish remains (25%), and inland silversides (18%). All other prey items contributed <4% by occurrence. For percent by number, gizzard shad composed 43% of all diet items, followed by unidentified fish remains (23%), inland silversides (20%), and centrarchids (sunfish and white crappie; 8%). All other fishes represented <2% by total number. Gizzard shad comprised over half (52%) of the prey items by weight, followed by white crappie (19%), inland silversides (13%), and combined sunfish (9%). All other fishes represented <6% by total weight.

Table 2. Diets of two year-classes (YC) of stocked saugeye collected from Arcadia Reservoir, Oklahoma, from July 2017–May 2019.

	2017 YC			2018 YC		
	% Occurrence	% Number	% Weight	% Occurrence	% Number	% Weight
Fish						
Bluegill (*Lepomis macrochirus*)	12.6	11.1	13.4	2.7	1.8	0.7
Cyprinidae	0.8	0.6	0.1	N/A	N/A	N/A
Freshwater drum (*Aplodinotus grunniens*)	1.7	1.2	6.1	1.3	0.9	5.0
Gizzard shad (*Dorosoma cepedianum*)	28.6	26.5	28.6	39.7	42.7	52.4
Green sunfish (*Lepomis cyanellus*)	1.7	1.2	1.0	N/A	N/A	N/A
Ictalurus spp.	N/A	N/A	N/A	0.7	0.4	0.1
Inland silverside (*Menidia beryllina*)	15.1	12.4	27.0	17.9	19.6	12.6
Lepomis spp.	6.7	6.2	3.4	1.3	0.9	3.1
Longear sunfish (*Lepomis megalotis*)	N/A	N/A	N/A	0.7	0.4	2.0
Orangespotted sunfish (*Lepomis humilis*)	1.7	2.5	2.2	0.7	0.4	2.6
Redear sunfish (*Lepomis microlophus*)	1.7	1.2	2.4	N/A	N/A	N/A
Unidentified centrarchid	1.7	1.2	0.5	2.0	1.3	0.9
Unidentified fish	37.8	32.7	7.5	25.2	23.1	1.5
White crappie (*Pomoxis annularis*)	2.5	1.9	7.8	3.3	3.6	19.0
Invertebrates						
Decapoda (crayfish)	N/A	N/A	N/A	0.7	0.9	<0.01
Diptera	N/A	N/A	N/A	2.0	1.8	<0.01
Nematoda	0.8	0.6	<0.01	N/A	N/A	N/A
Miscellaneous						
Detritus	0.8	0.6	0.1	1.3	1.8	0.1
Fish eggs	N/A	N/A	N/A	0.7	0.4	<0.01

Discussion

Age-0 saugeye in Arcadia Reservoir were primarily piscivorous over the course of this evaluation. Gizzard shad and, to a lesser extent, inland silversides, were the most important prey items found in juvenile saugeye diets for both stocked cohorts. This appeared to be true whether fish were stocked as fry in April or fingerlings in May. Young saugeye consumed mostly shad (gizzard shad and threadfin shad [*Dorosoma petenense*]) in Cherokee Reservoir, Tennessee (Humphreys et al. 1984). Similarly, Johnson et al. (1988) found that saugeye fed primarily on gizzard shad, but also consumed other species including brook silverside (*Labidesthes sicculus*). Inland silversides also were the predominant prey item found in diets of age-0 saugeye, followed by gizzard shad, in Thunderbird Reservoir, Oklahoma (Leeds and Summers 1987). It appears saugeye have prey preferences similar to walleye, which prefer soft-rayed prey species over spiny-rayed fishes (Knight et al. 1984).

Although saugeye typically consume mostly soft-rayed species, they readily consume other common littoral-zone species in systems where they are stocked (Humphreys et al. 1987, Johnson et al. 1988). For instance, we also found centrarchids to be important to the diets of age-0 saugeye in Arcadia Reservoir. When sunfish and crappies were combined, they contributed slightly less by number but more by weight than gizzard shad in diets of saugeye from the 2017 year class. In 2018, centrarchids were numerically less common than in 2017 but were still ranked second to gizzard shad by weight. Similarly, Lynch et al. (1982) found that saugeye will readily feed on centrarchids in small ponds. The willingness of saugeye to consume centrarchids has resulted in fisheries management agencies stocking saugeye to manipulate size structure of crappies (e.g., Summers et al. 1994, Boxrucker 2002, Galinat et al. 2002). Previous research suggests that crappies are an important prey item for large saugeye (> 400 mm TL; Leeds 1988). However, we observed direct consumption of white crappie even by age-0 saugeye in Arcadia Reservoir, suggesting that crappie number reductions may begin even when saugeye are small, although probably at low frequencies.

Despite differences in size at stocking, saugeye in both year classes grew to similar sizes by late summer and both cohorts achieved sizes comparable to other saugeye populations by fall. By October, saugeye in Arcadia Reservoir averaged approximately

250 mm TL (249 mm in 2017; 248 mm in 2018). Leeds and Summers (1987) found that age-0 saugeye averaged 271 mm and 256 mm TL by October for two year-classes in Thunderbird Reservoir, Oklahoma. Similarly, Boxrucker (1996) documented age-0 saugeye averaging approximately 250 mm TL by fall from Thunderbird Reservoir. When compared to saugeye populations outside of Oklahoma, growth rates by fall exceeded those from Pleasant Hill Reservoir, Ohio (243 mm TL; Johnson et al. 1988), but were less than those calculated from Cherokee Reserovir, Tennessee (~275 mm TL; Humphreys et al. 1984). Although growth to the first fall was similar for both saugeye cohorts in Arcadia Reservoir, their size diverged by spring. Saugeye stocked as fingerlings in 2017 attained larger sizes (mean TL = 314 mm) than those stocked as fry in 2018 (mean TL = 275 mm). Both cohorts grew to sizes comparable to or greater than age-1 saugeye in other populations. Leeds (1988) found age-1 saugeye in May were 325 mm TL in Thunderbird Reservoir, Oklahoma, slightly larger than saugeye in Arcadia Reservoir. However, age-1 saugeye from Arcadia Reservoir grew to larger sizes than those in Norris Reservoir, Tennessee (275–300 mm TL; Humphreys et al. 1984) and several Ohio reservoirs (202–280 mm TL; Johnson et al. 1988).

Growth and survival to fall can be variable for some saugeye populations (Stahl et al. 1996, Donovan et al. 1997). We found that saugeye size was comparable through fall but differed by the first spring. Further, we found daily mortality rates of age-0 saugeye stocked in 2018 as fry were lower than those of saugeye stocked in 2017 as fingerlings; however, fry likely experienced a higher mortality rate immediately post-stocking that could not be detected with our sampling design. During the time period that we sampled, CPUE was generally higher for saugeye stocked as fry in 2018 compared to those stocked as fingerlings in 2017. Stocking density may explain differences in catch rates between the two saugeye cohorts, as approximately four times more saugeye were stocked in 2018 than 2017. Boxrucker (1996) found a strong relationship between stocking density and catch rate of age-0 saugeye in fall. Density-dependent growth rates have been observed for saugeye and walleye in experimental ponds, with fish growing to larger sizes when reared at low density than high density (Qin et al. 1994). If these density-dependent growth effects translate into larger reservoir environments, this may explain the possible growth differences between the two saugeye year-classes in Arcadia Reservoir by their first spring. ODWC typically stocks fingerling saugeye into reservoirs to capitalize on rapid growth rates commonly observed in southern U.S. reservoirs (Leeds and Summers 1987, Humphreys et al. 1987, Boxrucker 1996). This study, however, suggested that fry survival can be higher than expected although stocking rates may have been too high to allow for rapid growth. Further research is needed to identify the appropriate stocking rates of saugeye fry that could achieve growth rates comparable to fingerling stocked saugeye.

Our results suggest that stocking either fry or fingerling saugeye can be successful depending on environmental conditions and forage availability associated with stocking. On the other hand, Pope et al. (1996) found that size at stocking influences saugeye stocking success in some cases, and studies also show that timing of a stocking event can affect saugeye stocking success (Boxrucker 1996, Stahl et al. 1996, Donovan et al. 1997). We found that gizzard shad were the most important prey item in saugeye diets in both years, but more so for the 2018 year-class stocked as fry. The difference in the proportion of gizzard shad in the diets between the two year-classes suggests that gizzard shad abundance may have been higher in 2018. Previous studies have found as prey abundances increase, the importance of that prey item increases in predator diets (Knight et al. 1984, Michaletz 1997a). However, changes in gizzard shad size structure can affect predator diet composition and growth rates (Hartman and Margraf 1992, Michaletz 1997b), which may have led to the eventual size differences we observed between the two cohorts of age-1 saugeye in Arcadia Reservoir.

We recognize that our evaluation had limited scope (one study lake following year-classes over two years); however, these results have important management implications. Our results suggest that fisheries managers should stock fingerlings if their goal is to quickly produce saugeye that contribute to recreational fisheries. Where hatchery demands require the stocking of fry, however, those stocking events may be most effective when timed with a strong cohort of gizzard shad which have been produced under these conditions: when fall proportional size distribution and relative weights of adults are high (Willis 1987), during springs with warm water temperatures or rising reservoir water levels (Michaletz 1997b), and following winterkills (Sammons et al. 1998). Prior to implementation of widespread fry stockings, fisheries managers should evaluate stocking rates in other systems to achieve optimal survival and growth of fish stocked at this stage. Further, the effects of prey abundance and size structure on saugeye growth are in need of further evaluation.

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