Early Life History Characteristics and Contribution of Stocked Juvenile Alligator Gar in Lake Texoma, Oklahoma

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Abstract: Due to concerns of overexploitation and population decline caused by anthropogenic influences, fisheries managers have turned to hatchery produced Alligator Gar (*Atractosteus spatula*) stocking to supplement inconsistent wild year classes. Aquaculture can be a useful option to reestablish or supplement natural populations, as many states currently have stocking programs to reintroduce this species. Recent interest in Alligator Gar ecology and conservation has led the Oklahoma Department of Wildlife Conservation to attempt to better understand early life history characteristics of age-0 Alligator Gar in Lake Texoma by tracking growth, diet, habitat use, mortality and stocking contribution. A total of 33,900 Alligator Gar fingerlings were stocked into Lake Texoma in 2017. During June-September 2017, a total of 46 age-0 Alligator Gar were captured in 279 net nights of effort using mini-fyke nets. Mean CPUE (catch-per-unit-effort; number per net night) was highly variable with CPUE varying based on vegetation stem density in the location of the net set. Of the 46 Alligator Gar captured in 2017, 84.5% (39 of 46) were stocked (OTC mark present). During the 4-month sampling period, the daily mortality estimate for stocked age-0 Alligator Gar was 0.049%/day. After the first four months (4.7% mortality rate), 32,306 of the initial 33,900 Alligator Gar remained in the system. The annual estimated mortality rate is 16.7%. The mortality estimate of fish stocked into Lake Texoma is substantially lower than the 94.8% mortality rate observed in the hatchery over three months (1,043 of 20,001 age-0 Alligator Gar remained). Stocking Alligator Gar as fingerlings when water level and habitat availability is sufficient may be more beneficial than holding them in a hatchery setting. Conversely, stocking Alligator Gar early may not be beneficial in a marginal year when nursery habitat is limited and inflow is not consistent enough to maintain a constant pool elevation. During these years it may be better to grow-out fingerlings to larger sizes, such that when stocked they are not easily preyed upon.

Introduction

The Alligator Gar (*Atractosteus spatula*) is one of four species of gar (Lepisosteidae) found in Oklahoma and is the largest fish found in the state (Miller and Robison 2004). Historically, Alligator Gar were found throughout the Arkansas River and Red River drainage systems (Page and Burr 1991, Miller and Robison 2004, Brinkman 2008). Anthropogenic influences such as dams, dredging, habitat change, unlimited recreational harvest and commercial fishing (Robinson and Buchanan 1988, Etnier and Starnes 1993, Ferrara 2001, Brinkman 2008, Inebnit 2009, Snow and Long 2015) have resulted in the disappearance of Alligator Gar from the Arkansas River system from Robert S. Kerr Dam up river in Oklahoma (ODWC unpublished data), but the Red River basin is still a stronghold for Alligator Gar in Oklahoma. The Red River basin is highly altered (by the Denison Dam and agricultural practices) yet still exhibits periodic flooding that is critical for spawning and providing nursery cover (Brinkman 2008, Snow and Long 2015, Buckmeier et al. 2017).

These flooding events are sporadic. However, Alligator Gar exhibit a periodic life history strategy having increased longevity (>50 years), delayed maturation (>10 years), high fecundity (>4000 eggs/kg body weight) and variable recruitment (Ferrarra 2001, Brinkman 2008, Buckmeier et al. 2012, Buckmeier et al. 2017). Previous research has focused on adult Alligator Gar, providing limited information on early life history characteristics of this species. The information available regarding young Alligator Gar details the difficulty in capturing age-0 fish. For example, Pigg and Gibbs (1996) described accidental capture of 21 age-0 Alligator Gar using a siene from a large shallow backwater area below Robert S. Kerr Dam. In 2007, juvenile Alligator Gar were successfully collected from Lake Texoma during April through November using mini-fyke nets during a flood year (Brinkman 2008). Snow and Long (2015) used mini fyke nets to collect 9 age-0 Alligator Gar from Lake Texoma in 2013 that were used to back calculate hatch date using their otoliths. In that year, hatch date was associated with an increase in pool elevation caused by high flows from the Red River.

Due to concerns of overexploitation and population decline, fisheries managers have begun using hatchery-produced fish to overcome the variable year class production by wild Alligator Gar (Porta et al. in-press). Aquaculture can be a useful option to re-establish or supplement natural populations, as many states currently have successful stocking programs for Alligator Gar (Todd 2005, Mendoza et al. 2008, Militello 2013, Richardson 2015). A recent study found that Alligator Gar stocked into marsh and wetland habitats in Monopoly Marsh (Mingo National Wildlife Refuge, Missouri) exhibited site fidelity. These Alligator Gar occupied small areas ranging from 4.8 to 12.9 ha (Solomon et al. 2013). Consequently, strong site fidelity of stocked Alligator Gar allows managers to more consistently collect stocked juveniles, giving insight to their early life history that typically cannot be obtained because of low abundance of wild fish.

The Oklahoma Department of Wildlife Conservation (ODWC) began stocking age-0 Alligator Gar into inundated vegetation at the Red River-Lake Texoma interface in 2017. The impetus for this stocking effort was to gain an understanding of early life history characteristics of juvenile Alligator Gar in Lake Texoma. Therefore, the objectives of this study were to 1) evaluate early life history characteristics (growth, mortality, habitat use) and contribution of stocked juvenile Alligator Gar and 2) compare mortality estimates and growth rates of Alligator Gar stocked in Lake Texoma to those allowed to grow in a hatchery setting.

Methods

Study Area - This study was conducted in the river-reservoir interface of the Red River arm of Lake Texoma, which is largely comprised of backwater habitat (Brinkman 2008). Sampling areas were generally < 1 m in depth with varying densities of aquatic or terrestrial vegetation. Lake Texoma is a 36,000-ha reservoir on the Oklahoma-Texas border. During normal flow, the Red River is constrained within a river channel, cut off from adjacent floodplains where terrestrial vegetation colonizes (Patton and Lyday 2008, Snow et al. 2016). When these areas are flooded, they are accessible to adult spawning Alligator Gar and the terrestrial vegetation is suitable spawning habitat for attachment of adhesive eggs and development of larval gar (Moore et al. 1973).

Marking and Stocking - Fingerling Alligator Gar (exogenous stage; actively feeding with yolk sac depleted) were obtained on May 23, 2017 from the Tishomingo National Fish Hatchery, Tishomingo, Oklahoma. Prior to stocking, fish were placed into hauling tanks containing 341 - 1,477.5 L of water in a concentration of 600 mg/L of Pennox 343 (Pharmgate, Omaha, Nebraska), of which each 1.32 g of powder contains 1 g of Oxytetracycline (OTC) HCl. Sodium phosphate dibasic was added at a rate of 62 mg/L per 100 mg/l of OTC to neutralize the pH. Alligator Gar were exposed to the OTC treatment for 4-6 hrs prior to stocking (Snow and Long 2017). OTC is incorporated into skeletal structures, which can be seen using ultraviolet light (Figure 1). In this study, otoliths were used to determine if Alligator Gar were stocked or wild.

After marking, Alligator Gar were transferred to a holding tank located on a boat for stocking into Lake Texoma. Water from Lake Texoma was slowly pumped into the holding tank to acclimate fish to in-lake water conditions. Once acclimated, fish were stocked by boat into nursery habitat consisting of flooded terrestrial and aquatic vegetation. All fish were stocked in the river-reservoir interface of the Red River in Lake Texoma.

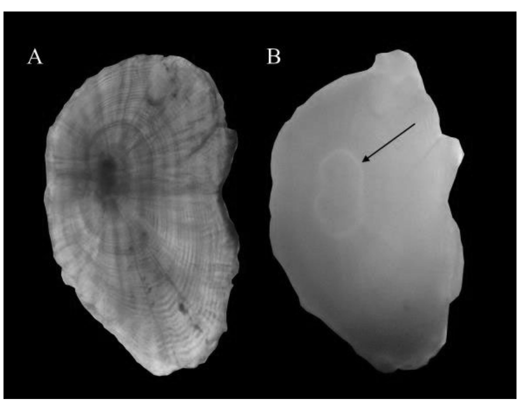

Figure 1. Photograph of a lapillus otolith (A) without fluorescence, and (B) with fluorescence, illuminating the OTC mark on lapillus otolith of a 67 mm stocked Alligator Gar captured using mini-fyke net on June 22, 2017 in Lake Texoma, Oklahoma. The OTC mark is identified with a black arrow.

Sampling – Sampling began two weeks after the last stocking event. Mini-fyke nets (0.6 m x 6.35 m; with 3.18 mm mesh, 9.14 m lead, 0.6 m x 1.92 m rectangular cab, and 510 mm metal throat; Snow et al 2016) were set in the Red River-Lake Texoma reservoir interface during June – September 2017. Sample sites were selected monthly by placing a 100- m grid over the map of all backwaters and shallow-water coves in the river-reservoir interface and individually numbered grids were randomly selected as fyke net sampling locations (Snow et al. 2016). Upon arriving at each sampling location, net leads were anchored with a T-Post, pulled tight, and anchored on the cod end. Nets were set perpendicular to the shoreline in water < 0.6 m in depth. Nets were allowed to fish for 24 hours. All Alligator Gar captured were preserved on ice until frozen and brought back to the Oklahoma Fisheries Research Laboratory where they were measured (mm total length (TL), weighed (nearest g), and otoliths were removed for aging and OTC mark detection purposes.

At the time of net deployment, depth measurements (cm) were taken at the opening of the fyke net and 3 replicate vegetation stem counts were taken in the area of the set net. This was done by haphazardly tossing a 0.32 m² hoop into the area around the lead of the net and stem density within the diameter of the hoop was counted for each of the three tosses (MacKenzie and Kaster 2004, MacKenzie 2005, Aikens and Roach 2014). To expedite stem density enumeration, a rating system was developed from average stem counts taken from 115 net sites during previous sampling efforts to estimate stem densities (Table 1). The rating system was tested by randomly selecting 5 sites out of 17 net sites (total net set in a day; totaling 44 sites)

Table 1. Criteria used to rate habitat sampled with mini-fyke nets for age-0 Alligator Gar from June through September of 2017 in Lake Texoma, Oklahoma. (SE = standard error).

Rating	Mean Stem Count (SE)	Stem Density m²	Description
0	1.00 (0.68)	3.13	Vegetation very sparse
1	5.47 (1.33)	17.09	Vegetation patchy (but mainly open water)
2	13.93 (2.87)	43.53	Vegetation patchy (with moderate open water)
3	43.33 (4.87)	135.41	Even distribution of vegetation
4	87.35 (6.29)	272.97	Mostly even with small areas of dense vegetation
5	191.11 (28.67)	597.22	Vegetation very dense

that had already been enumerated, assigning a rating to each site, and ensuring that the ratings assigned to a particular site were within the range of stem densities in Table 1.

Otolith processing – Otoliths were allowed to dry for >24 hr prior to processing. Following drying, lapilli otoliths were embedded and sectioned near the otolith center in a frontal plane and mounted to slides for processing and viewing (Long and Snow 2016). Prior to viewing, otoliths were polished with 2000 grit wetted sandpaper to reveal the core. Otoliths were viewed for the presence of an OTC mark using an Olympus BH2 RFCA compound microscope equipped with a 100-W mercury lamp for fluorescence detection with a B3 filter cube. A single reader examined each otolith, independently three times to evaluate whether an OTC mark was present (Snow and Long 2017).

Analysis – Alligator Gar with an OTC mark present on the otolith were considered to be a stocked fish. Year class contribution was defined as the proportion of stocked to wild fish. Linear regression analysis was used to determine relationships for hatchery raised (held and grown at Tishomingo National Fish Hatchery) and stocked (growth in Lake Texoma post-stocking) Alligator Gar throughout the sampling season (TL at age [days]). Data pertaining to hatchery raised Alligator Gar was provided by Tishomingo National Fish Hatchery for comparison purposes. Catch-curve regression was used to assess daily mortality of stocked Alligator Gar over 4 months (June – September) using $\log_e$ transformed frequency of capture for each sampling day in 2017 (Miranda and Bettoli 2007). An analysis of variance (ANOVA) was used to determine difference in CPUE between the various habitat ratings at each net site. All data were $\log_e$+0.01 transformed to conform to the assumptions of normality and tests were performed at a significance level of $P \leq 0.05$. If significant, ANOVA results were conducted with a Tukey's HSD test.

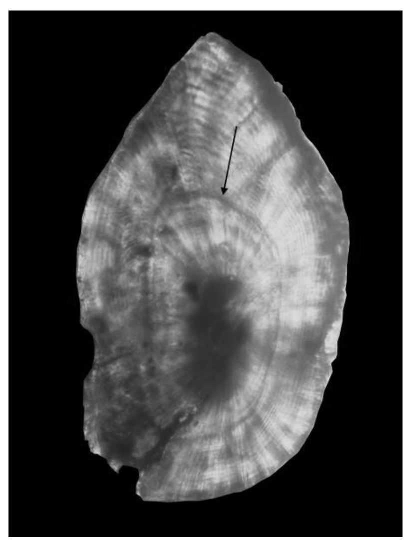

Figure 2. Photograph of a lapillus otolith from a 63 mm stocked Alligator Gar captured using mini fyke nets on June 23, 2017 with the presence of a stocking check. Stocking checks were observed in 28.2% of Alligator Gar sampled. The stocking check is identified with a black arrow.

Results

A total of 33,900 Alligator Gar fingerlings were stocked into Lake Texoma in 2017. Age-0 Alligator Gar were 46 mm mean TL at stocking. During June-September 2017, 46 age-0 Alligator Gar were captured in 279 net nights of effort. The mean catch-per-unit-effort (CPUE) was 0.17/net night with June having the highest CPUE (0.36 fish/net night) and September having the lowest CPUE (0.05 fish/ net night). Of the 46 Alligator Gar captured, 84.5% (39 of 46) were stocked (OTC mark present; Figure 1). Stocking checks were observed in 28.2% of stocked fish (Figure 2). The remaining 7 fish were wild fish (no OTC mark present).

Both terrestrial and aquatic vegetation stem density were enumerated from three separate samples taken at 115 net sites. Stem density ranged from 3 – 597 m². A subjective rating system was employed to reduce the time needed to enumerate vegetation density at each site. The rating system was on a 0-5 scale, with 0 having very sparse vegetation and 5 having very dense vegetation (Table 1). Forty-four sites were evaluated to ensure habitat categories were correctly assigned to areas of vegetation previously measured using the hoop method.

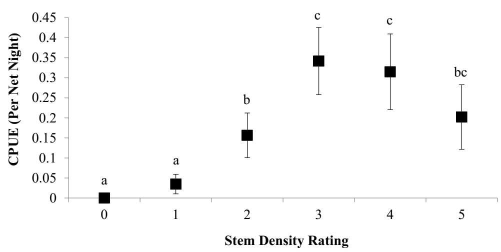

Figure 3. Post-hoc test results comparing mean CPUE among stem density ratings (0 = Vegetation very sparse, 1 = Vegetation patchy (but mainly open water), 2 = Vegetation patchy (with moderate open water), 3 = Even distribution of vegetation, 4 = Mostly even with small areas of dense vegetation, 5 = Vegetation very dense) sampled with mini-fyke nets during June-September in 2017 in Lake Texoma, Oklahoma. Different letters indicate significant differences of the post-hoc test.

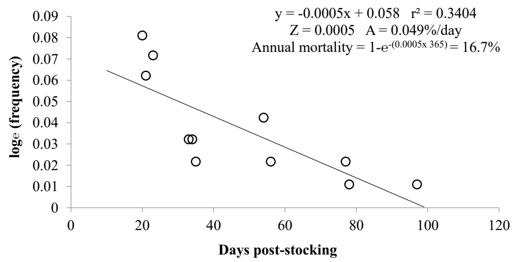

Figure 4. Catch curve regression and annual mortality (A) calculated from the 39 age-0 OTC marked Alligator Gar collected using mini-fyke nets from Lake Texoma, Oklahoma during June – September 2017.

Correct habitat density rating occurred for 88.6% of sites. The ability to rate categories 4 (mostly even with small areas of dense vegetation) and 5 (Vegetation very dense) proved difficult, as 5 (three category 4 and two category 5) sites were incorrectly rated. We found that stem density influences mean CPUE using mini-fyke nets (F_{279} = 3.65, P < 0.01; all Tukey's HSD comparisons P < 0.01; Figure 3). Catch rates were also lowest at sites with habitat ratings of 0. As the habitat rating increased, so did the mean CPUE until the stem density reached >135.41/m² when catch rates declined.

During the 4 month sampling period, the daily mortality estimate for stocked age-0 Alligator Gar was 0.049%/day (Figure 4). After the first four months (4.7% mortality rate), an estimated 32,307 of the initial 33,900 Alligator Gar remained in the system. The annual estimated mortality rate is 16.7%. The estimated mortality rates of Alligator Gar stocked into Lake Texoma are substantially lower than the mortality rate observed in the hatchery over three months 94.2%; 1,043 of 20,001 age-0 Alligator Gar remained). However, age-0 Alligator Gar grew 4.09 mm/day (r^2 = 0.98, P < 0.01) in the hatchery setting over three months. Age-0 Alligator Gar captured in summer of 2017 from Lake Texoma grew slower at 1.77 mm/day (r^2 = 0.66, P < 0.01; Figure 5).

Discussion

Contribution of hatchery produced Alligator Gar was high (84.5%) in this study. During

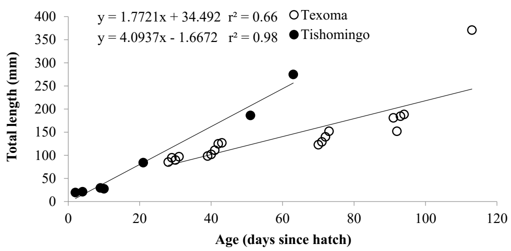

Figure 5. Relationship between total length and age of stocked age-0 Alligator Gar (open circle = ○) captured from Lake Texoma, Oklahoma in June – September of 2017 and hatchery raised age-0 Alligator Gar (filled circle = ●) from the Tishomingo National Fish Hatchery. Solid line is fit from linear regression.

spring and summer 2017, the pool elevation stayed high enough to maintain inundated vegetation in the river-reservoir interface of Lake Texoma. These conditions resulted in high survival and contribution of stocked juveniles, and also led to successful spawning of wild Alligator Gar that produced a low abundance of wild age-0 fish. Snow and Long (2015) found that drought kept water levels low in Lake Texoma until spring 2013, allowing herbaceous vegetation to establish exposed shorelines. This was followed by heavy rains that increased pool elevation, inundating these areas, which created spawning and nursery habitat for Alligator Gar. Habitat availability (for spawning and nursery cover) is probably the most critical variable affecting the early life history of wild Alligator Gar. Alligator Gar spawn in inundated vegetation (Brinkman 2008, Inebnit 2009, Snow and Long 2015, Buckmeier et al. 2017), which then serves as critical nursery habitat for young gar. Therefore, stocking fingerling Alligator Gar will likely produce the best results when water level and available habitat is sufficient, similar to conditions observed in Lake Texoma in 2017. Buckmeier et al. (2017) suggested that vegetation needs to be inundated for a period ≥ 5 days, which is enough time for eggs to hatch and fry to respond to receding waters. Furthermore, recruitment increased as days of inundation increased (Buckmeier et al. 2017). However, stocking fingerlings early may not be beneficial in years when nursery habitat is limited by low water levels. During years when these conditions are present, it would be better to grow-out fingerlings to larger sizes in a hatchery setting, such that when stocked they are not easily preyed upon.

Alligator Gar growth rates are fast in hatchery settings due to cannibalism, a high protein pellet diet, and little effort needed to forage in confined environments. Hatcheries provide optimal growing conditions in which fish get larger in a short period of time. However, rates of cannibalism are high in aquaculture facilities that raise Alligator Gar and cannibalism is one of the leading causes of mortality during production (Mendoza et al. 2002, Mendoza et al. 2008, Perschbacher 2011). Additionally, Alligator Gar can be impacted by infection in hatcheries because they are held in confined spaces, and this contributed to high mortality rates in this study (bacterial infection). Differences in mortality between the hatchery environment and post-stocking in Lake Texoma were substantially different. Habitat availability in 2017 likely resulted in the low observed mortality rates of juvenile Alligator Gar stocked into Lake Texoma. However, the higher mortality of juvenile Alligator Gar in a hatchery setting is acceptable, particularly in years when reservoir hydrology prevents the stocking of fingerling Alligator Gar.

The ability to sample juvenile Alligator Gar using mini-fyke nets may have affected mortality and growth rate estimation for juvenile Alligator Gar stocked into Lake Texoma. Based on catch rates, it appears that we can only effectively sample smaller, slower growing age-0 Alligator Gar that rely on the nursery cover sampled in this study. We speculate that age-0 Alligator Gar may move from nursery cover to open water flats or main lake coves when they reach a certain size, suggesting that mini-fyke nets are not effective for capturing larger juvenile Alligator Gar. It appears that mini-fyke nets are most effective at catching age-0 gar only when water levels inundate aquatic and terrestrial vegetation to maintain gar habitat. Brinkman (2008) captured juvenile Alligator Gar successfully using mini-fyke nets in Lake Texoma during a flood year that allowed habitat to be accessed the entire growing season (April through November). As water level decreases mini-fyke nets become ineffective gear for sampling age-0 Alligator Gar. It appears that in years when water level decreases following a spawn, age-0 Alligator Gar movement increases, resulting in the need for future research to understand this movement and how it affects diet, growth, and survival. Future research should concentrate on understanding movement of juvenile Alligator Gar (ages 0 – 2). This information may provide important insight into sampling this size class of fish and may strengthen our knowledge of the early life history of this species.

A multiple gear approach may be necessary to sample juvenile Alligator Gar effectively. However, before that can be determined, a movement study needs to be conducted to evaluate habitats that various size classes of fish utilize. This will allow for refinement of a sampling approach. Alligator Gar < 100 mm do not recruit to mini-fyke nets (Snow et al. 2016). However, mini-fyke nets are effective for sampling Alligator Gar up to 630 mm if habitat stays consistent (Brinkman 2008). An active gear may be better at capturing gar <100 mm because their body movement is limited because of their reliance on the notochord appendage (Carpenter 1975). Effective sampling of individuals >100 mm may depend on lake elevation and available habitat. The high density of vegetation may not have allowed the nets to deploy correctly or Alligator Gar may not prefer habitat that dense, ultimately affecting catch rates. However, it is possible that a stem density >135.41/m² provide age-0 Alligator Gar with ideal ambush cover and movement is not needed to forage, thereby reducing capture with mini-fyke nets.

In this study, hatchery produced Alligator Gar were effectively used to evaluate early life history characteristics in Lake Texoma. We assumed that hatchery produced Alligator Gar would be easier to recapture post-stocking, similar to results of Solomon et al. (2013). However, habitat differences make Lake Texoma entirely different than those sampled by Solomon et al. (2013). In a typical year, habitat availability is low in Lake Texoma due to low summer water levels that limit habitat availability, whereas habitat was always available in the marsh system evaluated by Solomon et al. (2013). Alligator Gar in Lake Texoma did not appear to maintain small home ranges in 2017 (4.8-12.9 ha; Solomon et al. 2013), which may have led to the decreasing catch rates over time. Despite some difficulties in capturing juvenile Alligator Gar in Lake Texoma, important early life history information was collected for Alligator Gar in this system. The use of hatchery produced Alligator Gar provides a practical approach to evaluate early life history of this species in situations where they would otherwise be too rare to study. This approach will benefit other resource agencies that are evaluating stocking programs and early life history of Alligator Gar introduced into their jurisdictional waters. Although we are confident in our findings, these results should be interpreted with caution as they represent a single-year evaluation. Future evaluations should be conducted over an extended time period (8-10 years) to ensure that weather patterns (and resulting reservoir hydrology) affecting early life history traits of Alligator Gar are encompassed during the study period. A long-term evaluation will allow development of trend data, which will help better understand early life ecology of Alligator Gar.

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