Estimating Spawning Times of Alligator Gar (*Atractosteus spatula*) in Lake Texoma, Oklahoma

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Abstract: In 2013, juvenile Alligator Gar were sampled in the reservoir-river interface of the Red River arm of Lake Texoma. The Red River, which flows 860 km along Oklahoma's border with Texas, is the primary in-flow source of Lake Texoma, and is impounded by Denison Dam. Mini-fyke nets were deployed using an adaptive random cluster sampling design, which has been used to effectively sample rare species. Lapilli otoliths (one of the three pair of ear stones found within the inner ear of fish) were removed from juvenile Alligator Gar collected in July of 2013. Daily ages were estimated by counting the number of rings present, and spawn dates were back-calculated from date of capture and subtracting 8 days (3 days from spawn to hatch and 5 days from hatch to swim-up when the first ring forms). Alligator Gar daily age estimation ranged from 50 to 63 days old since swim-up. Spawn dates corresponded to rising pool elevations of Lake Texoma and water pulses of tributaries.

Introduction

The Alligator Gar (*Atractosteus spatula)* is the largest freshwater fish species in Oklahoma and the third largest in North America (Page and Burr 1991). Alligator Gar inhabit sluggish back water areas in large rivers from Mexico to Florida (Miller and Robison 2004) and populations are declining thru much of their range (Robinson and Buchanan 1988, Etnier and Starnes 1993, Ferrara 2001). Alligator Gar is considered vulnerable in several states and has been extirpated from Ohio and Illinois (NatureServe 2012). Only Texas and Louisiana populations are considered stable (NatureServe 2012). Until recently, this species has received little attention from fisheries biologists who are just now beginning to understand their life history and develop management plans for conservation.

In its native range, Alligator Gar spawns from early April through the middle of June in conjunction with seasonal flooding events (Etnier and Starnes 1993, Ferrara 2001, Inebnit 2009). In Oklahoma, Alligator Gar are thought to spawn in early May (Miller and Robison 2004). Documented reports of Alligator Gar spawning are limited, but Oklahoma Department of Wildlife Conservation (ODWC) personnel videotaped a spawning event in Lake Texoma on 11 May, 2007. Spawning habitat is thought to consist mainly of flooded backwater areas and floodplains (Brinkman 2008, Inebnit 2009). On 16 June 1993, 21 age-0 Alligator Gar were collected from a large, shallow floodwater area below Robert S. Kerr Lock and Dam, and was thought to be the first evidence of reproduction of this species in Oklahoma since the early 1980s (Pigg and Gibbs 1996).

Because spawning seems to be related to seasonal flooding, spawning and recruitment may be inconsistent, accounting for the paucity of young Alligator Gar reported in the literature (May and Echelle 1968, Brinkman 2008).

In 2007 and 2008, multiple year classes of juvenile Alligator Gar were successfully collected from Lake Texoma during April through November using mini-fyke nets in back water areas and coves with woody vegetation and debris (Brinkman 2008). Intensive sampling in these habitats with mini-fyke nets may yield capture of significant numbers of juvenile Alligator Gar to provide insights into the role of spawning and early life history to recruitment. The ability to capture young-of-year gar would enable one to remove otoliths and estimate age (in days), calculate growth, and estimate spawning date. With this information, one can then look at environmental conditions and factors that may influence spawning.

Methods

Sampling site.— Alligator Gar were sampled in the river-reservoir interface section of the Red River arm of Lake Texoma (Figure 1). The Red River flows 860 km along Oklahoma's border with Texas and is impounded by Denison Dam forming Lake Texoma. The Red River is a typical braided prairie river composed of sand and silt substrate with woody debris deposited from flooding events and occasional rock outcroppings. During high water events, the Red River reconnects to adjacent flood plains and cut-off oxbow lakes where Alligator Gar spawn.

In the summer of 2013 mini-fyke nets with two different lead lengths ("short lead " 0.6 m x 6.35 m; with 3.18 mm mesh, 4.57 m lead, 0.6 m x 1.92 m rectangular cod, and "long lead" 510 mm metal throat and 0.6 m x 6.35 m; with 3.18 mm mesh, 9.14 m lead, 0.6 m x 1.92 m rectangular cod, and 510 mm metal throat) were used to sample age-0 Alligator Gar. Nets were set randomly in backwater areas and coves where herbaceous vegetation and woody debris are abundant (Brinkman 2008). Nets were deployed using an adaptive random cluster sampling design (Tompson 1990). A 100-m gridded map of all backwaters and shallow-water coves in the river-reservoir interface was used to randomly select initial sample sites. When a juvenile Alligator Gar was collected, additional neighboring grid sites were subsequently sampled until no additional Alligator Gar were collected. All age-0 Alligator Gar collected were measured to the nearest mm, weighed to the nearest gm and the lapilli otoliths were removed for daily age estimation because they provided the most precise and accurate estimates of age compared to the other otolith pairs (Snow 2014).

Otoliths are calcium carbonate accretions associated with the inner ear of teleost fishes and are used for orientation and hearing (Mathiesen and Popper 1987). There are three pair of otoliths (lapillus, sagitta, and asteriscus) (Popper and Lu 2000) and they grow in relation to fish metabolism creating a permanent record of growth throughout the life of the fish. The ability to use otoliths as a technique to estimate fish age gives fisheries managers insight into population dynamics.

Otoliths were removed as described by Snow (2014), positioning the specimen dorsal side down under a dissecting scope and removing the head by making an cut just in front the pectoral girdle. Dissection pins were used to secure the head, allowing the lower jaw and gill structures were removed with forceps while the ventral side of the braincase was exposed. The parasphenoid was then detached to expose the inner ear structures, located just under the large bulbous portion of the parasphenoid. After removing the parasphenoid, brain matter was then removed from around the utricle structures to remove the lapilli otoliths.

Otoliths were cleaned and stored dry, then browned at 104°C on a hot plate to increase contrast between accretion and discontinuous zones (Secor et al.1992, Snow 2014). After browning, otoliths were embedded in Loctite 349 (Mauck and Boxrucker 2004, Snow 2014) for sectioning with a low speed IsoMet® saw (127 mm x 0.4 mm). Lapilli were sectioned in a transverse plane, mounted to glass microscope

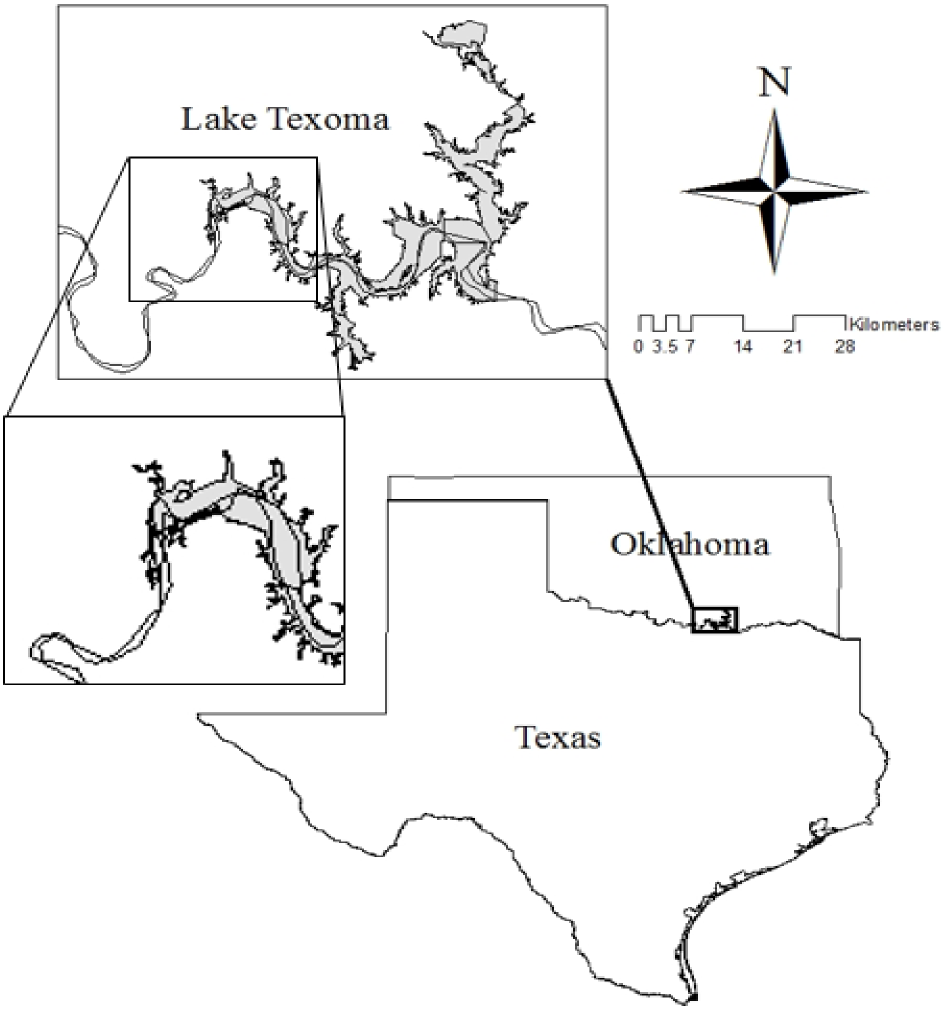

Figure 1. Location of Lake Texoma in south central Oklahoma where age-0 Alligator Gar were sampled.

slides (3" x 1" x 1mm) with thermoplastic cement, and polished wet with 600-grit sandpaper. Immersion oil was applied to the otolith to enhance visibility of daily rings. Daily rings were counted independently by two readers (Hoff et al. 1997) using a high resolution monitor connected to an optic-mount digital camera attached to an Olympus BH-2 microscope. Back calculating to date of spawn was done by adding 8 days to the age estimated (3 days for hatching, 5 days to swim-up) and subtracting from capture date (Mendoza et al. 2002).

Linear regression analysis was used to determine relationships for Alligator Gar: 1) daily age and total length, 2) daily age and weight, and 3) total length and weight. Length and weight were log10 transformed to correct for non-linearity. Pool elevation data for Lake Texoma at Denison Dam (U.S. Army Corps of Engineers) and river discharge for the Red River upstream of Lake Texoma (U.S. Geological Survey gage #07316000) were compared with back-calculated spawning dates for Alligator Gar.

Results

Nine age-0 Alligator Gar (102 to 176 mm

TL) were collected during June and July of 2013 and were estimated to be between 50–63 days old since swim-up. Spawn dates were estimated to have occurred between May 18 to June 1, 2013. Lake Texoma pool elevation rose steadily during the estimated time of spawning, from 187 m on May 15 to 188 m on June 10, 2013 (Figure 2). Flow data from upstream in the Red River recorded two pulse events coincident with the estimated time of spawning (Figure 3).

Based on the slope of the regression equation relating size to age, Alligator Gar captured in summer of 2013 grew an average of 5.49 mm (r^2 = 0.85, P < 0.01; Figure 4) and 1.15g (r^2 = 0.82, P < 0.01; Figure 5) per day. The

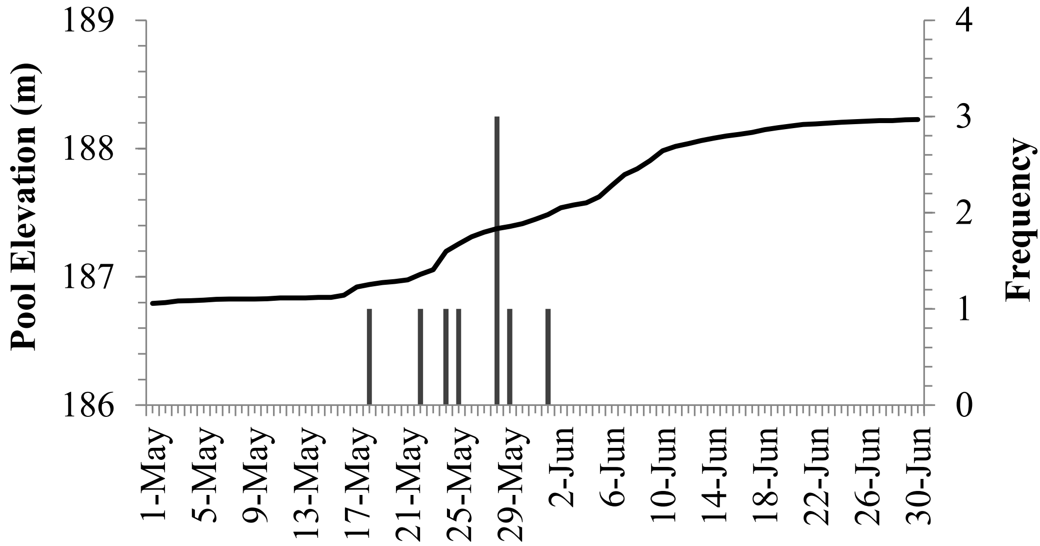

Figure 2. Frequency of back-calculated spawn dates in 2013 estimated from daily rings in lapilli otoliths of Alligator Gar in relation to pool elevation of Lake Texoma at Denison Dam, Oklahoma.

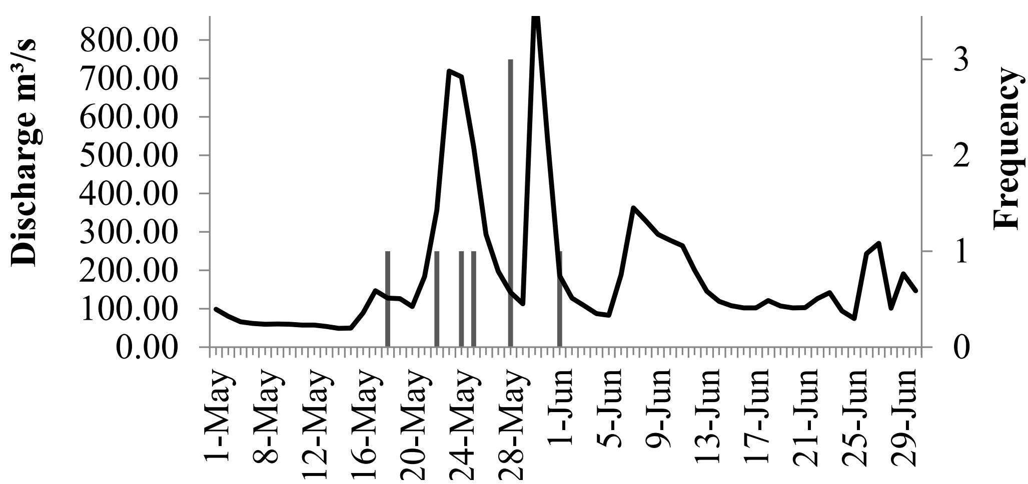

Figure 3. Frequency of back-calculated spawn dates in 2013 estimated from daily rings in lapilli otoliths of Alligator Gar in relation to discharge (USGS gage #07316000) of the Red River into Lake Texoma, Oklahoma.

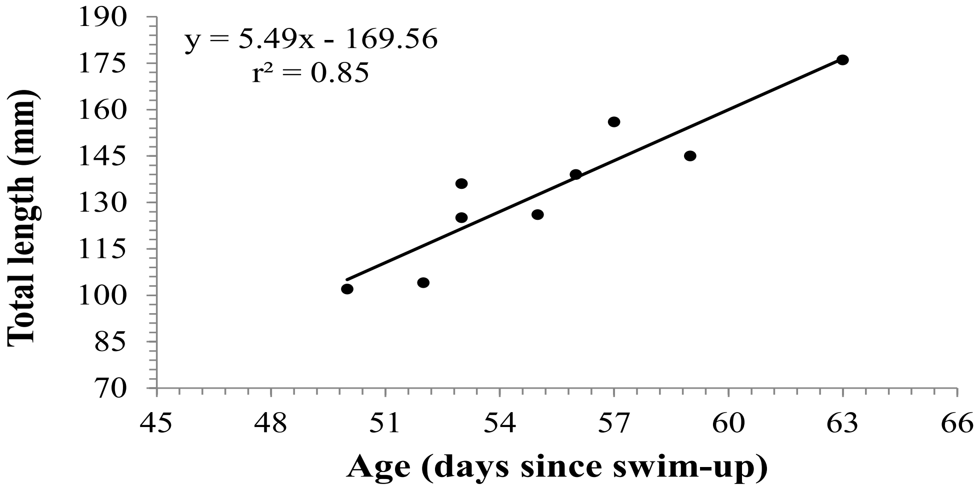

Figure 4. Relationship between total length and age of age-0 Alligator Gar captured from Lake Texoma, Oklahoma in July of 2013. Solid line is fit from linear regression.

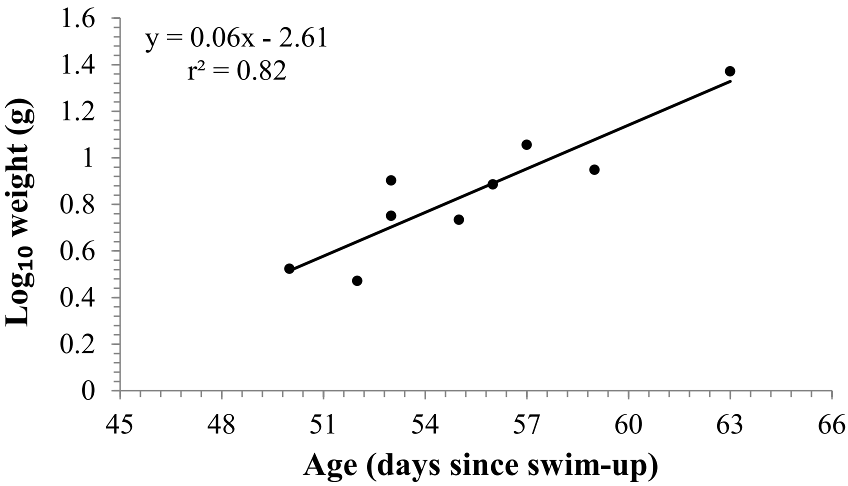

Figure 5. Relationship between $\log_{10}$ weight and age for age-0 Alligator Gar captured from Lake Texoma, Oklahoma in July of 2013. Solid line is fit from linear regression.

length-weight regression indicated a cubed relationship ($\log_{10}$ weight (g) = 3.50 ($\log_{10}$ TL (mm) – 6.58; $r^2 = 0.96$, $P < 0.01$; Figure 6).

Discussion

Collection of age-0 Alligator Gar proved difficult, with only 9 individuals captured out of 70 nights of netting. Developing a better sampling strategy would be beneficial. Anecdotally, we did catch more juvenile Alligator Gar in long-lead nets (*N*= 5) compared to short-lead nets (*N*= 2) and two others were captured haphazardly, but we did not test for statistical differences. Additional studies on the utility of long-lead nets could prove beneficial. Longer leads allow for increased sampling range while still allowing the cod end to remain in shallow water where juvenile Alligator Gar occur.

The back-calculated spawn dates for wild-caught Alligator Gar corresponded to an increase in pool elevation and two pulses of water from the Red River, which has been generally

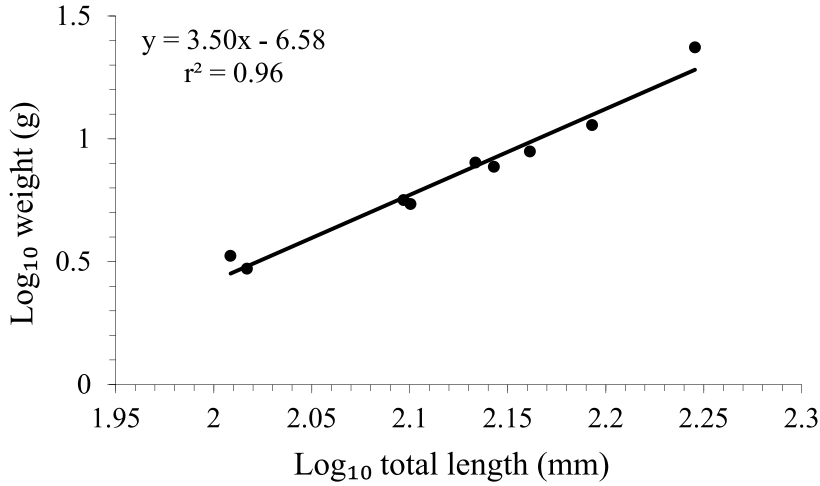

Figure 6. Relationship between $\log_{10}$ weight and $\log_{10}$ length for age-0 Alligator Gar captured from Lake Texoma, Oklahoma in July of 2013. Solid line is fit from linear regression.

accepted as their mode of reproduction. However, few observations of Alligator Gar spawning behavior and collections of age-0 fish exist in Lake Texoma, providing limited location-specific insight into reproduction of this species (May and Echelle 1968; Echelle and Riggs 1972; Brinkman 2008; Inebnit 2009). But, because Alligator Gar deposit eggs on vegetation, where they adhere and juvenile gar develop over a period of days (Aguilera et al. 2002; Balfour and Parker 1882), water level history in Lake Texoma provides some insight. Lake Texoma water storage in general has been reduced through sedimentation (Patton and Lyday 2008) and persistent drought since 2011 kept water levels low in Lake Texoma until early 2013, allowing herbaceous vegetation to establish in back-water areas. Subsequent inundation of these areas created attachment substrate for Alligator Gar eggs and larvae. The cycle of drying, encroachment of terrestrial vegetation, and subsequent flooding should be examined in future research related to spawning and recruitment of Alligator Gar in reservoirs.

Fish spawning activity may be limited in some ageing reservoirs due to sedimentation or poor quality of availability sites (Summerfelt, 1993); this is particularly important to nest building species. However, siltation and fragmentation caused by sedimentation in an ageing reservoir create habitats in the river-reservoir interface that function as a floodplain (Buckmeier et al. 2014; Patton and Lyday 2008) as an alternative for spawning habitat that was lost due to origninal impoundment (Buckmeier et al. 2014). For some native species, such as Alligator Gar, this habitat is critical for completing their life cycle (Graebs et al. 2009). The ageing of reservoirs may actually benefit Alligator Gar because the floodplains that were originally lost through impoundment of the watershed may now be coming back through a prolonged process of sedimentation. However, future research on the potential influence of these artificial habitats on spawning success of Alligator Gar in in the river-reservoir interface would be required to test this hypothesis.

Understanding that Alligator Gar spawning coincides with rises in reservoir pool elevation and pulses of water from inflowing rivers can be used for management purposes. Because Alligator Gar spawning is linked to seasonal flooding of riparian vegetation, successful recruitment may be infrequent. Alligator Gar has the potential to overcome year-class failures because of late maturity, high fecundity, and long life span (Ferrara 2001; Buckmeier 2008; Inebnit 2009). Reservoir water levels could, in theory, be manipulated to allow re-vegetation of backwaters. Subsequent flooding during the

Alligator Gar spawning season might enhance recruitment. Water levels would need to be maintained for at least 8 days after spawning to allow Alligator Gar to reach the lecithoextrophic stage (i.e., swim-up) when larvae are no longer attached to vegetation (Inebnit 2009). How this strategy would fit with management of other species (e.g., Largemouth Bass [*Micropterus salmoides*] or Striped Bass [*Morone saxatilis*]) is unknown, but it appears that this level of management could be one aspect to consider within the fisheries management plans developed for impoundments such as Lake Texoma.

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