Relative Abundance and Biomass Estimate of a Spotted Gar Population in a Seasonally Connected Large River Floodplain Lake

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Abstract: In order to assess the change in spotted gar (*Lepisosteus oculatus*) density relative to water level in a disconnected low-water refuge, we used monofilament gill nets to collect adult gar throughout the annual flood pulse in the Atchafalaya River Basin (ARB), Louisiana. Spotted gar density was greatest during low-water periods and there was a strong negative correlation between spotted gar catch per unit effort and the Atchafalaya River water level at Butte La Rose ($P = 0.0002$, $R^2 = 0.5763$). The spotted gar population in Deer Lake, a disconnected backwater area, was estimated to be 2,079 individuals (95% CL = $849 < N < 5{,}198$) during a low-water period. Adult spotted gar biomass in Deer Lake at bank-full level was one of the highest recorded levels (267 kg ha^{-1}; $P\,[109 \leq 267 \leq 668] = 0.95$) in a large river floodplain. Fall 2005 water levels in the ARB were among the lowest on record. During abnormally low-water years in disconnected habitats, high densities of top predators such as spotted gar may alter trophic food webs in backwater areas of large river floodplains. Mean water stage for the Atchafalaya River has decreased over the last few decades ($P = 0.0002$, $R^2 = 0.2615$) due to down cutting of the channel, thus the size of the fish population carried over to the following year is partly dependent on the amount of water remaining during the low-water period. If water levels drop to extreme levels as in 2005, piscivory will likely reduce community abundance for the following year, and several consecutive years of extremely low flood pulses could significantly reduce fish population abundance in the ARB.

Key words: spotted gar, *Lepisosteus oculatus*, Atchafalaya Basin, backwater lake, biomass

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The predictable seasonal inundation of large river floodplains provides a mechanism of energy and nutrient transfer between the aquatic and terrestrial zones which supports high levels of fisheries production. Inundation of the floodplain provides access to feeding and spawning areas for many large-river floodplain fishes (Guillory 1979, Ross and Baker 1983, Walker and Sniffen 1985, Kwak 1988, Lambou 1990, Slipke et al. 2005), and high levels of primary production during low-water periods can provide quality habitats for growth and survival of young-of-the-year fishes (Fontenot et al. 2001). During the low-water period, fish may be isolated in floodplain water bodies that are disconnected from the mainstem river, and depending on the length of isolation and local precipitation patterns, isolated water bodies may completely dry out.

The Atchafalaya River Basin (ARB) in southcentral Louisiana, is the largest bottomland hardwood forest in North America, covering approximately 5,000 km^2 (Lambou 1990). The Atchafalaya River is a major distributary of the Mississippi River and receives 30% of the combined volume of the Mississippi and Red Rivers. Although flood magnitude varies from year to year, water levels typically peak in spring and are lowest in early fall (Denes and Bayley 1983, Lambou 1990, Fontenot et al. 2001). When spring floodwaters recede, backwater areas become contained within their banks and the majority of the floodplain is dry. As water levels recede throughout the low-water period, fish trapped in backwater areas that are disconnected from the main stem river may reach high densities.

Sedimentation rates in the ARB are among the highest in forested wetlands in the United States (Hupp et al. 2008). Since the 1950s, many lakes and swamps in the ARB have filled with sediment (Tye and Coleman 1989, McManus 2002). The size and water holding capacity of low lying areas on the ARB floodplain have decreased over time due to sedimentation and some low lying areas dry between high-water periods. Low-water levels during the summer can lead to hypoxic conditions (dissolved oxygen [DO] ≤ 2 mg L^{-1}) in the ARB (Kangur et al. 2005). Furthermore, densities of fishes confined in small shallow areas increase as the

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wetted area decreases and may result in increased predation rates (Welcomme and Halls 2001).

Spotted gar (*Lepisosteus oculatus*) are an abundant large piscivore in the ARB (Lambou 1990, Rutherford et al. 2001), and move from inundated backwater areas onto the inundated floodplain during high-water periods (Snedden et al. 1999). Because spotted gar can respire atmospheric oxygen, they are physiologically well adapted for survival in backwater areas of large river floodplains that may become hypoxic. Furthermore, because of their predatory potential (Goodyear 1967, Scott 1968, Tyler and Granger 1984, Ostrand et al. 2004), spotted gar and other piscivorous fishes can take advantage of high prey densities found in disconnected backwaters during low-water periods, making them important elements in the floodplain trophic food web. Due to their abundance, tolerance of poor water quality, and vulnerability to collection gear, spotted gar are a good candidate species with which to model fish density responses to changing water levels in disconnected backwater areas of large river floodplains. The purpose of this study was to quantify the change in spotted gar density relative to water level in a low-water refuge in the ARB through an annual flood pulse and to estimate the biomass of adult spotted gar in a disconnected backwater area.

Methods

The project study site was Deer Lake (3019N, 9132W), a small lake in the ARB surrounded by bald-cypress (*Taxodium distichum*), tupelo gum (*Nyssa aquatica*), black willow (*Salix nigra*), and button bush (*Cephalanthus occidentalis*). Water level and surface area in Deer Lake varies throughout the flood pulse, but during low water the lake covers approximately 6.6 ha at bank-full level. Water in Deer Lake becomes disconnected from the Atchafalaya River during low-water periods and is connected to the Atchafalaya River and its adjacent floodplain during the flood pulse.

Daily Atchafalaya River water level values between 1959 and 2006 were obtained from the U. S. Army Corps of Engineers recording gauge (#03120) located at Butte La Rose, Louisiana (301657N, 914117W). Daily values for each year from 1959 to 2005 were used to determine the mean water level for each month of each year. Mean water level for each year was also calculated.

Deer Lake bank-full level was determined during the high-water period on 2 February 2005. Ten measurements of water depth on the adjacent floodplain approximately 20 m from the bank tree line were made parallel to the east and west banks of Deer Lake. Average depth (2.12 ± 0.01 m) was subtracted from the reading at the Butte La Rose gauge for that day (5.76 m) to determine Atchafalaya River water level when Deer Lake is at bank-full level.

Relative Density and Physicochemistry

Spotted gar were sampled biweekly between 11 November 2004 –22 July 2005 and between 26 January–18 February 2006, with monofilament gill nets (23 m long, 1.8 m depth, 38 mm bar mesh) with a minimum of three replicates per sampling date. Net soak time was between 0.25–1 hour and physicochemical measurements and net deployment occurred between 1000–1500 hours CST. Surface dissolved oxygen (mg L^{-1}) and temperature (C) were measured with a handheld oxygen-conductivity-salinity-temperature meter (Yellow Springs Instruments, Yellow Springs, Ohio) and Secchi disk depth (cm) was measured for each collection between 2 March 2005 and 18 February 2006. We did not target other fish species or juvenile spotted gar. Based on previous sampling, adult spotted gar were fully recruited to 38 mm bar mesh. Low-water between 22 July 2005 and 26 January 2006, precluded sampling in Deer Lake because of limited boat access. Based on visual approximations only 30% of the lake remained wet; spotted gar were observed in the lake during the low-water period.

Net set time (time the nets were deployed) was subtracted from the mean of the initial and final retrieval time to estimate soak time. Catch per unit effort (CPUE) was calculated as the number of spotted gar captured per net soak time and was standardized to number per hour. All variables except for CPUE were normally distributed. CPUE was $\log_{(e)}$ transformed prior to analysis to improve normality. Regression analysis was used to determine relationships between CPUE and water depth, temperature, DO, and Secchi disk depth. Correlation and regression analysis inferences were made at alpha = 0.0127 following a Dunn-Sidak adjustment for multiple comparisons (SAS 2003).

Population Estimation

To estimate the spotted gar population size in Deer Lake during the low-water period, a combined total of 107 spotted gar were collected on 26 January 2006 and 4 February 2006 with monofilament gill nets (23 m long, 1.8 m deep, 38 mm bar mesh). Each fish was measured (TL; cm) and double tagged with individually numbered T-bar tags to estimate tag retention rate. Recapture collections were made on 18 February 2006 and 24 February 2006. Chapman modification of the Peterson method with replacement was used to estimate spotted gar population size in Deer Lake. To estimate weights (g) of individual spotted gar for the mark-recapture study, the following length-weight regression from 468 adult spotted gar collected from the upper Barataria Estuary, Louisiana was used (Smith 2008):

$$\text{Log}_{10}(\text{Weight}) = 3.106[\text{Log}_{10}(\text{Length})] - 5.683$$

Spotted gar mean weight was then calculated and multiplied by the mean population estimation to estimate total spotted gar biomass in Deer Lake.

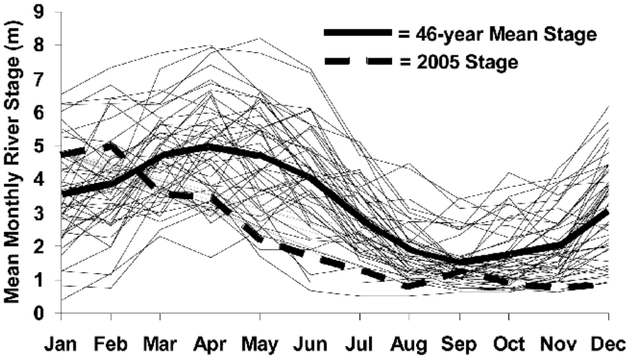

Figure 1. Mean monthly Atchafalaya River stage at Butte La Rose, Louisiana (USACE gauge 03120), from 1959–2004. Each line represents an individual year. The solid bold line represents the 46-year mean. The dashed bold line represents 2005.

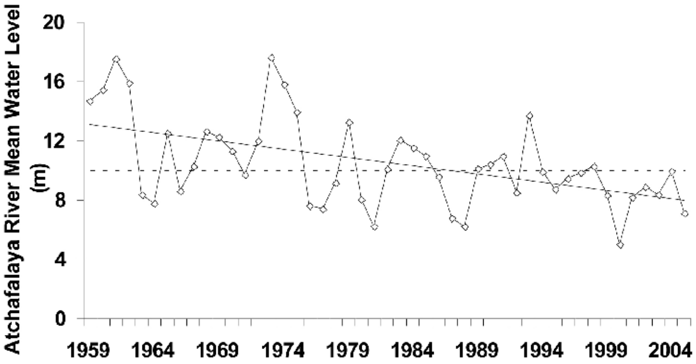

Figure 2. Mean yearly Atchafalaya River stage at Butte La Rose, Louisiana (USACE gauge 03120), from 1959–2005. The dashed line represents the 47-year mean water level.

Table 1. Number of observations, mean (± SD), range, and results of regression analysis between spotted gar CPUE and water depth, temperature, DO, and Secchi disk depth. Analysis using the Dunn-Sidak adjustment for multiple comparisons establishes an alpha level of 0.0127.

				Relation to CPUE			
Variable	*n*	Mean	Range	Slope	Intercept	*P*	R^2
Water depth (m)	19	3.92 ± 1.36	0.43–7.48	–0.00863	3.87750	0.0002	0.5763
Temperature (C)	19	18.94 ± 6.08	10.6–31.2	0.09965	–0.57160	0.0343	0.2375
DO (mg L^{-1})	19	5.63 ± 2.28	1.70–9.32	0.25366	–0.11301	0.0448	0.2163
Secchi (cm)	11	50.35 ± 19.85	16–86	–0.03862	3.52826	0.0124	0.5190

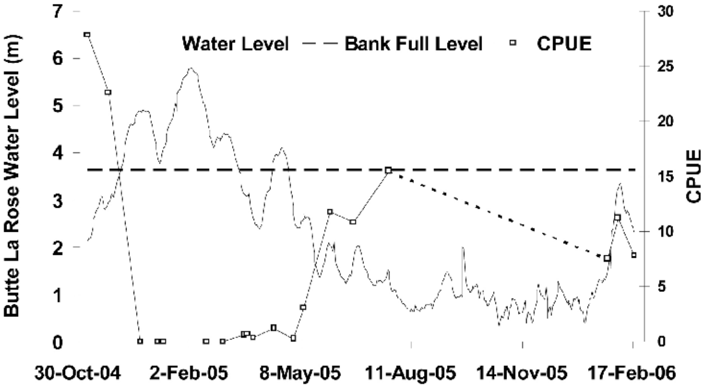

Figure 3. Catch per unit effort (CPUE) of spotted gar and Butte La Rose water level from 6 November 2004 to 18 February 2006. The short dashed segment of the CPUE line between 22 July 2005 and 26 January 2006 is attributed to no sampling because of low-water. The horizontal long dashed line represents water level at the Butte La Rose gauge (3.64 m) when Deer Lake is at bank-full level.

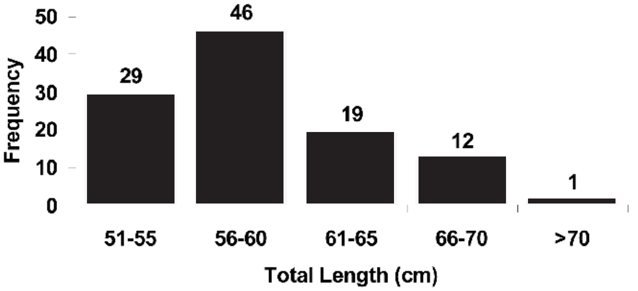

Figure 4. Length frequency for spotted gar collected in Deer Lake during the mark-recapture study. Mean size = 58.8 cm.

Results

Atchafalaya River water level typically peaks in April and reaches its lowest level in September (Figure 1). However, there is much year-to-year variation in flood pulse timing and duration and it appears that spring flood levels are more variable than fall low-water levels (Figure 1). The 2005 flood pulse differed from the typical flood pulse by reaching its peak water level in February and having among the lowest recorded water levels from August through December (Figure 1). Mean water stage for the Atchafalaya River has decreased over the last few decades ($P = 0.0002$, $R^2 = 0.2615$, Figure 2). The observed Butte La Rose maximum water level during our study was 5.79 m on 3 February 2005, with a minimum water level of 0.43 m on 25 October 2005. Deer Lake average depth (2.12 ± 0.01 m) subtracted from the Butte La Rose gauge reading for the same day (5.76 m) establishes that Deer Lake is bank-full at the 3.64 ± 0.01 m level on the Butte La Rose gauge.

Relative Density and Physicochemistry

Although Secchi disk depth was slightly correlated to CPUE, water level was highly correlated and appears to have the largest impact on spotted gar relative density in Deer Lake (Table 1; Figure 3). CPUE for spotted gar was 0 at water levels greater than 3.14 m at the Butte La Rose gage and greater than 0 when water levels were less than 3.14 m. The maximum number of spotted gar collected in one net (set for 42 minutes) was 32 on 6 November 2004.

Population Estimation

Tagged spotted gar total length was 58.8 ± 4.8 cm (mean ± SD; Figure 4). Of the 76 spotted gar captured, three were recaptures that retained both T-bar tags; therefore, a tag retention rate of

100% was assumed. The spotted gar population in Deer Lake was estimated to be 2,079 individuals with a 95% confidence interval of $849 < N < 5{,}198$. Based on bank-full surface area of 6.6 ha and an estimated mean weight of 848 g, spotted gar standing stock biomass was 267 kg ha^{-1} at bank-full level. Spotted gar standing stock biomass at our lower and upper confidence interval ranged from 109–668 kg ha^{-1}.

Discussion

As flood waters recede on large river floodplains, fish become isolated in low-water refuges that become disconnected from the main stem river. Fish that do not return to the main stem river depend on disconnected backwater areas such as Deer Lake to survive low-water periods. When Atchafalaya River water levels were high and the majority of the floodplain was inundated, CPUE for spotted gar was zero. Spotted gar presumably moved out of Deer Lake and onto the inundated floodplain to spawn and feed (Snedden et al. 1999). We estimated that Deer Lake water level was at bank-full when the Butte La Rose staff gauge equaled 3.64 m, which was similar to other studies in the ARB (3.7 m; Hupp et al. 2008). Relative density of spotted gar increased as declining water levels in the ARB approached Deer Lake bank-full level. When Deer Lake was disconnected from the main stem river and was confined within its banks, spotted gar relative density was greatest.

The range of our population estimate is necessarily broad, but was based on only three recaptured individuals. Standing stock biomass of all gars (*Lepisosteus* spp. and *Atractosteus* spp.) and bowfin (*Amia calva*) in rotenone samples from the lower ARB was estimated to be 243 kg ha^{-1} (Bryan and Sabins 1979). Our estimate of spotted gar standing stock biomass in Deer Lake, though imprecise ($P\,[109 \leq 267 \leq 668] = 0.95$), (267 kg ha^{-1}) was slightly higher and excluded large bowfin ($n = 33$) that were also collected during our study. A high density of top predators in disconnected backwater areas, particularly during abnormally low-water years, may alter trophic food webs in disconnected backwater areas of large river floodplains. Our spotted gar density estimates were based on Deer Lake bank-full level, but water levels were much lower during summer 2005. Although we did not measure predation rates for this study, we believe that piscivory in Deer Lake during 2005 was enhanced by very high spotted gar densities caused by extremely low water levels. It is likely that the density of potential prey species in Deer Lake increased as water levels declined, potentially benefiting aquatic predators such as gar and bowfin during low-water years.

Although the annual flood pulse is important to fishes in the ARB, each flood brings additional sediment to backwater areas (van Beek 1979, Hupp 2000, Hupp et al. 2008). Since 1932, there has been a net accretion of 2.5 billion m^3 of sediment in the ARB (Bryan et al. 1999) and the magnitude and frequency of sediment deposition in backwater areas is expected to increase as backwater areas of the ARB become filled (Smith et al. 1986). Although water levels dropped considerably in Deer Lake during this study, water did remain in the deepest part of the lake throughout the low-water period. Billy Littles Lake (3017N, 9133W), which is approximately 3.6 km southwest of Deer Lake, completely dried out by the end of 2005 (J. Fontenot, Department of Biological Science, Nicholls State University, personal communication). As backwater areas fill with sediment and lose their capacity to hold water throughout the low-water period, fishes in the ARB will have fewer low-water refuges.

Floodplain simulation studies indicate that the amount of water during high-water periods influences within-the-year ichthyomass, and that the size of the population carry-over to the following year is dependent on the amount of water remaining during the low-water period (Welcomme and Hagborg 1977). The degree to which high-water will influence populations can be affected by how much water is remaining during low-water periods (Hall and Lambou 1990).

While Atchafalaya River discharge has remained relatively unchanged, the mean annual stage of the Atchafalaya River at Butte La Rose has decreased since 1959 due to down cutting of the channel. Therefore, more water is required to top the natural levees immediately adjacent to the Atchafalaya River, which means there is less water available in a given year for backwater areas of the ARB. Even though spring high-water levels may enhance fish populations, if water levels drop to extreme levels as in 2005, some fish populations may experience high mortality rates as disconnected backwaters dry out.

Unusually low water levels reduce refuge habitat for fishes (Crook and Robertson 1999) and may concentrate fishes near the surface where spotted gar forage (Ostrand et al. 2004). Additionally, shallow areas may dry up, making juvenile fishes more vulnerable to predation (Lindholm et al. 2007). Arthington et al. (2005) observed changes in fish assemblage structure during low-water periods that were related to habitat loss. The effect of high fish mortality rates on community structure in disconnected backwater areas may be magnified by the inability of individuals in the main stem river to re-colonize disconnected areas during low-water periods (Sheaves et al. 2007). The biomass of predator species such as gar and bowfin may increase and the biomass of prey species decrease following an unusually low-water year in the ARB (Bryan and Sabins 1979). Although we did not assess fish community or biomass changes for this study, it is reasonable to expect that the extreme low water levels of 2005 led to top-down changes in fish communities in disconnected backwaters of the ARB (Kushlan 1976, Ostrand et al. 2004).

Low-water refuges that are disconnected from the main stem river are an important component of large river floodplain structure and function, particularly during extreme low-water years such as 2005. Sparks et al. (1990) describe an atypical flood pulse as a disturbance to floodplain systems, and the 2005 flood pulse was an atypical event. It is during extreme low water years that low-water refuges probably have the greatest impact on large river floodplain ecosystems. Further studies should investigate the relationship between fish community structure and the length of time that backwater areas are disconnected from the main stem river.

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