

CERTIFICATE

This is to certify that the thesis entitled “The use of a low-water refuge in the Atchafalaya River Basin by adult spotted gar *Lepisosteus oculatus*” submitted for the award of Master of Science to the Nicholls State University is a record of authentic, original research conducted by Mr. Christopher P. Bonvillain under our supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship, or other similar titles.

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ABSTRACT

As annual spring-time flood waters in the Atchafalaya River Basin recede, low-water refuges become important to fishes in back water areas. However, many back water areas are filling in with sediment, reducing the amount of important low-water habitats for fish. Fish year class strength in the Atchafalaya River Basin may be strongly influenced by fall low-water levels. The purpose of this study was to quantify the use of a low-water refuge for adult spotted gar, *Lepisosteus oculatus*, in an interior lake (Deer Lake) of the Atchafalaya River Basin. The relative density of adult spotted gar was quantified throughout the annual flood pulse by sampling with monofilament gill nets. A minimum of three replicates per sample date were used and nets were set between 0.25 and 1 hour. Catch per unit effort (CPUE) was determined by the number of spotted gar caught per net hour. Spotted gar density was greatest during low-water periods. Deer Lake water level was determined by a staff gage installed at an arbitrary depth. There was a strong negative correlation between spotted gar CPUE and Deer Lake water level ($P < 0.0001$, $r^2 = 0.7390$). Deer Lake water temperature, dissolved oxygen, and Secchi disk depth followed seasonal trends and relationships expected in the Atchafalaya River Basin. Assessment of the population size of adult spotted gar was estimated using a Chapman modification with replacement of the Peterson method mark recapture method during a low-water period. A combined total of 107 spotted gar were collected on 26 January 2006, and 4 February 2006, with monofilament gill nets (23m long, 1.8m depth, 38mm bar mesh). All fish were 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. Out of a total of 76 spotted gar captured, three were recaptured and

had both tags. The spotted gar population in Deer Lake was estimated to be 2,079 individuals (95% C.I. = $849 < N < 5,198$). Adult spotted gar biomass in Deer Lake at bank-full level was estimated to be 214.5 kg/ha. Water levels during fall 2005 were one of the lowest on record. The size of the fish population carried over to the following year is dependent on the amount of water remaining during the low-water period. If water levels drop to extreme levels as in 2005, fish populations will have reduced numbers for the following year. Consecutive years of extreme low-water could decrease fish populations in the Atchafalaya River Basin. The results of this study demonstrate the importance of low-water refuges in the Atchafalaya River Basin to fish.

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INTRODUCTION

The Atchafalaya River is the largest Mississippi River distributary, and the name Atchafalaya originates from the Choctaw word for “long river” (Reuss 1998). The water body that historically connected the Mississippi River to the Atchafalaya River was called Old River (Figure 1). Old River was created when Captain Henry Shreve dredged across a loop in the Mississippi River to create a shorter route on the river (Figure 2). Shreve cut off the loop which then created Old River. The Atchafalaya River flows 225 km from the latitude of Old River to the Gulf of Mexico. Prior to 1846, the Atchafalaya River received very little water from the Mississippi River because of a massive raft of logs and other debris approximately 48 km in length that impeded water flow. After the state of Louisiana removed the raft, the Atchafalaya River began to enlarge and capture an increasing amount of Mississippi River water. Atchafalaya River discharge began to steadily increase, while Mississippi River discharge began to decrease (Fisk 1952). Essentially, the Mississippi River was beginning to change course due mostly to the fact that the Atchafalaya River provided a steeper gradient to the Gulf of Mexico. In his study of the Atchafalaya River Basin, Fisk (1952) predicted that in the absence of any intervention, the Mississippi River would eventually change its course to flow down the Atchafalaya River through Old River sometime between 1965 and 1975. This would leave New Orleans and Baton Rouge without sufficient supplies of freshwater for domestic and industrial needs.

To prevent the Mississippi River from changing course, Congress authorized the building of the Old River Control Structure (Figure 1) to regulate the amount of Mississippi River water captured by the Atchafalaya River. The Old River Control

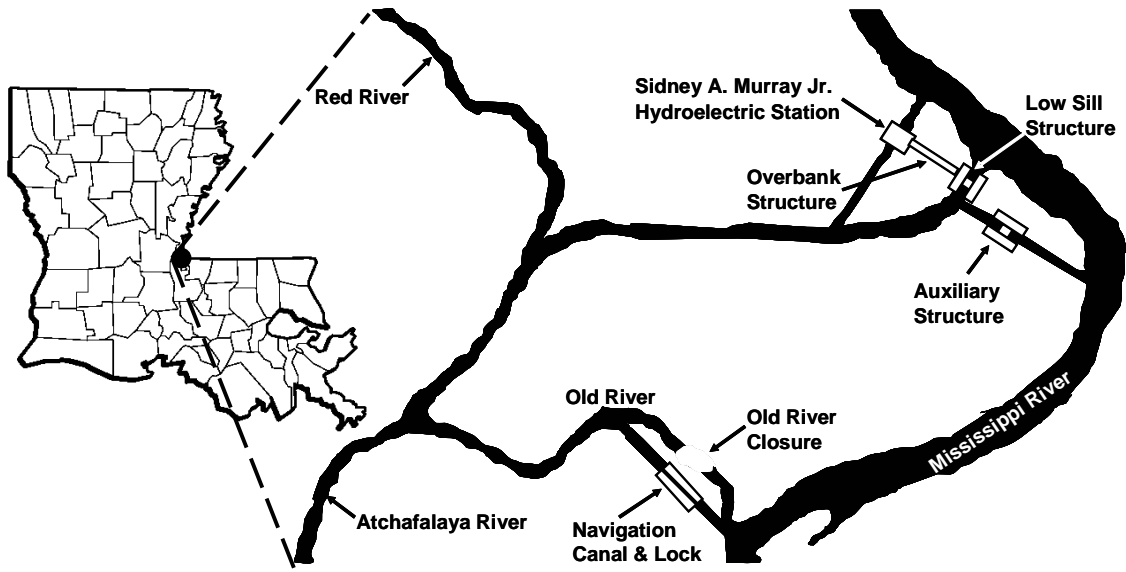


Figure 1. Old River Control Structure Complex and historic Old River connection (adapted from Silvas and Mundell 1999). The Atchafalaya River flow is composed of 30% of the combined discharges of the Mississippi and Red Rivers and is regulated by the influx of Mississippi River water from the hydroelectric station, low sill structure, and the auxiliary structure.

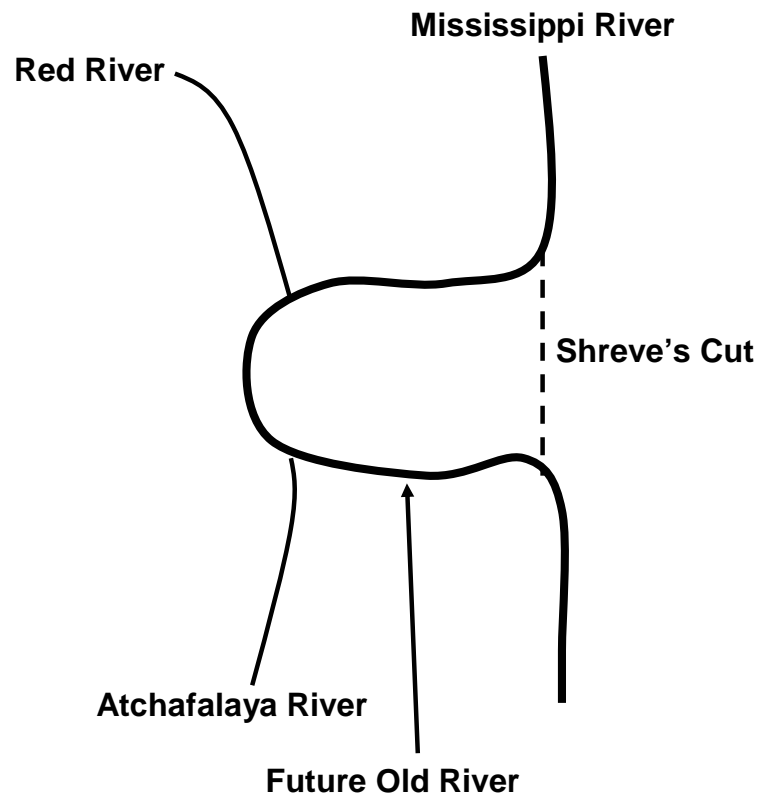


Figure 2. Shreve's cut made in the Mississippi River. The upper loop of the Mississippi River filled in with sediment and the bottom loop became Old River.

Structure was constructed about 80 km northwest of Baton Rouge, and approximately 5 km north of Old River, the historic connection between the Mississippi and Atchafalaya Rivers. The original Old River Control Structure, which consisted of a low sill structure and an overbank structure, was completed in 1963 and allowed 30% of the combined discharges of the Mississippi and Red Rivers to flow down the Atchafalaya River (USACE 1974), the proportions that occurred in 1950 (Van Beek et al. 1979). A navigation canal and lock was constructed to connect Old River and the Mississippi River and the historic Old River connection was blocked off, essentially preventing Mississippi River water from flowing through Old River to the Atchafalaya River. In 1973, record flood waters damaged the low sill structure, and if the low sill structure would have completely failed, the Mississippi River would have changed its course. The Old River Control Structure was repaired and the Auxiliary Control Structure was built in 1986 to help divert and control Mississippi River water. In 1990, the Sidney A. Murray Jr. Hydroelectric Power Plant and channel were built just north of the Old River Control Structure. The current Old River Control Structure Complex now consists of three channels that can direct Mississippi River water to the Atchafalaya River (Figure 1).

As the Atchafalaya River runs through the Atchafalaya River Basin, it disperses large amounts of water and sediments throughout the Atchafalaya River Basin and the Gulf of Mexico via Atchafalaya Bay. The average discharge of the Atchafalaya River is $1,642 \text{ m}^3 \text{ s}^{-1}$ (Kammerer 1990). When the raft on the Atchafalaya River was cleared, the increased discharge of the Atchafalaya River caused deposition of 0.9 – 6 m of sediment over much of the former open water of Atchafalaya Bay, causing accelerated filling-in of open water areas (Krinitzsky and Smith 1969). Since the early 1900s, approximately 85%

of the lower Atchafalaya River Basin lakes have filled in with sediment (Roberts et al. 1980). The average suspended sediment load for the Atchafalaya River at Simmesport between 1952-1989 was 84×10^6 metric tons per year (Allison et al. 2000). This sediment load is responsible for delta building at the mouth of the Atchafalaya River and Wax Lake Outlet. Beginning in the 1950s, many lakes and swamps in the Atchafalaya River Basin were filled with sediment to the point where most of the sediment was deposited into Atchafalaya Bay (Allison et al. 2000). Thompson first documented this sedimentation in 1951 (Thompson 1951) and in 1953, Morgan noticed that sediment was accumulating in Atchafalaya Bay (Morgan et al. 1953). In the large flood of 1973, vast amounts of water and sediment were carried to Atchafalaya Bay by the Atchafalaya River and Wax Lake Outlet. After the 1973 flood, subaqueous delta development was observed in Atchafalaya Bay (Shlemon 1975).

Sedimentation is also occurring in back water areas of the Atchafalaya River Basin. During flood periods, large quantities of sediment are deposited on the low-lying floodplain (Tye 1986; Smith et al. 1986). Most of the flood waters and sediments introduced into back water areas below Interstate 10 (van Beek 1979) are delivered from diversion channels and canals connected to the Atchafalaya River (van Beek et al. 1979; Tye and Coleman 1989). The sediment settles from the water column as the water spreads over the floodplain and velocity decreases. By the time flood waters begin to recede, most of the sediment has settled and the water is relatively clear. Sediment deposition in back water areas of river floodplains reduces the total amount of water area during low-water periods (van Beek 1979; van Beek et al. 1979) and will eventually fill in low-lying areas (Tye 1986), eliminating low-water refuges that are important to fish.

The Atchafalaya River Basin is the floodplain of the Atchafalaya River and is one of the largest bottomland hardwood forests in North America covering approximately 5,000 km² (Lambou 1990). The Atchafalaya River Basin floodplain once extended from Bayou Teche on the west to Bayou Lafourche on the east. However, the Atchafalaya River Basin currently averages approximately 24 km in width because of flood protection levees on both sides constructed over several decades (Jennings and Land 1977; Figure 3). One of the functions of the Atchafalaya River Basin is to contain and route one-half (42,735 m³ s⁻¹) of the design project flood waters from the Mississippi River Valley to the Gulf of Mexico without flooding outside of the protection levees (Jennings and Land 1977).

The Atchafalaya River Basin experiences an annual flood pulse from the Atchafalaya River with peak water levels usually occurring in the spring. Water levels typically recede throughout the summer, and are minimal in the fall (Denes and Bayley 1983; Lambou 1990; Fontenot et al. 2001; Figure 4). The magnitude of the flood will determine how much of the floodplain is inundated with water (Figure 5). This annual flooding in the Atchafalaya River Basin contributes to its high fisheries production (Lambou 1963, 1990). Fish distribution and year-class strength are a function of the high-water period (Bryan and Sabins 1979). Fish move onto the inundated floodplain for spawning or feeding (Harrell 1978; Guillory 1979; Ross and Baker 1983; Walker and Sniffen 1985; Kwak 1988; Lambou 1990). Spawning for many fishes of the Atchafalaya River Basin occurs during some part of the flood pulse (Holland et al. 1983; Hall and Lambou 1990) and studies have indicated that the timing and duration of the flood pulse

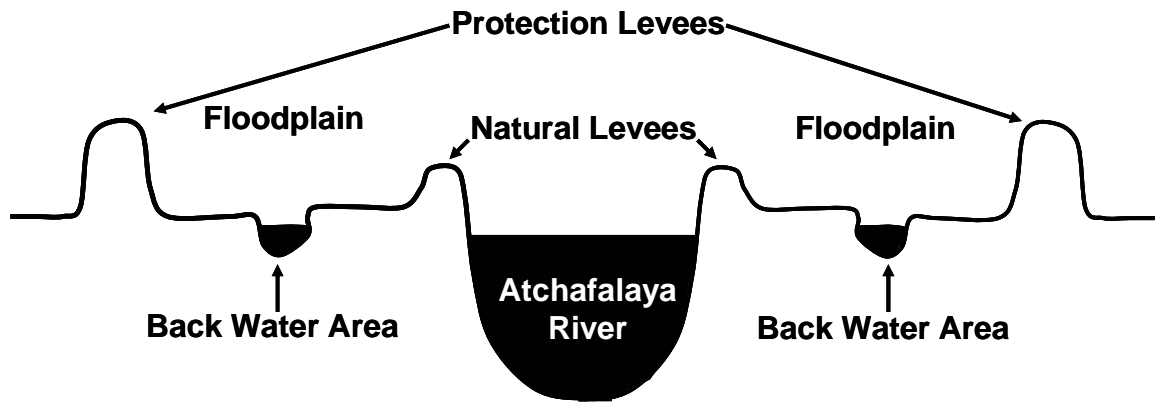


Figure 3. Theoretical cross section of the Atchafalaya River Basin. The Atchafalaya River is bounded by natural levees built up from overbank flooding. However, there are cuts in the natural levees that conduct water between the Atchafalaya River and the floodplain. The floodplain of the Atchafalaya River Basin is contained within the man made protection levees that line its sides. Back water areas of the Atchafalaya River Basin are areas on the floodplain away from the mainstem channel that are flooded during high-water periods and serve as low-water refuges during low-water periods.

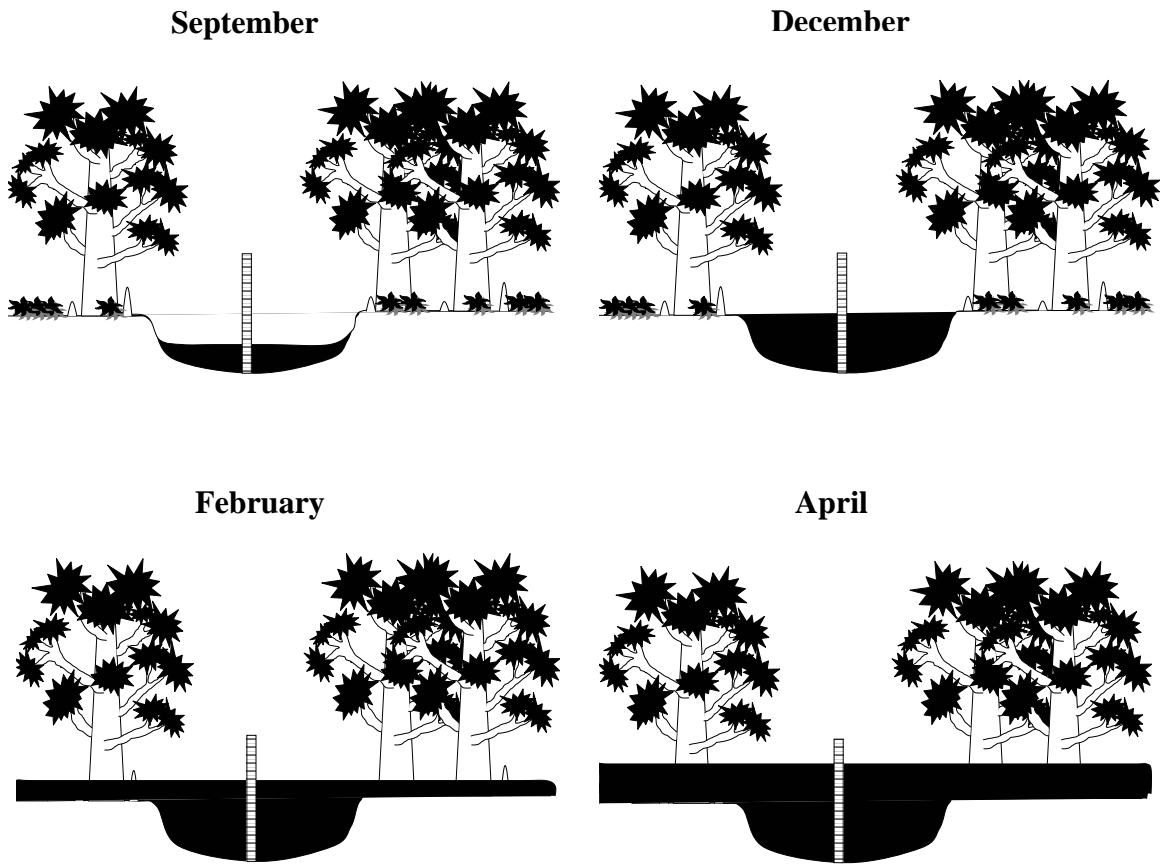


Figure 4. Progression of water level rise in Deer Lake in the Atchafalaya River Basin throughout a typical flood pulse. The dashed vertical bar represents a staff gage installed in Deer Lake.

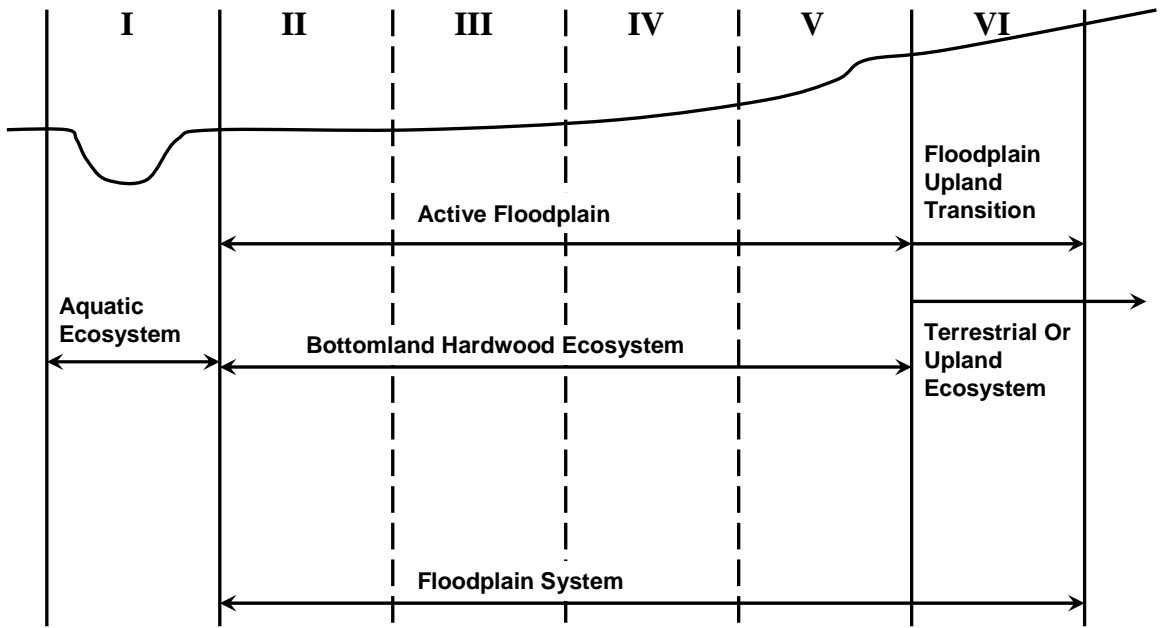


Figure 5. Profile of a floodplain system. The horizontal solid lines represent elevation. Zones further away from the aquatic ecosystem are flooded less frequently by the flood pulse (after Larson et al. 1981; Hall and Lambou 1990).

can affect fish populations in large river floodplains (Bryan and Sabins 1979; Junk et al. 1989; Bayley 1995). Optimal spawning conditions, habitat, and food for young fish occur when water level and temperature rise concurrently (Junk et al. 1989; Sparks et al. 1990). Nutrients from accumulated decomposing organic matter on the floodplain are released into flood waters (Junk et al. 1989). During a typical flood pulse, primary production is greater than respiration when the water level is rising. Once water levels peak and temperature increases, respiration rates become greater than primary production rates because of the increased decomposition of floodplain organic matter (Junk et al. 1989; Bayley 1995). This can create periods of hypoxia [dissolved oxygen (DO) \leq 2 mg/L] in the Atchafalaya River Basin (Bryan and Sabins 1979; Davidson 1996; Rutherford et al. 2001; Fontenot et al. 2001). Hypoxia is greatest when floodplain vegetation inundated by floodwaters begin to decompose (Rutherford et al. 2001). Productive capabilities of floodplain nurseries may be reduced by extended periods of low DO (Fontenot et al. 2001). Fishes inhabiting low DO waters may experience respiratory stress (Schreck 1981), have reduced growth (Bejda et al. 1992; Hales and Able 1995), and may have reduced fecundity (Brunet 1997). Depending on the timing and duration of the flood pulse, hypoxia can last for several weeks in back water swamp habitats (Sabo et al. 1999).

Back water areas in river floodplains (Figure 3) are important nursery grounds for several fish taxa (Junk et al. 1989; Brown and Coon 1994; Bayley 1995; Sparks 1995) and larval fish densities are typically higher in back water areas of river floodplains than their respective mainstem rivers (Hall 1979; Clary 1981; Turner et al. 1994). When floodwaters recede, bayous, canals, and lakes become contained within their banks and

the majority of the floodplain is dry. Primary production increases in back water areas because of nutrient accumulation from the floodplain (Bayley 1995). Fish become concentrated in back water areas when flood waters recede (Lambou 1990) and use back water areas during low-water periods for refuge (Welcomme 1979) and feeding (Junk et al. 1989). Seasonal movement studies of spotted gar *Lepisosteus oculatus* in the Atchafalaya River Basin have shown that spotted gar migrate to back water refuges during low-water periods and move onto the floodplain during high-water periods (Snedden et al. 1999).

Low-water refuges are important to fish, especially in years with abnormally low water levels. These low-water refuges provide fish a place to survive until water levels begin to rise. As sedimentation fills in low-water areas, their size and capacity begin to decrease. This means that during extreme low-water years, fish will have less area or no area at all to occupy. This could cause some fish populations to decline. Fish will be confined to smaller, shallower water areas, resulting in increased predation from terrestrial animals and aquatic top predators such as bowfin *Amia calva* and gar *Lepisosteus* spp. and *Atractosteus spatula*. Lower water levels can also lead to water quality problems such as decreased DO. Because some low-water refuges may completely dry up, killing all fish that inhabited that area, atypical low-water events may be important to fish populations and year-class strength.

Spotted gar belong to the family Lepisosteidae and range from Lake Erie and southern Lake Michigan through the Mississippi River basin to the Gulf Coast (Page and Burr 1991). Spotted gar live in clear pools and back water areas to large rivers, lakes, swamps, and ditches with abundant vegetation or debris (Page and Burr 1991). Spotted

gar possess a physostomous gas bladder (Potter 1927), which allows them to gulp air from the surface. Some studies indicate that spotted gar get as much as 53% of their oxygen from aerial breathing (Burlison et al. 1998; Farmer and Jackson 1998). This allows spotted gar to sustain activity for a longer period of time than physoclistus fish (Farmer and Jackson 1998) and survive under hypoxic conditions, which occur frequently in the Atchafalaya River Basin.

Spotted gar were chosen for this study because they are abundant in back water areas of the Atchafalaya River Basin (Lambou 1990; Rutherford et al. 2001), they are a top predator, they are easily caught with gill nets throughout the year, and they are able to survive if waters become hypoxic. The purpose of my study was to quantify the use of a low-water refuge in the Atchafalaya River Basin by adult spotted gar. The specific objectives of my study were to:

1. Quantify the water quality and level in an interior lake of the Atchafalaya River Basin throughout a single year.
2. Determine the relationship between spotted gar relative density and water level and quality in an interior lake of the Atchafalaya River Basin.
3. Estimate the adult spotted gar population size in an interior lake of the Atchafalaya River Basin during the low-water period.

METHODS

The project study site was Deer Lake (30° 19' N, 91° 32' W), a small lake in the Atchafalaya River Basin, Louisiana, surrounded by bald-cypress *Taxodium distichum*, tupelo gum *Nyssa aquatica*, black willow *Salix nigra*, and button bush *Cephalanthus occidentalis*. Deer Lake is located approximately 9.6 km south of Interstate 10, 1.5 km west of the eastern Atchafalaya River Basin protection levee, and is approximately 7.9 km to the east of the Whiskey Bay Pilot Channel (Figure 6). Water level in Deer Lake can vary more than three meters through a single flood pulse, therefore surface area fluctuates with water level. However, the bank of Deer Lake is delineated by a distinct tree line and the lake covers approximately 6.6 hectares at bank-full level. Water in Deer Lake becomes isolated from the floodplain during low-water periods and is continuous with the floodplain during high-water periods.

Daily Atchafalaya River water level values between 1959 and 2006 were obtained from the U. S. Army Corps of Engineers recording gage (#03120) located at Butte La Rose, Louisiana (30° 16' 57" N, 91° 41' 17" W). Daily values for each year from 1959 to 2005 were used to determine the mean water levels for each month of each year, and for each year. A staff gage (cm) was installed in Deer Lake at an arbitrary depth to measure relative water level in the lake for each sample period. Regression analysis ($\alpha = 0.05$) was used to determine the relationship between water level in the Atchafalaya River and Deer Lake.

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



Figure 6. The shaded area is the approximate location of the Atchafalaya River Basin in south-central Louisiana. The star represents the approximate location of Deer Lake.

approximately 20 m from the bank were made with a calibrated weighted rope along the east and west banks paralleling Deer Lake. The average depth (212 ± 9.5 cm) was determined then subtracted from the reading on the Deer Lake staff gage for that day (278 cm). Based on these measurements, Deer Lake is bank-full at the 66 ± 9.5 cm level on the Deer Lake staff gage.

Relative Density

Spotted gar were sampled bimonthly between 11 November 2004, and 22 July 2005, and between 26 January 2006, and 18 February 2006, using monofilament gill nets (23m long, 1.8m depth, 38mm bar mesh) with a minimum of three replicates per sample. Nets were deployed from the pirogues R/V Amphiuma and R/V Tou Lou Lou. Low-water between 22 July 2005, and 26 January 2006, precluded sampling in Deer Lake with gill nets; however, rainfall in January 2006 added enough water into Deer Lake to resume sampling. Spotted gar were visually observed in Deer Lake between 22 July 2005, and 26 January 2006. Relative density sampling began again on 26 January 2006. Net soak time was always between 0.25 and 1 hour. Nets were set between 1000 and 1500 hours CST. Surface dissolved oxygen (mg/L), and temperature ($^{\circ}\text{C}$) were measured with a handheld oxygen-conductivity-salinity-temperature meter (Yellow Springs Instruments, Yellow Springs, Ohio). Secchi disk depth (cm) was also measured at each collection between 2 March 2005, and 18 February 2006. All water quality variables were measured between 1000 and 1500 hours CST.

Catch per unit effort (CPUE) for spotted gar was determined by the mean number caught per net hour for each sample date. Net set time (time the nets were deployed), retrieval time (time of initial net retrieval), and end time (time when nets were completely

retrieved) were recorded. The time of net deployment used to determine CPUE was calculated as:

$$\text{Time} = [\text{retrieval time} - \text{set time}] + [(\text{end time} - \text{retrieval time})/2].$$

This formula was used to compensate for extended soak time caused by an abundance of fish in the nets. All fish collected were identified to species and enumerated.

All variables except for CPUE and species richness were normally distributed therefore CPUE and species richness were $\log_{(e)}$ transformed. $\log_{(e)}$ transformed species richness was normally distributed, and $\log_{(e)}$ transformed CPUE approached normality. All analysis that included CPUE and species richness were conducted with the $\log_{(e)}$ transformed values. Data were subject to correlation and regression analysis and all inferences were made at $\alpha = 0.05$ (SAS 2003).

Population Estimation

To estimate population size, a combined total of 107 spotted gar were collected on 26 January 2006, and 4 February 2006, during the low-water period with monofilament gill nets (23m long, 1.8m depth, 38mm bar mesh). Each fish was measured (TL; mm) 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. Of the 76 total spotted gar captured, three were recaptures. Chapman modification of the Peterson method with replacement was used to estimate spotted gar population size in Deer Lake. To estimate spotted gar biomass in Deer Lake, a length-weight regression [Weight = - 857.37 + (2.62 x Length)] based on a population of spotted gar collected from Lake Seminole, Florida, was used (Ferrara 2001). Individual weights were estimated for each spotted gar tagged for the mark-recapture study. Spotted gar mean weight was then

calculated and multiplied by the mean population estimation to estimate total spotted gar biomass.

RESULTS

Atchafalaya River water level typically peaks in April and reaches its lowest level in September (Figure 7). However, there is much variation among year-to-year flood pulse timing and duration (Figure 7). It appears that spring flood levels are more variable than fall low-water levels (Figure 7). The 2005 flood pulse differed from the typical flood pulse by reaching its peak water level in February and having below average water levels from August through December (Figure 7; Table 1). Also, mean water levels for the Atchafalaya River have been decreasing over the last few decades ($P = 0.0002$, $r^2 = 0.2615$; Figure 8). There was a strong positive correlation between the water level in Deer Lake and the Atchafalaya River water level at Butte La Rose (Deer Lake = 0.57249 (Atchafalaya River) – 58.99841 ; $P < 0.0001$, $r^2 = 0.8922$; Figure 9). Based on the relationship between the water level in Deer Lake and the Atchafalaya River water level at Butte La Rose, Deer Lake can be used as a model lake for the surrounding Atchafalaya River Basin. Based on the Deer Lake and Atchafalaya River water level regression, Deer Lake is expected to be at bank full level (66 cm) when the Atchafalaya River at Butte La Rose reaches 218 cm (7.15 ft). The observed Deer Lake maximum water level was 278 cm on 2 February 2005 and minimum water level of 0 cm on 8 September 2005. The Deer Lake staff gage remained dry (completely out of the water) until 26 January 2006. Although the staff gage was out of the water, water did remain in the deepest part of the lake throughout the low-water period. The water level in Deer Lake fluctuated greater than 2.78 m in 2005.

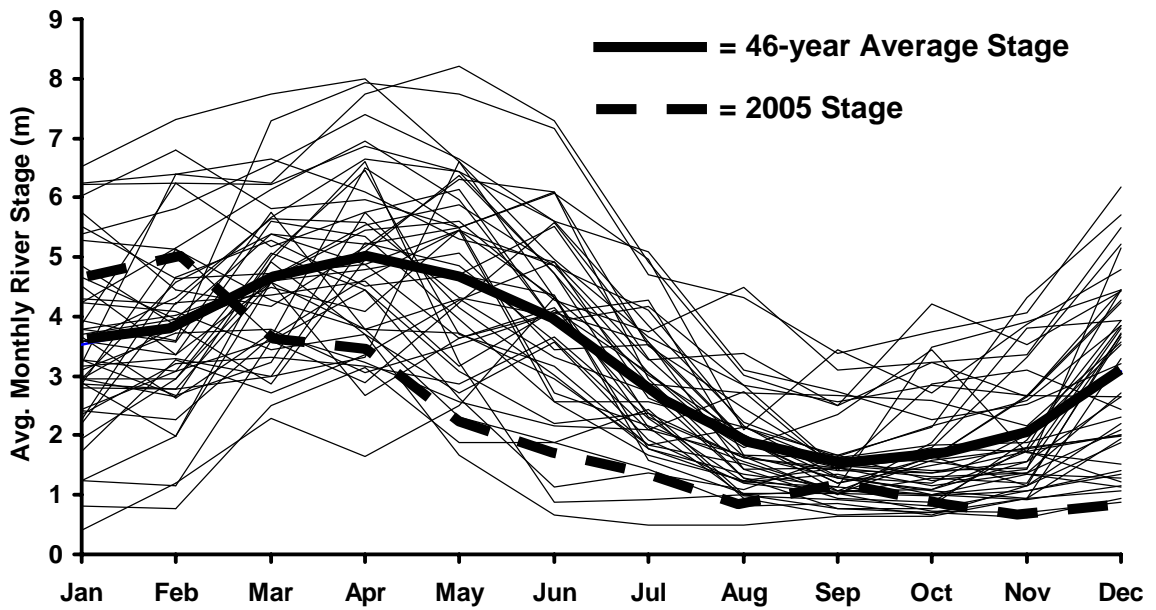


Figure 7. Mean monthly Atchafalaya River stage at Butte La Rose, LA, (USACE gage 03120) from 1959-2004. Each line represents an individual year. The solid bold line represents the 46-year mean. The dashed bold line represents 2005.

Table 1. Ten lowest recorded mean monthly Atchafalaya River stages at Butte La Rose, LA, USACE gage 03120 from 1959-2005 for August-December. Mean river stage (m) is in parenthesis below year. Values for 2005 are in bold. Mean river stage was ranked 20th (3.97) for September 2005.

Rank	Month				
	Aug	Sep	Oct	Nov	Dec
1	1988 (0.50)	1988 (0.63)	1998 (0.63)	1999 (0.60)	1963 (0.88)
2	2005 (0.75)	1976 (0.68)	1987 (0.66)	1963 (0.69)	2005 (0.90)
3	1987 (0.83)	2000 (0.75)	1999 (0.70)	2005 (0.73)	1999 (0.96)
4	1976 (0.94)	1999 (0.76)	1976 (0.71)	1980 (0.91)	1976 (1.07)
5	1991 (0.97)	1987 (0.84)	1963 (0.73)	1978 (0.94)	1989 (1.12)
6	1964 (1.01)	1991 (0.91)	2000 (0.75)	1988 (0.94)	1980 (1.15)
7	2000 (1.01)	1983 (0.95)	1991 (0.83)	1976 (0.96)	1981 (1.22)
8	2002 (1.03)	1984 (1.01)	2005 (0.87)	2000 (1.06)	1995 (1.26)
9	1977 (1.11)	2002 (1.02)	1983 (0.89)	1997 (1.06)	2000 (1.35)
10	2001 (1.20)	1997 (1.03)	1997 (0.97)	1966 (1.15)	1997 (1.40)

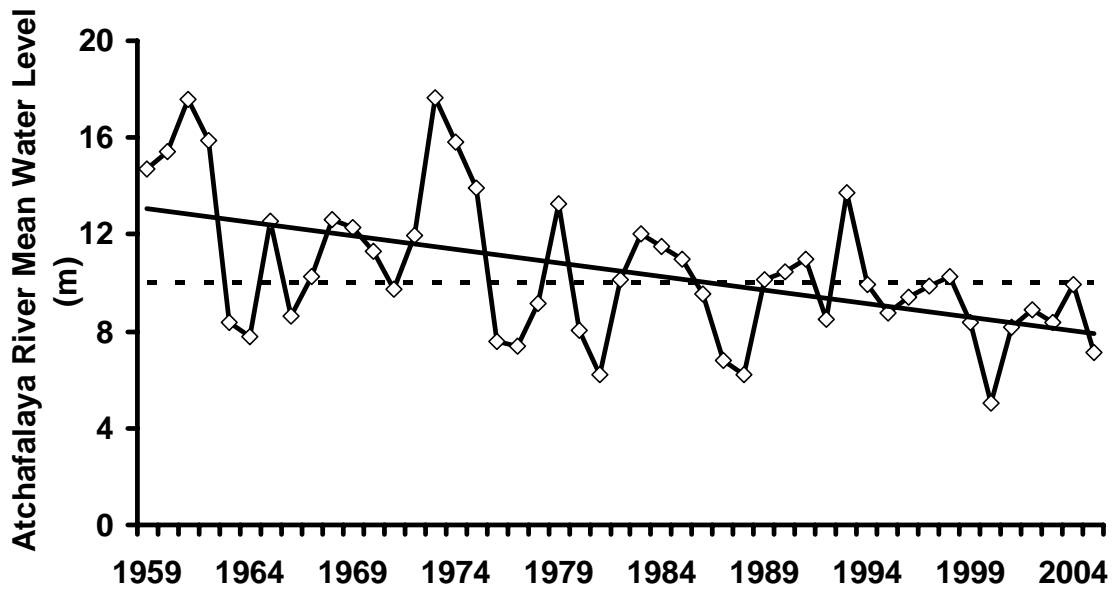


Figure 8. Mean yearly Atchafalaya River water level at Butte La Rose, LA, (USACE gage 03120) from 1959-2005. The dashed line represents the 47-year average water level.

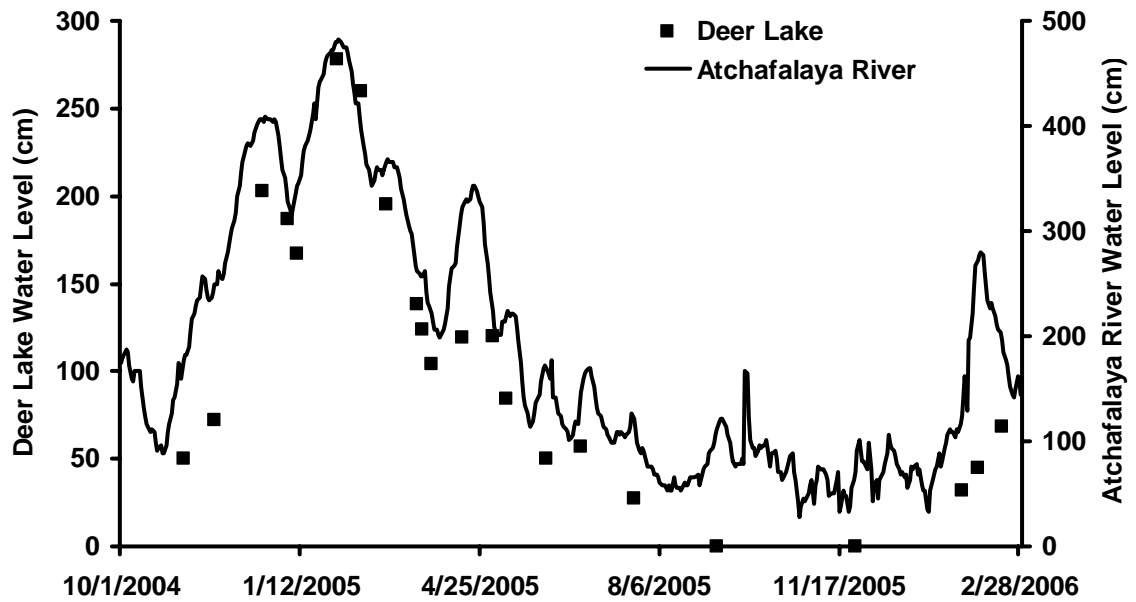


Figure 9. Water level for the Atchafalaya River and Deer Lake from 6 November 2004, to 18 February 2006. The daily Atchafalaya River water level at Butte La Rose, LA, USACE gage 03120 is represented by the solid line. Deer Lake water level is represented by the square points. Water did remain in the deepest part of Deer Lake from August to January even though water level at the staff gage was zero.

Relative Density

A total of 11 fish species were collected with gill nets during relative density sampling (Table 2). Spotted gar, bowfin, and gizzard shad *Dorosoma cepedianum* were the three most abundant species collected (Table 2). Although bluegill *Lepomis macrochirus* were not collected with gill nets, they were observed in Deer Lake immediately following a summertime fish kill on 22 July 2005. Other fishes (golden shiner *Notemigonus crysoleucas*, mosquitofish *Gambusia affinis*, and pirate perch *Aphredoderus sayanus*) that were too small to be collected with gill nets were observed in Deer Lake as well. Based on gill net collections, species richness in Deer Lake is negatively correlated to water level ($P < 0.0001$, $r^2 = 0.6445$; Figure 10). Water levels appeared to have the largest impact on spotted gar relative density. CPUE for spotted gar was 0 at water levels greater than 138 cm on the Deer Lake staff gage and greater than 0 when water levels were less than 138 cm. The maximum number of spotted gar collected in one net (set for 42 minutes) was 32 on 6 November 2004. There was a strong negative correlation between spotted gar CPUE and Deer Lake water level ($P < 0.0001$, $r^2 = 0.7390$; Figure 11). Spotted gar CPUE was weakly correlated to DO ($P = 0.0462$, $r^2 = 0.2138$) and was correlated to Secchi disk depth ($P = 0.0037$, $r^2 = 0.6274$).

Deer Lake water temperature ranged from 10.6 °C on 21 December 2004 to 31.2 °C on 22 June 2005. Temperature followed expected seasonal trends and was weakly negatively correlated to Deer Lake water level ($P = 0.0045$, $r^2 = 0.3694$; Figure 12). Secchi disk depth ranged from 16 cm on 22 July and 8 September 2005 to 86 cm on 2 May 2005 and was positively correlated to Deer Lake water level ($P = 0.0219$, $r^2 = 0.4238$; Figure 13). Secchi disk depth was negatively correlated with temperature

Table 2. Total number of each fish species collected during relative density sampling in Deer Lake with monofilament gill nets (23 m long, 1.8 m depth, and 38 mm bar mesh).

Species	Common Name	Number
<i>Lepisosteus oculatus</i>	Spotted Gar	280
<i>Amia calva</i>	Bowfin	33
<i>Dorosoma cepedianum</i>	Gizzard Shad	24
<i>Ameiurus melas</i>	Black Bullhead	15
<i>Ameiurus natalis</i>	Yellow Bullhead	10
<i>Micropterus salmoides</i>	Largemouth Bass	9
<i>Pomoxis nigromaculatus</i>	Black Crappie	9
<i>Atractosteus spatula</i>	Alligator Gar	5
<i>Lepomis gulosus</i>	Warmouth	3
<i>Mugil cephalus</i>	Striped Mullet	1
<i>Cyprinus carpio</i>	Common Carp	1

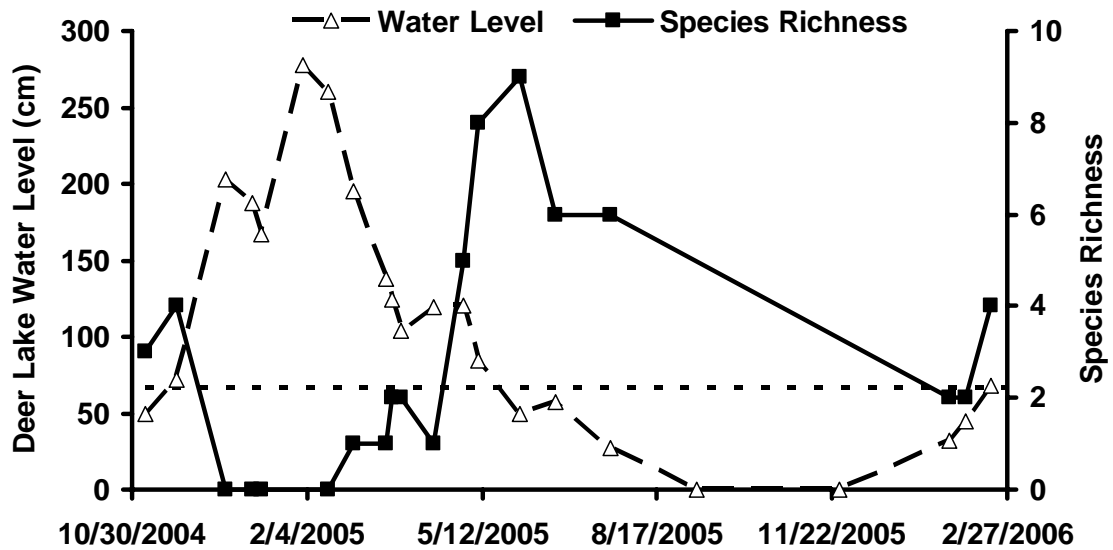


Figure 10. Deer Lake water level and species richness from 6 November 2004, to 18 February 2006. Species richness is based on gill net collections only. The horizontal dashed line represents water level of Deer Lake at bank-full level (66 cm). Water remained in the deepest part of Deer Lake even though water level at the staff gage was zero.

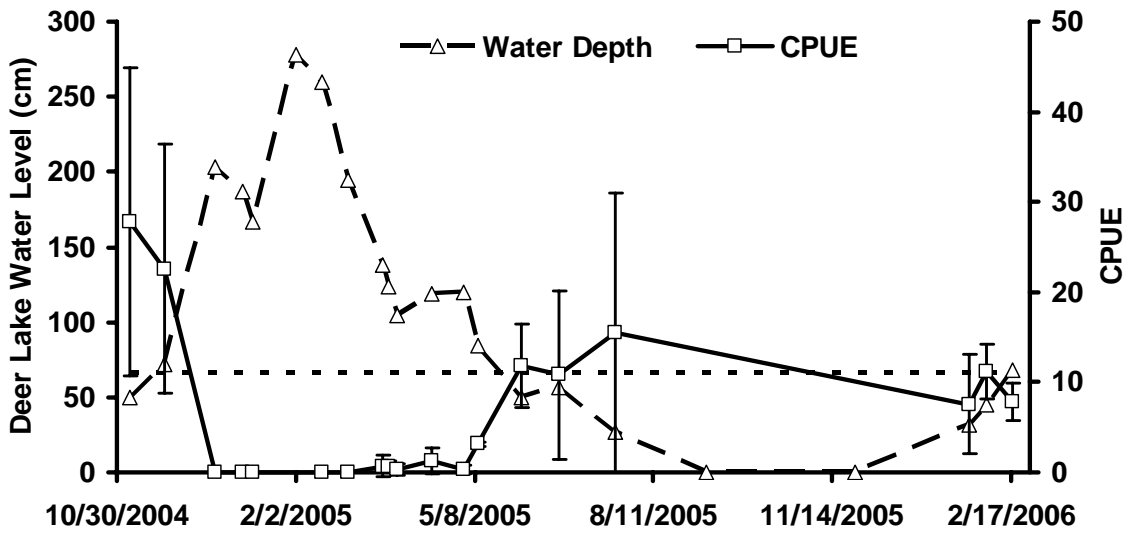


Figure 11. Mean (\pm SD) catch per unit effort (CPUE) of spotted gar and Deer Lake water level from 6 November 2004, to 18 February 2006. The horizontal dashed line represents water level of Deer Lake at bank-full level (66 cm). Water remained in the deepest part of Deer Lake even though water level at the staff gage was zero.

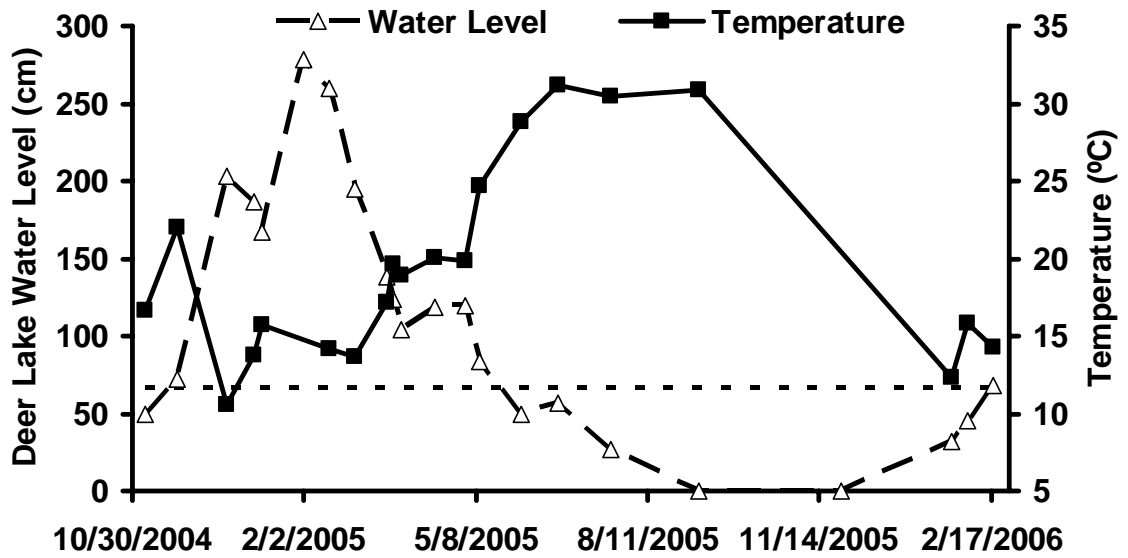


Figure 12. Temperature and water level in Deer Lake from 6 November 2004, to 18 February 2006. The horizontal dashed line represents water level of Deer Lake at bank-full level (66 cm). Water remained in the deepest part of Deer Lake even though water level at the staff gage was zero.

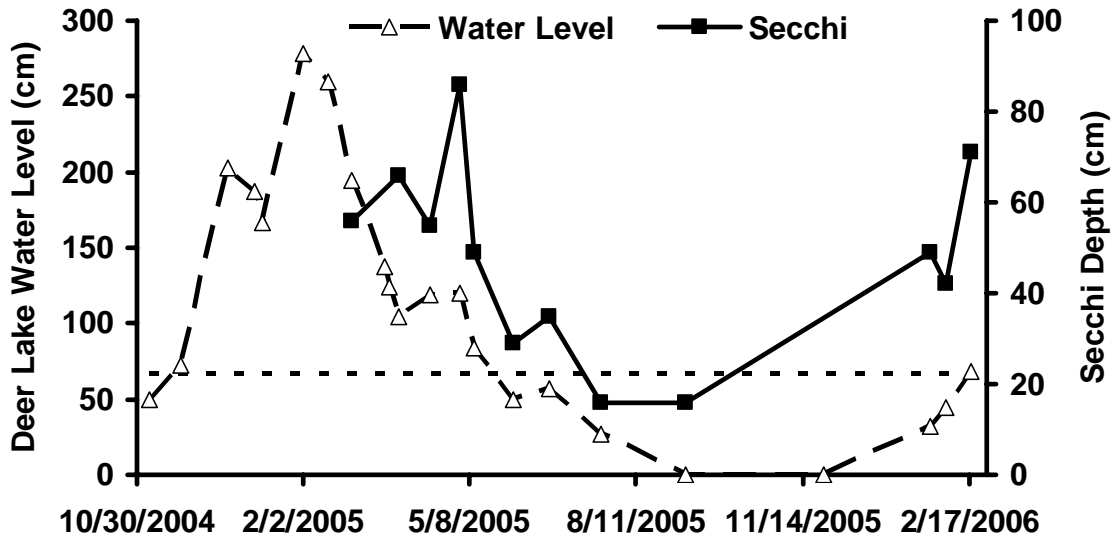


Figure 13. Secchi disk depth and water level in Deer Lake from 2 March 2005, to 18 February 2006. The horizontal dashed line represents water level of Deer Lake at bank-full level (66 cm). Water remained in the deepest part of Deer Lake even though water level at the staff gage was zero.

($P = 0.0122$, $r^2 = 0.4820$; Figure 14) and DO ($P = 0.0250$, $r^2 = 0.4140$; Figure 15). DO levels ranged from 1.7 mg/L on 2 May 2005 to 12.5 mg/L 8 September 2005 and were not correlated to Deer Lake water level ($P = 0.1380$, $r^2 = 0.1181$; Figure 16).

Population Estimation

Tagged spotted gar total length was 58.8 ± 4.8 cm. The three recaptured spotted gar retained both of their 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 680.9 g, spotted gar standing stock biomass was 214.5 kg/ha at bank-full level.

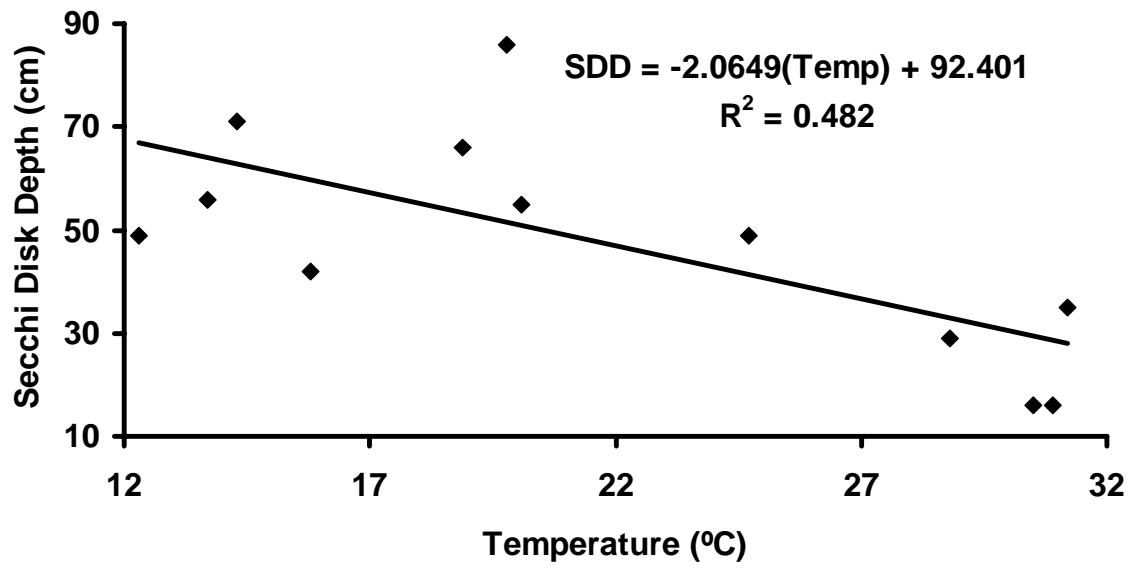


Figure 14. Relation between Secchi disk depth (SDD) and temperature (Temp) in Deer Lake from 2 March 2005, to 18 February 2006.

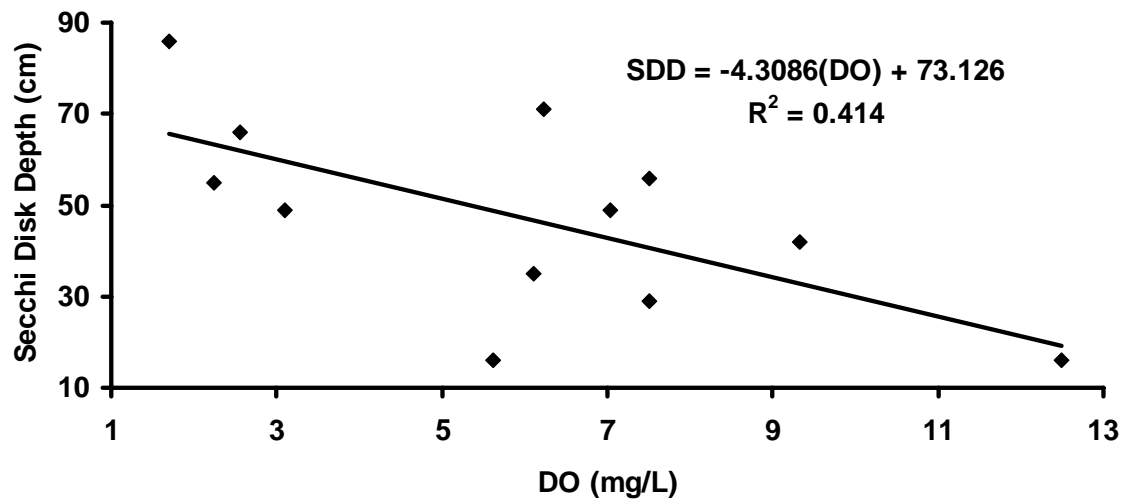


Figure 15. Relation between Secchi disk depth (SDD) and DO in Deer Lake from 2 March 2005, to 18 February 2006.

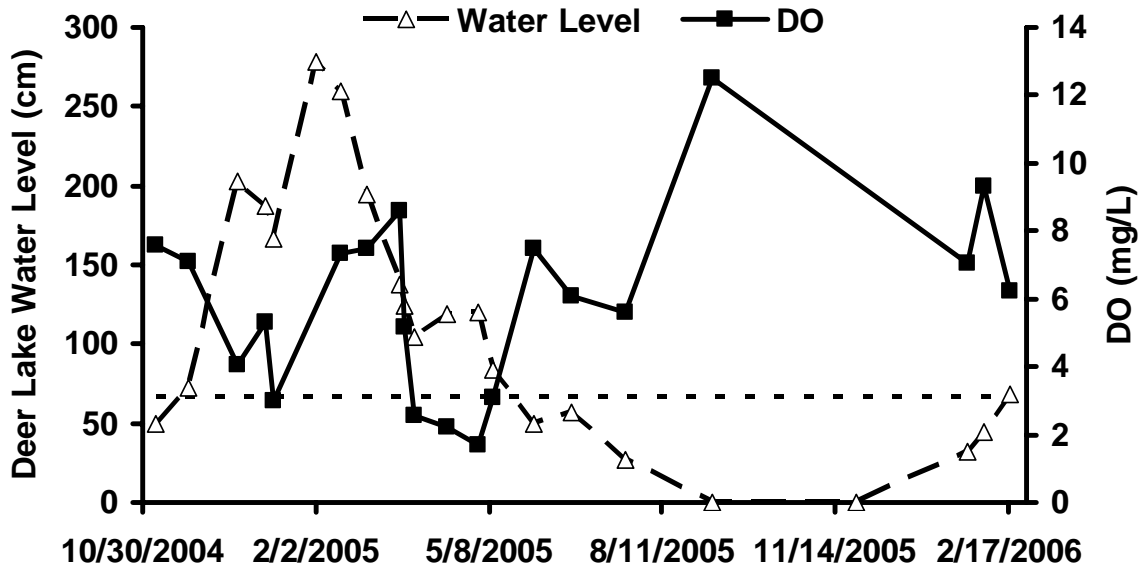


Figure 16. DO and water level in Deer Lake from 6 November 2004, to 18 February 2006. The horizontal dashed line represents water level of Deer Lake at bank-full level (66 cm). Water remained in the deepest part of Deer Lake even though water level at the staff gage was zero.

DISCUSSION

The timing and duration of the flood pulse is vital to fish and influences their populations (Bryan and Sabins 1979; Junk et al. 1989; Bayley 1995). Many fish in the Atchafalaya River Basin depend on the annual flood pulse for reproductive success (Lambou 1990), and the spawning of many fishes in the Atchafalaya River Basin is timed to coincide with the flood pulse (Holland et al. 1983; Hall and Lambou 1990). Spawning fish depend on the rising waters of the flood pulse to coincide with other variables such as temperature and photoperiod for maximum reproductive success. Decoupling of increasing temperature and rising water can constitute as a disturbance in a large river floodplain system and can negatively affect fish populations (Sparks et al. 1990; Junk et al. 1989). Synchronization of the flood pulse with spawning is also important because the release of nutrients from the floodplain into flood waters triggers increased primary production, which increases available food for newly hatched larvae (Junk et al. 1989). The increased primary production allows fish to grow quickly so that they can reach sufficient size so as to reduce predation losses when water levels are low (Bayley 1995).

An extended flood period allows fish more time on the floodplain for spawning, feeding, and growth (Bayley 1995). Lambou (1990) found that 54% of fish species in the Atchafalaya River Basin use the inundated floodplain for spawning and/or rearing of young and 56% use it for feeding. Spring time high-water years benefit fish populations because of the increased area available for spawning and increased nutrient input from the floodplain floor (Sparks 1995). Larval fish populations are greater (Killgore and Baker 1996) and year-class strength of fish is often stronger when spring time water levels are high (Gallagher 1979; Raibley et al. 1997). Deviations in the flood pulse can

be detrimental to fish populations that rely on the spring high-water levels for access to the floodplain for spawning (Sparks 1995).

The total annual amount of water flowing down the Atchafalaya River at Butte La Rose has decreased since 1959 (Figure 8), making less water available to back water areas of the Atchafalaya River Basin. The decreased amount of water could also magnify the adverse conditions experienced during low-water periods. Floodplain zones II-V will be inundated less often or for a shorter amount of time (Figure 5). Even though spring time high-water may enhance fish populations, if water levels drop to extreme levels as in 2005, some fish populations will experience a large number of mortalities and have reduced numbers for the following year. Consecutive years of extreme low-water could decrease some fish populations in the Atchafalaya River Basin. Aquatic predators such as gar and bowfin might benefit from low-water years because of a higher density of prey. This will also be true for terrestrial predators that will have an easier time capturing food from areas with reduced water level. Extreme low-water years will also result in more dry land area for trees such as bald-cypress to germinate.

The annual flood pulse is important to fishes in the Atchafalaya River Basin; however, each flood brings additional sediment and back water areas in the Atchafalaya River Basin are filling in, reducing their size and capacity. Sedimentation in the Atchafalaya River Basin is expedited by channels dug in the Atchafalaya River Basin which carry large amounts of sediments from the Atchafalaya River into back water areas (van Beek 1979). Since 1932, there has been a net accretion of 2.5 billion m³ of sediment in the Atchafalaya River Basin (Bryan et al. 1999) and the magnitude and frequency of sediment deposition in back water areas is expected to increase as more areas of the

Atchafalaya River Basin become filled (Smith et al. 1986). Sedimentation also impairs water circulation (Hern et al. 1980) and the health of forested wetlands (van Beek 1979). Reduced water surface area will limit the amount of space available for fish during low-water periods, greatly influencing fish populations in the Atchafalaya River Basin. Reduced water surface area can result in spawning failure (Starrett 1951) and in a decrease of foraging area or of shelter needed by larval fish (Pezold 1998). Floodplain simulation studies indicate that the amount of water during high-water periods influences the within-the-year ichthyomass, but 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.

The 2005 flood pulse peaked early, with above average water levels occurring in February. Fish had access to most of the floodplain during the peak of the 2005 flood pulse, but most were not ready to spawn because of the time of year and temperature. Water levels then declined through December with a small increase in September due to rainfall from Hurricane Rita. Water levels from March through December 2005 were all below average with August and December 2005 having the second lowest on record (Table 1). Although water levels dropped to below the Deer Lake staff gage, water still remained in the deepest part of Deer Lake throughout the low-water period. Another low-water refuge, Billy Littles Lake (30° 17' N, 91° 33' W) in the Atchafalaya River Basin, which is approximately 3.6 km southwest of Deer Lake, was completely dry in January 2006 (J. Fontenot, Department of Biological Sciences, Nicholls State University, personal communication), and all fish presumably perished.

As flood waters begin to recede, fish get “trapped” in low-water refuges throughout the floodplain. Apparently, not all fish return to the main stem river during low-water periods, and depend on back water areas such as Deer Lake to survive low-water periods. The importance of low-water refuges to fish was demonstrated by this study. Species richness was greatest immediately after Deer Lake became contained within its bank. Water level was the main variable in determining CPUE of spotted gar. When water levels were high and the majority of the floodplain was inundated, CPUE for spotted gar and all fish was zero. Fish were presumably moving out of Deer Lake and onto the floodplain for spawning and feeding. Dugas et al. (1976) showed that during low-water periods, 80% of bowfin sampled contained fish and during high-water periods, 81% contained crawfish, a floodplain species. Snedden et al. (1999) demonstrated that spotted gar move onto the floodplain when water levels and temperatures increase concurrently. As declining water levels in the Atchafalaya River Basin approached bank-full level, relative density of spotted gar and other fish (Appendix I) began to increase. When Deer Lake became isolated from the floodplain, CPUE for spotted gar was greatest.

Deer Lake water temperature was weakly negatively correlated to Deer Lake water level. This was the expected seasonal trends because low-water occurs during summer months and high-water occurs during winter and spring months. Secchi disk depth was positively correlated to Deer Lake water depth and negatively correlated with water temperature and DO. This is to be expected in back water areas of the Atchafalaya River Basin as flood waters recede. The low Secchi disk depth levels recorded in summer, when Deer Lake water level was low, reflects increased primary production due

to nutrient input from the floodplain and temperature increases. Sager and Bryan (1981) reported peak phytoplankton densities in the Atchafalaya River Basin during months when temperatures were high and water levels were low. The increased amount of primary production made the water column more turbid, decreasing Secchi disk depth. The relationships between CPUE and Secchi disk depth and DO were probably a function of increased primary production during low-water periods, when CPUE was at its highest. Although DO and Secchi disk depth were correlated to CPUE, the correlations were probably artifacts of the influence of water level and season on all variables.

Recaptures of only three spotted gar resulted in a large 95% confidence interval, but the spotted gar population estimation of 2,079 individuals was within the confidence interval. Standing stock biomass of all gars and bowfin, based on rotenone samples, for the lower ARB was estimated to be 243 kg/ha (Bryan and Sabins 1979). This study estimated approximately 214.5 kg of spotted gar per hectare. Several large bowfin were also collected, but unfortunately their standing stock could not be determined. The biomass of spotted gar in Deer Lake was among the highest recorded. This high abundance of top predators could be part of the reason species richness declined over the low-water period.

Results of this study demonstrate the importance of low-water refuges in the Atchafalaya River Basin to fishes. CPUE of spotted gar and other fish species were higher during low-water periods than during high-water periods, showing that these fish depend on low-water refuges during periods of low-water. These low-water refuges are very important in extremely low-water years such as 2005. At least one low-water refuge in the Atchafalaya River Basin completely dried up in 2005, eliminating any fish

inhabiting that area. Fish populations will decline during extreme low-water years because of reduced water area, food, and high predation rates. When sampling began again in Deer Lake in January 2006, spotted gar and bowfin, both top predators, were caught in abundance but other species of fish were not. The smaller water column resulted in reduced refuge for fish and concentrated them near the surface where spotted gar tend to forage (Ostrand et al. 2004). Commercial fish species have been shown to decrease over 50% following a low-water year, while predator species increased (Bryan and Sabins 1979). Also, spotted gar and bowfin have been shown to be able to tolerate high nitrite concentrations (Boudreaux 2005) which might have existed in Deer Lake because of low-water levels and high densities of fish. Extreme low-water events may have significant impacts on fisheries in the Atchafalaya River Basin.

RECOMMENDATIONS

Efforts should be made to allow more water into the Atchafalaya River when summer time levels are falling at an accelerated rate. While a low-water period is important to the overall function of the Atchafalaya River Basin, if the water recedes too fast, low-water refuges have a longer period to dry out. Indeed, the time that a low-water refuge is isolated from the main stem river can be critical in determining whether or not it dries out.

Finally, there are very few published studies that determine the effect of low-water period duration on year-class strength of fish. A multiple year study is necessary to determine critical low-water levels in the Atchafalaya River Basin.

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APPENDIX I

Appendix I. Total number of spotted gar (# SG) collected and CPUE in each net during relative density sampling. Fish time (number of minutes nets were in the water), percent hour, and the corresponding Deer Lake (DL) and Atchafalaya River (AR) water levels (cm) are listed.

Date	Net	# SG	Fish Time	% Hour	CPUE	DL Level	AR Level
11/6/2004	1	16	37	0.62	25.95	50	177.8
11/6/2004	2	32	42	0.70	45.71	50	177.8
11/6/2004	3	7	36	0.60	11.67	50	177.8
11/24/2004	1	9	36	0.60	15.00	72	248.9
11/24/2004	2	27	42	0.70	38.57	72	248.9
11/24/2004	3	9	38	0.63	14.21	72	248.9
12/21/2004	1	0	35	0.58	0.00	203	406.4
12/21/2004	2	0	36	0.60	0.00	203	406.4
12/21/2004	3	0	35	0.58	0.00	203	406.4
12/21/2004	1	0	31	0.52	0.00	203	406.4
12/21/2004	2	0	32	0.53	0.00	203	406.4
12/21/2004	3	0	31	0.52	0.00	203	406.4
1/5/2005	1	0	61	1.02	0.00	187	327.7
1/5/2005	2	0	62	1.03	0.00	187	327.7
1/5/2005	3	0	65	1.08	0.00	187	327.7
1/10/2005	1	0	40	0.67	0.00	167	342.9
1/10/2005	2	0	43	0.72	0.00	167	342.9
1/10/2005	3	0	46	0.77	0.00	167	342.9
2/16/2005	1	0	34	0.57	0.00	260	396.2
2/16/2005	2	0	32	0.53	0.00	260	396.2
2/16/2005	3	0	34	0.57	0.00	260	396.2
3/2/2005	1	0	30	0.50	0.00	195	365.8
3/2/2005	2	0	31	0.52	0.00	195	365.8
3/2/2005	3	0	32	0.53	0.00	195	365.8
3/20/2005	1	0	55	0.92	0.00	138	261.6
3/20/2005	2	0	56	0.93	0.00	138	261.6
3/20/2005	3	2	59	0.98	2.03	138	261.6
3/23/2005	1	1	56	0.93	1.07	124	256.5
3/23/2005	2	0	58	0.97	0.00	124	256.5
3/23/2005	3	1	61	1.02	0.98	124	256.5
3/28/2005	1	1	60	1.00	1.00	104	221
3/28/2005	2	0	59	0.98	0.00	104	221
3/28/2005	3	0	62	1.03	0.00	104	221
4/15/2005	1	3	62	1.03	2.90	119	322.6
4/15/2005	2	0	67	1.12	0.00	119	322.6
4/15/2005	3	1	70	1.17	0.86	119	322.6
5/2/2005	1	0	59	0.98	0.00	120	223.5
5/2/2005	2	1	63	1.05	0.95	120	223.5

Date	Net	# SG	Fish Time	% Hour	CPUE	DL Level	AR Level
5/2/2005	3	0	64	1.07	0.00	120	223.5
5/10/2005	1	3	62	1.03	2.90	84	218.4
5/10/2005	2	4	78	1.30	3.08	84	218.4
5/10/2005	3	5	89	1.48	3.37	84	218.4
6/2/2005	1	8	60	1.00	8.00	50	170.2
6/2/2005	2	14	81	1.35	10.37	50	170.2
6/2/2005	3	30	106	1.77	16.98	50	170.2
6/22/2005	1	0	30	0.50	0.00	57	147.3
6/22/2005	2	10	38	0.63	15.79	57	147.3
6/22/2005	3	15	54	0.90	16.67	57	147.3
7/22/2005	1	4	23	0.38	10.43	27	121.9
7/22/2005	2	18	28	0.47	38.57	27	121.9
7/22/2005	3	2	19	0.32	6.32	27	121.9
7/22/2005	4	2	18	0.30	6.67	27	121.9
1/26/2006	1	11	53	0.88	12.45	32	124.5
1/26/2006	2	1	36	0.60	1.67	32	124.5
1/26/2006	3	5	35	0.58	8.57	32	124.5
2/4/2006	1	4	31	0.52	7.74	45	271.8
2/4/2006	2	8	38	0.63	12.63	45	271.8
2/4/2006	3	10	45	0.75	13.33	45	271.8
2/18/2006	1	6	37	0.62	9.73	68	195.6
2/18/2006	2	4	42	0.70	5.71	68	195.6
2/18/2006	3	6	45	0.75	8.00	68	195.6

APPENDIX II

Appendix II. Number of each fish species collected and CPUE for each net during relative density sampling and fish time (number of minutes nets were in the water).

Date	Net	Species	#	Fish Time	CPUE
11/6/2004	1	<i>Amia calva</i>	3	37	4.86
11/6/2004	2		0	42	0.00
11/6/2004	3	<i>Ameiurus melas</i>	2	36	3.33
11/24/2004	1	<i>Amia calva</i>	1	36	1.67
11/24/2004	2	<i>Ameiurus melas</i>	1	42	1.43
11/24/2004	2	<i>Dorosoma cepedianum</i>	1	42	1.43
11/24/2004	3		0	38	0.00
11/24/2004	3	<i>Dorosoma cepedianum</i>	3	38	4.74
12/21/2005	1		0	35	0.00
12/21/2005	2		0	36	0.00
12/21/2005	3		0	35	0.00
12/21/2005	1		0	31	0.00
12/21/2005	2		0	32	0.00
12/21/2005	3		0	31	0.00
1/5/2005	1		0	61	0.00
1/5/2005	2		0	62	0.00
1/5/2005	3		0	65	0.00
1/10/2005	1		0	40	0.00
1/10/2005	2		0	43	0.00
1/10/2005	3		0	46	0.00
2/16/2005	1		0	34	0.00
2/16/2005	2		0	32	0.00
2/16/2005	3		0	34	0.00
3/2/2005	1	<i>Dorosoma cepedianum</i>	1	30	2.00
3/2/2005	2	<i>Dorosoma cepedianum</i>	1	31	1.92
3/2/2005	3		0	32	0.00
3/20/2005	1		0	55	0.00
3/20/2005	2		0	56	0.00
3/20/2005	3		0	59	0.00
3/23/2005	1	<i>Dorosoma cepedianum</i>	2	56	2.15
3/23/2005	2		0	58	0.00
3/23/2005	3	<i>Dorosoma cepedianum</i>	2	61	1.96
3/28/2005	1		0	60	0.00
3/28/2005	2	<i>Ameiurus melas</i>	2	59	2.04
3/28/2005	3		0	62	0.00
4/15/2005	1		0	62	0.00
4/15/2005	2		0	67	0.00
4/15/2005	3		0	70	0.00
5/2/2005	1	<i>Ameiurus melas</i>	1	59	1.02
5/2/2005	1	<i>Lepomis gulosus</i>	1	59	1.02

Date	Net	Species	#	Fish Time	CPUE
5/2/2005	1	<i>Ameiurus natalis</i>	1	59	1.02
5/2/2005	2		0	63	0.00
5/2/2005	3	<i>Dorosoma cepedianum</i>	1	64	0.94
5/10/2005	1	<i>Amia calva</i>	2	62	1.96
5/10/2005	1	<i>Ameiurus melas</i>	2	62	1.96
5/10/2005	1	<i>Dorosoma cepedianum</i>	4	62	3.92
5/10/2005	1	<i>Ameiurus natalis</i>	1	62	0.98
5/10/2005	2	<i>Ameiurus melas</i>	5	78	4.24
5/10/2005	2	<i>Ameiurus natalis</i>	7	78	5.93
5/10/2005	2	<i>Lepomis gulosus</i>	1	78	0.85
5/10/2005	2	<i>Pomoxis nigromaculatus</i>	1	78	0.85
5/10/2005	2	<i>Atractosteus spatula</i>	2	78	1.69
5/10/2005	3	<i>Dorosoma cepedianum</i>	2	89	1.55
5/10/2005	3	<i>Pomoxis nigromaculatus</i>	1	89	0.78
5/10/2005	3	<i>Atractosteus spatula</i>	2	89	1.55
6/2/2005	1	<i>Micropterus salmoides</i>	1	60	1.00
6/2/2005	2	<i>Mugil cephalus</i>	1	81	0.74
6/2/2005	2	<i>Amia calva</i>	2	81	1.48
6/2/2005	2	<i>Micropterus salmoides</i>	3	81	2.22
6/2/2005	2	<i>Ameiurus melas</i>	1	81	0.74
6/2/2005	3	<i>Micropterus salmoides</i>	1	106	0.56
6/2/2005	3	<i>Dorosoma cepedianum</i>	1	106	0.56
6/2/2005	3	<i>Amia calva</i>	2	106	1.13
6/2/2005	3	<i>Lepomis gulosus</i>	1	106	0.56
6/2/2005	3	<i>Pomoxis nigromaculatus</i>	1	106	0.56
6/2/2005	3	<i>Cyprinus carpio</i>	1	106	0.56
6/22/2005	1	<i>Amia calva</i>	2	30	4.00
6/22/2005	2	<i>Dorosoma cepedianum</i>	1	38	1.58
6/22/2005	2	<i>Micropterus salmoides</i>	3	38	4.74
6/22/2005	2	<i>Atractosteus spatula</i>	1	38	1.58
6/22/2005	2	<i>Amia calva</i>	1	38	1.58
6/22/2005	3	<i>Dorosoma cepedianum</i>	2	54	2.22
6/22/2005	3	<i>Pomoxis nigromaculatus</i>	2	54	2.22
6/22/2005	3	<i>Amia calva</i>	1	54	1.11
7/22/2005	1	<i>Ameiurus melas</i>	1	23	2.63
7/22/2005	1	<i>Amia calva</i>	1	23	2.63
7/22/2005	2	<i>Micropterus salmoides</i>	1	28	2.13
7/22/2005	2	<i>Pomoxis nigromaculatus</i>	1	28	2.13
7/22/2005	3	<i>Amia calva</i>	3	19	9.38
7/22/2005	3	<i>Pomoxis nigromaculatus</i>	3	19	9.38
7/22/2005	3	<i>Dorosoma cepedianum</i>	2	19	6.25
7/22/2005	4	<i>Amia calva</i>	2	18	6.67
1/26/2006	1	<i>Amia calva</i>	1	53	1.14
1/26/2006	2		0	36	0.00
1/26/2006	3	<i>Amia calva</i>	1	35	1.72

Date	Net	Species	#	Fish Time	CPUE
2/4/2006	1	<i>Amia calva</i>	5	31	9.62
2/4/2006	2	<i>Amia calva</i>	4	38	6.35
2/4/2006	3		0	45	0.00
2/18/2006	1		0	37	0.00
2/18/2006	2	<i>Amia calva</i>	1	42	1.43
2/18/2006	3	<i>Amia calva</i>	1	45	1.33
2/18/2006	3	<i>Dorosoma cepedianum</i>	1	45	1.33
2/18/2006	3	<i>Ameiurus natalis</i>	1	45	1.33

APPENDIX III

Appendix III. Mean monthly Atchafalaya River Stage (m) at Butte La Rose, LA, USACE gage #03120 from 1959-2005.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1959	3.20	6.40	6.64	6.10	5.30	4.91	3.26	3.38	2.50	4.21	3.54	4.42
1960	6.22	6.25	6.22	6.86	6.43	5.61	5.09	3.11	2.74	2.26	2.53	3.20
1961	3.93	3.60	7.28	7.92	7.74	7.16	4.69	4.33	3.38	3.75	4.05	6.19
1962	6.52	7.32	7.74	7.99	6.61	4.97	3.66	2.83	2.56	2.83	2.68	2.65
1963	2.96	2.65	5.03	6.46	3.69	3.17	1.83	1.52	1.04	0.73	0.70	0.88
1964	1.25	1.98	4.94	6.61	3.23	0.88	0.91	1.01	1.07	1.65	1.16	3.72
1965	4.24	5.15	6.13	6.95	5.97	3.90	2.77	1.80	2.35	3.44	1.71	1.52
1966	2.87	2.77	2.99	3.32	6.61	4.33	1.77	1.34	1.13	1.01	1.16	2.19
1967	2.41	2.26	3.66	4.63	5.46	4.85	4.11	2.16	1.31	1.19	2.01	3.54
1968	5.27	5.12	3.66	6.49	5.49	6.10	3.51	2.47	1.49	1.37	1.55	3.81
1969	3.87	6.25	5.18	5.76	6.13	3.90	4.18	2.83	1.46	1.77	1.74	2.01
1970	3.60	3.35	4.57	5.09	6.37	4.72	2.32	1.62	1.40	2.87	3.11	2.44
1971	3.78	3.57	5.76	3.78	3.72	2.96	1.83	2.13	1.52	1.40	1.46	3.69
1972	4.85	3.84	4.48	4.08	5.46	2.56	2.56	2.13	1.68	2.13	4.33	5.70
1973	6.25	6.40	6.25	7.74	8.20	7.28	4.91	3.02	2.50	3.23	3.35	5.49
1974	6.04	6.80	5.82	5.97	5.49	6.07	4.97	2.10	3.44	2.71	3.87	4.79
1975	5.39	5.82	6.55	7.41	6.64	5.61	3.84	2.23	1.62	1.83	1.89	2.32
1976	3.26	3.08	5.06	4.45	3.08	2.19	2.38	0.94	0.67	0.70	0.94	1.07
1977	1.25	1.16	3.60	4.45	2.62	1.13	1.37	1.10	1.65	2.16	2.59	3.84
1978	3.17	3.29	2.99	5.24	4.85	3.60	2.10	1.68	1.28	1.07	0.94	3.29
1979	4.30	4.21	5.67	6.64	6.43	4.72	2.87	2.71	2.68	2.59	2.16	3.57
1980	3.26	2.68	3.23	5.76	4.15	3.02	1.77	1.22	1.34	1.01	0.91	1.16
1981	0.40	1.19	2.29	1.65	2.50	4.33	3.02	2.01	1.28	1.10	1.74	1.22
1982	2.19	4.24	4.36	4.60	3.17	4.11	3.05	1.83	1.68	1.25	1.43	5.15
1983	5.76	4.45	4.18	5.18	6.31	6.10	2.96	1.43	0.94	0.88	1.80	4.45
1984	2.96	2.96	4.66	5.55	5.88	4.85	3.05	1.65	1.01	1.89	3.81	3.93
1985	4.51	3.35	5.61	5.33	3.96	2.56	1.68	1.25	1.46	1.80	3.32	5.21
1986	2.35	3.20	3.32	3.17	2.87	3.66	2.29	1.22	1.13	3.47	3.90	4.45
1987	2.80	2.77	4.57	3.78	2.32	1.89	1.43	0.82	0.85	0.67	1.16	1.89
1988	4.24	4.08	3.44	3.69	1.68	0.67	0.49	0.49	0.64	0.64	0.94	1.95
1989	3.69	3.96	5.39	4.88	3.63	4.05	4.27	1.68	1.62	1.55	1.34	1.13
1990	2.26	4.66	5.27	4.51	4.69	5.52	3.29	1.86	1.46	1.31	1.37	2.10
1991	5.52	4.63	4.72	4.88	5.46	4.33	2.13	0.98	0.91	0.82	1.92	3.93
1992	3.66	2.62	3.72	3.23	2.56	2.16	2.10	2.74	1.40	1.37	1.74	3.84
1993	4.66	3.96	4.63	5.46	5.61	4.27	3.75	4.48	3.11	3.23	2.65	4.24
1994	2.96	4.57	5.39	5.21	5.49	2.71	2.16	1.55	1.07	1.10	1.55	2.65
1995	2.44	3.08	3.60	2.90	4.24	5.58	3.57	1.95	1.07	1.01	1.34	1.28
1996	1.74	3.26	2.71	3.35	4.27	4.91	2.62	1.95	1.19	1.62	2.68	4.27
1997	3.57	4.33	5.64	5.58	4.33	3.99	2.90	1.28	1.04	0.98	1.07	1.40
1998	3.78	4.02	4.60	4.79	5.06	3.44	3.54	1.92	1.19	1.49	1.80	1.98
1999	2.87	5.12	4.27	3.78	4.30	3.32	2.74	1.28	0.76	0.70	0.61	0.94
2000	0.82	0.76	2.50	3.14	1.89	1.89	2.44	1.01	0.76	0.76	1.07	1.34

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	1.95	2.96	4.91	3.69	2.71	3.57	1.92	1.19	1.04	1.28	1.19	3.66
2002	2.96	3.84	2.87	4.97	4.69	4.36	1.58	1.04	1.04	1.58	1.77	2.01
2003	2.90	1.98	4.57	2.68	3.63	4.15	2.38	1.62	1.46	1.16	1.37	2.71
2004	3.11	3.72	3.78	3.05	3.54	4.05	3.57	1.43	1.46	1.62	2.65	4.45
2005	4.72	4.97	3.57	3.41	2.16	1.68	1.28	0.76	1.22	0.88	0.73	0.88

BIOGRAPHICAL SKETCH

Christopher Bonvillain was born on October 30, 1979, in Thibodaux, Louisiana. After graduating from Thibodaux High School in 1997, Chris attended Nicholls State University and Louisiana State University. Chris graduated from Nicholls State University in May of 2004 with a B. S. in Biology with a concentration in Environmental Biology and a minor in Chemistry. Chris then continued his education by enrolling in the graduate program in Marine and Environmental Biology at Nicholls State University. Chris conducted research on the use of low-water refuges in the Atchafalaya River Basin by adult spotted gar. Chris also conducted research on the treatment of shrimp aquaculture wastewater with a sequencing batch reactor. Chris is scheduled to graduate in the Spring of 2006. Chris will either continue his education in a doctorate program or seek employment as a biologist.

CURRICULUM VITAE

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EDUCATION

M. S. Marine and Environmental Biology, May 2006, Nicholls State University, Thibodaux, Louisiana, 70310. Thesis title: The use of a low-water refuge in the Atchafalaya River Basin by adult spotted gar *Lepisosteus oculatus*.

B. S. Biology with a concentration in Environmental Biology and a minor in Chemistry, May 2004, Nicholls State University, Thibodaux, Louisiana 70310.

TEACHING EXPERIENCE

Spring 2005, 2006: Taught experimental techniques in Environmental Biotechnology laboratory.

Fall 2005: Presented lectures on large river floodplain ecology to senior level Ecology class.

RESEARCH EXPERIENCE:

1. The use of a low-water refuge in the Atchafalaya River Basin by adult spotted gar, *Lepisosteus oculatus*.
2. Age determination of larval largemouth bass from hypoxic and normoxic waters using otoliths.
3. Organic and inorganic analysis of shrimp aquaculture waste.
4. Optimization of Carbon:Nitrogen ratios in sequencing batch reactor treatment of shrimp aquaculture waste.

FIELD EXPERIENCE:

Small boat operation, pirogue operation, gill net sampling, water quality monitoring (DO, pH, salinity, specific conductance, Secchi disk depth, ammonia, nitrate, nitrite, phosphorus, BOD, COD, total solids, suspended solids, volatile solids), soil analysis, ATV operation, GPS, local plant identification, oyster lease bottom profiling.

LABORATORY EXPERIENCE:

Care and maintenance of live fish, induced spawning of spotted gar, larvae rearing, water quality monitoring and maintenance, spectrophotometry, organic and inorganic analysis of water and shrimp aquaculture waste.

MEMBERSHIP AND SERVICES:

Louisiana Chapter of the American Fisheries Society
World Aquaculture Society
Louisiana Academy of Sciences
Nicholls State University Biology Society

HONORS AND AWARDS:

2006 1st place, Poster competition, Nicholls State University Research Week Competition
2006 3rd place, Abstract competition, Nicholls State University Research Week Competition
2005 Chancellors List, Nicholls State University
2005/06 R. H. "Dickie" and Charlene Barker Scholarship for Marine and Environmental Biology Excellence
Eagle Scout

PUBLICATIONS:

Bonvillain, C. P. (In Review) The use of a low-water refuge in the Atchafalaya River Basin by adult spotted gar *Lepisosteus oculatus*. M. S. Thesis, Department of Biological Sciences, Nicholls State University.

Fontenot, Q. C., R. Boopathy, and **C. P. Bonvillain**. (In Review) Evaluation of sludge carbon:nitrogen ratios on sequencing batch reactor treatment of wastewater taken from an intensive recirculating shrimp culture system. *Journal of the World Aquaculture Society*.

Bonvillain, C. P. and Q. C. Fontenot. (In Prep) Effect of naturally occurring hypoxia on largemouth bass *Micropterus salmoides* in the Atchafalaya River Basin.

SCIENTIFIC PRESENTATIONS:

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