

## CERTIFICATE

This is to certify that the thesis entitled “Assessment of Water Quality in the Upper Barataria Estuary” submitted for the award of Master of Science to the Nicholls State University is a record of authentic, original research conducted by Mr. Marcel S. Estay 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

An annual flood pulse is one of the most important factors influencing water quality in large river floodplains. Flood protection measures have severed the upper Barataria Estuary from the Mississippi River's annual flood pulse. Water levels in the upper Barataria Estuary are directly affected by unpredictable rain events; therefore water quality patterns in the upper Barataria Estuary may be different from what is expected for a large river floodplain. This study was developed to assess water quality, to evaluate and to better understand the mechanisms that impact water quality in the upper Barataria Estuary. Temperature ( $^{\circ}\text{C}$ ), dissolved oxygen (mg/L), specific conductance (us), salinity (ppt), and Secchi disk depth (cm), were measured at least biweekly at 11 fixed sites from 7 April 2006 to 22 February 2007. Nitrate+nitrite concentration (mg/L) and phosphate concentration (mg/L) were measured at least bimonthly at 11 fixed sites from 23 June 2006 to 22 February 2007. Water level data was obtained from the USGS monitoring site #07380401. The hydrology of this system is driven by rainfall, not an annual flood pulse. As a result, floodplain inundation was sporadic and of short duration. During times of low rainfall, water levels were tidally influenced, with a maximum tidal range of 5.0 cm. Temperature ranged from  $9.2^{\circ}$  to  $32.2^{\circ}\text{C}$ , and followed expected seasonal trends. The mean DO level for all sites and dates combined was  $2.40 \pm 0.11$  mg/L. System-wide mean DO levels were hypoxic for 52% of the sample dates, and for extended periods during low temperatures ( $12 - 16^{\circ}\text{C}$ ). Specific conductance levels increase downstream and are negatively correlated to water level. Thus, saltwater may intrude into the upper Barataria Estuary during drought years. Nutrient concentrations were not constant through time, and may be influenced by urban, industrial and agricultural areas in the

upper Barataria Estuary. Reinstating a seasonal and predictable flood pulse may improve the water quality of the upper Barataria Estuary.

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## INTRODUCTION

A predictable annual flood pulse is one of the most important hydrologic features that regulate production, diversity, and water quality in large river floodplain ecosystems (Junk et al. 1989). The flood pulse of large river systems is characterized by seasonally predictable high and low water periods (Denes and Bayley 1983), and depending on the geographic location of the river, the season of the high water period may vary. For example, the high water period for the Amazon River occurs from September to April during the local rainy season. The Mississippi River typically reaches its peak water level in April as the accumulation of snow melt and spring rains flow down river. During seasonal high water times, water overflows the banks of the river and major distributaries, inundating the adjacent low-lying floodplain. During seasonal low water times, the main stem river and major distributaries remain constrained within their banks and the surrounding floodplain is dry.

As the main stem water level rises at the beginning of a flood pulse, sediment-laden river water is distributed throughout the distributaries and inter-distributaries of the floodplain. The rising water level inundates the low-lying areas of the floodplain and the area of the floodplain that becomes inundated depends on the water level. The velocity of the river water decreases as it moves out of the main channels and onto the floodplain, allowing sediment to settle from the water column. Decomposition of inundated terrestrial vegetation and organic matter on the floodplain releases nutrients into the water column, but decomposition rates at high temperatures may reduce dissolved oxygen (DO) to hypoxic levels (Junk et al. 1989). Therefore, backwater floodplain habitats are usually characterized by low DO levels during the high water period.

As water levels in the main stem river decrease, water levels on the floodplain begin to recede and the distributaries and inter-distributaries become contained within their banks. Decreased water levels concentrate nutrients derived from the decomposing terrestrial organic matter and stimulate primary production. Phytoplankton growth is stimulated by the concentration of nutrients and warm temperatures which cause DO levels to increase. Terrestrial plants grow on the dry floodplain and will provide nutrients, food, and shelter for aquatic organisms the following high water period.

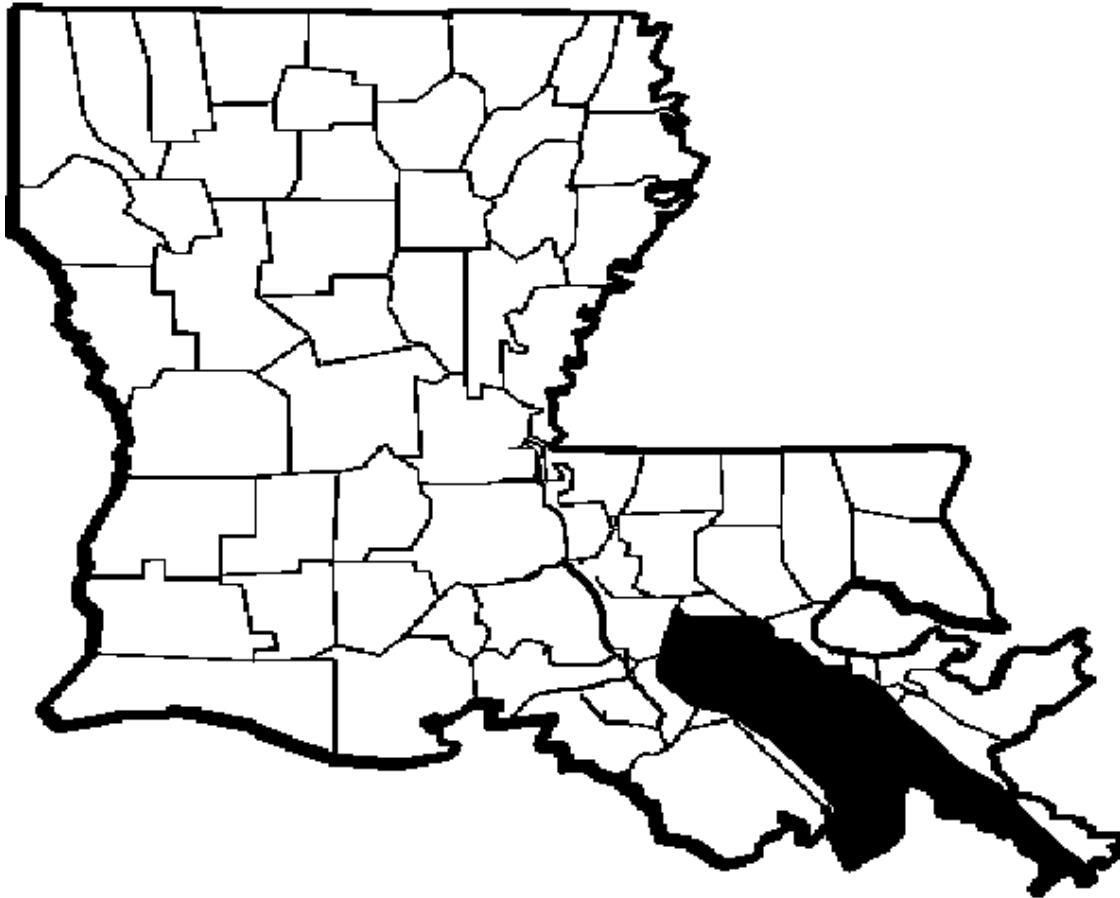
The timing and duration of the flood pulse is important for organisms that have adapted to the predictable rise and fall of water levels (Junk et al. 1989; Bonvillain 2006). Because high water levels provide access to spawning and foraging habitat for many fishes, it is important that high water levels coincide with the seasonal spawning period of floodplain dependent fishes (Harrell 1978; Guillory 1979; Ross and Baker 1983; Walker and Sniffen 1985; Kwak 1988; Lambou 1990). The newly hatched larvae and juveniles of many fishes benefit from the high levels of primary production common to large river floodplains immediately following the flood pulse. If the flood pulse is delayed, high levels of primary production may not overlap with the occurrence of the larval and juvenile stages of many floodplain-spawning fishes.

Many of the worlds large river floodplains have been reduced in size or hydrologically altered (Welcomme 1979), such as the Illinois River Basin, and the northern extent of the Nile River. The largest (approximately 5,000 km<sup>2</sup>) large river floodplain that receives a floodpulse in the United States is the Atchafalaya River Basin (ARB; Lambou 1990). The Atchafalaya River is a major distributary of the Mississippi River receiving 30% of the combined flow of the Red and Mississippi Rivers. The

Atchafalaya River rises and falls concurrently with the Mississippi River and the ARB may be viewed as a model depicting the structure and function of a large river floodplain. The flood pulse of the Atchafalaya River typically reaches its highest level in April and its lowest level in September, although the timing and duration of the high and low water period can vary from year to year (Bonvillain 2006).

The flood pulse has a temporal effect on water quality within the ARB (Sabo et al. 1999). Three distinct types of water have been described for the ARB and are delineated by color (Sabo et al. 1999; Rutherford et al. 2001). Brown water is characterized by a heavy sediment load, low Secchi disk depth (due to sediment load), high current velocity, and moderate DO levels that are usually above 2.0 mg/L. Green water is characterized by low sediment load, low Secchi disk depth (due to abundant phytoplankton), very low current velocity, and very high DO levels that are often greater than 100% saturation during the day. Black water is characterized by a low sediment load, high Secchi disk depth (due to lack of sediment and phytoplankton), low current velocity, and low DO levels that are often below 2.0 mg/L. Brown water is common throughout the ARB when water levels are rising as river water is distributed throughout the distributaries. Black water is especially common in ARB backwater habitats during the high water period after sediment has settled from the water column. Green water is common throughout the ARB during summer-time low water periods as primary production in the water column reaches its peak.

The Barataria Estuary is part of the Barataria-Terrebonne National Estuary and is a diverse wetland ecosystem, located between the Mississippi River and Bayou Lafourche (Figure 1). Bottomland hardwood forest, cypress-tupelo swamps, fresh marsh,



**Figure 1.** The shaded area is the approximate location of the Barataria Estuary in southeastern Louisiana.

intermediate marsh, brackish marsh, and saline marsh are found within the Barataria Estuary situated along a hydrologic and salinity gradient. The Barataria Estuary has little topographic variation and is poorly drained (Braud et al. 2006). This system was historically part of the active floodplain of the Mississippi River, and was created from alluvial deposits delivered by the Mississippi River annual flood pulse (USACE 2004). During high water periods, nutrient and sediment rich water flowed from the Mississippi River through distributaries and inter-distributaries within the Barataria Estuary to the Gulf of Mexico. Low-lying areas within the Barataria Estuary were inundated during high water periods and were dry during low water periods. However, the construction of levees and closing off of distributaries for flood protection along the Mississippi River have severed its connection to the Barataria Estuary (USACE 2004), and are factors that cause Louisiana to lose 65.63 square kilometers of land per year (USACE 2002). Present day short term water level variation in the Barataria Estuary is governed by tides and winds in the lower basin, and weather events in the upper basin, with winds having a more pronounced effect during winter (Conner and Day 1987). The main source of freshwater in the Barataria Estuary is precipitation, however, fresh water can also be introduced into the system through the Davis Pond freshwater diversion which is capable of flowing  $300 \text{ m}^3\text{s}^{-1}$  (Swenson et al. 2006).

Water from the Mississippi River watershed currently bypasses the Barataria Estuary and flows directly to the Gulf of Mexico via the Mississippi River Delta. Bayou Chevreuil, Bayou Citamon, Grand Bayou, and St. James canal are the main drainage channels in the upper Barataria Estuary and are surrounded by bottomland hardwood forest, cypress-water tupelo swamps, and low-lying wetlands. The outer margins of the

upper Barataria Estuary are lined with agriculture (27,709 ha; 38%), and urban lands (9,347 ha; 5.2%; Braud et. al. 2006). The main drainage channels of the upper Barataria Estuary receive runoff from the surrounding agriculture and urban areas. Because of the prominence of agriculture within the upper Barataria Estuary, industrial discharge and agriculture (fertilizer) are common in runoff during frequent and heavy precipitation (Conner and Day 1987). One study in a rural Canadian watershed demonstrated a significant positive relationship between nitrate concentrations during wet seasons and surplus fertilizer applications (Berka et al. 2001).

Increased nutrient loading in water bodies can lead to eutrophication. The chemistry of the Barataria Estuary may have been changed by urban and agricultural runoff and the severance from the Mississippi River. The development and urbanization of the surrounding areas, compounded by channelized agriculture drainage passages, deliver high levels of sediments and nutrients to the upper Barataria Estuary, and have altered the natural hydrology of the basin (Kemp 1985). However, the sediment arises from agriculture fields within the basin, so there is no basin-wide net gain of sediment. Also, nutrients are mostly derived from anthropogenic sources and may not flux similar to nutrients of a pristine large river floodplain.

A major result of the altered hydrology of the Barataria Estuary is eutrophication of the basin's waters and reduced swamp productivity (Conner and Day 1987; Day et al. 1982). Unlike non-modified large river floodplains, the Barataria Estuary is not flushed by an annual flood pulse, therefore the introduction of outside nutrients may have a chronic negative effect on the system. High levels of nitrate ( $\text{NO}_3$ ) and nitrite ( $\text{NO}_2$ ) can indicate anthropogenic influences. In 1978, Kemp estimated that 1.2 million kg of

nitrogen (N) and 130,000 kg of phosphorus (P) enter waterways of the upper Barataria Estuary annually from all upland sources within the basin. Swamps within the Barataria Estuary may effectively remove inorganic nutrients from the percolation of floodwaters (Meo et al. 1975; Kemp 1985), but nutrient removal within canals alone are not efficient at reducing runoff nutrient loads, leading to high nutrient loading into Lac des Allemands (Butler 1975).

Today, the swamps of the Barataria Estuary are inundated only during locally heavy precipitation events (Sklar and Conner 1979). There is no predictable seasonal pattern of frequency of inundation, and the swamp forest is typically only flooded for weeks at a time (Conner and Day 1987). Because the hydrology of the Barataria Estuary is not governed by a predictable flood pulse, seasonal water quality patterns are likely to be different from the expected patterns for a large river floodplain, like the ARB. The purpose of this study was to determine the mechanisms that govern seasonal patterns of water quality within the upper Barataria Estuary.

## METHODS

### Water Quality

To describe water quality trends in the upper Barataria Estuary, 11 fixed sites were sampled periodically between 7 April 2006 and 22 February 2007 (Figure 2). Nautical distance (km) from sites 1, 2, 3, 4, 5, 6, 7, 8, and 9 to the Louisiana Highway 20 bridge (Figure 2) was determined using the measurement tool of Google Earth™ (earth.google.com; Table 1). Dissolved oxygen (DO; mg/L), temperature (°C), and specific conductance ( $\mu\text{s}$ ) were measured approximately 10 cm below the water's surface and approximately 10 cm above the waterway bottom at each site and for each sample date using a handheld oxygen-conductivity-salinity-temperature meter (Yellow Springs Instruments, Yellow Springs, Ohio). Water quality parameters were measured in the middle of the water channel between 1000 and 1600 hours. The mean of surface and bottom measurements was used for analysis. Secchi disk depth (cm) was recorded and water color was noted according to Rutherford et al. (2001). During times of floodplain inundation, black water was clearly moving out of the swamps and into the main channels. On sites where this was evident, Secchi disk depth was measured downstream from where the black swamp water, and brown main channel water mixed. Temperature, DO, specific conductance, and Secchi disk depth were determined from 7 April 2006 to 22 February 2007. All sites were sampled on each sample date, except for 7 April 2006, 31 July 2006, 11 August 2006, 26 August 2006, 23 October 2006, 2 December 2006, and 6 January 2007. On 7 April 2006, only sites 4 – 9 were sampled due to inclement weather. On 31 July 2006, only sites 3 – 11 were sampled because vegetation overgrowth prevented access to some sites. On 11 August 2006, only sites 4-11 were

sampled because vegetation overgrowth prevented access to some sites. On 26 August 2006, only sites 5 – 9 were sampled due to inclement weather. On 23 October 2006, only sites 4 – 11 were sampled due to inclement weather. On 2 December 2006, only sites 6 – 9 were sampled due to inclement weather. On 6 January 2006 only sites 1 – 5 were sampled due to inclement weather. Secchi disk depth was not measured on 7 July 2006.

### **Water Level**

Water level and rainfall was obtained from a United States Geological Survey (USGS) continuous recorder #07380401 located in St. James canal along Louisiana Highway 3127 near Donaldsonville (Figure 2). Water level was recorded every 15 minutes from 7 April 2006 to 22 February 2007. The mean water level was calculated for each day. To investigate water level fluctuations, two low water periods with <5 mm daily rain events were examined (17 May 2006 – 21 May 2006; 26 June 2006 – 30 June 2006). Also, two high water periods with >100 mm daily rain events were examined (20 December 2006 – 27 December; 28 December 2006 – 3 January 2007). Although wind speed and direction can affect water levels in the Barataria Estuary (Hopkinson and Day 1980), I did not attempt to analyze wind effects on water level for this study.

### **Nutrient Analysis**

To determine nitrogen and phosphorus content, approximately 50 ml of surface water was collected at least biweekly from each sample site from 23 June 2006 to 22 February 2007, and was spun in a centrifuge at 3000 RPM's for 10 minutes to remove suspended solids from the sample. All sites were sampled on every sample date, except for 31 July 2006, 11 August 2006, 26 August 2006, 23 October 2006, 2 December 2006, and 6 January 2007. On 31 July 2006, only sites 3 – 11 were sampled because vegetation

overgrowth prevented access to some sites. On 11 August 2006, only sites 4-11 were sampled because vegetation overgrowth prevented access to some sites. On 26 August 2006, only sites 5 – 9 were sampled due to inclement weather. On 23 October 2006, only sites 4–11 were sampled due to inclement weather. On 2 December 2006, only sites 6–9 were sampled due to inclement weather. On 6 January 2006 only sites 1–5 were sampled due to inclement weather.

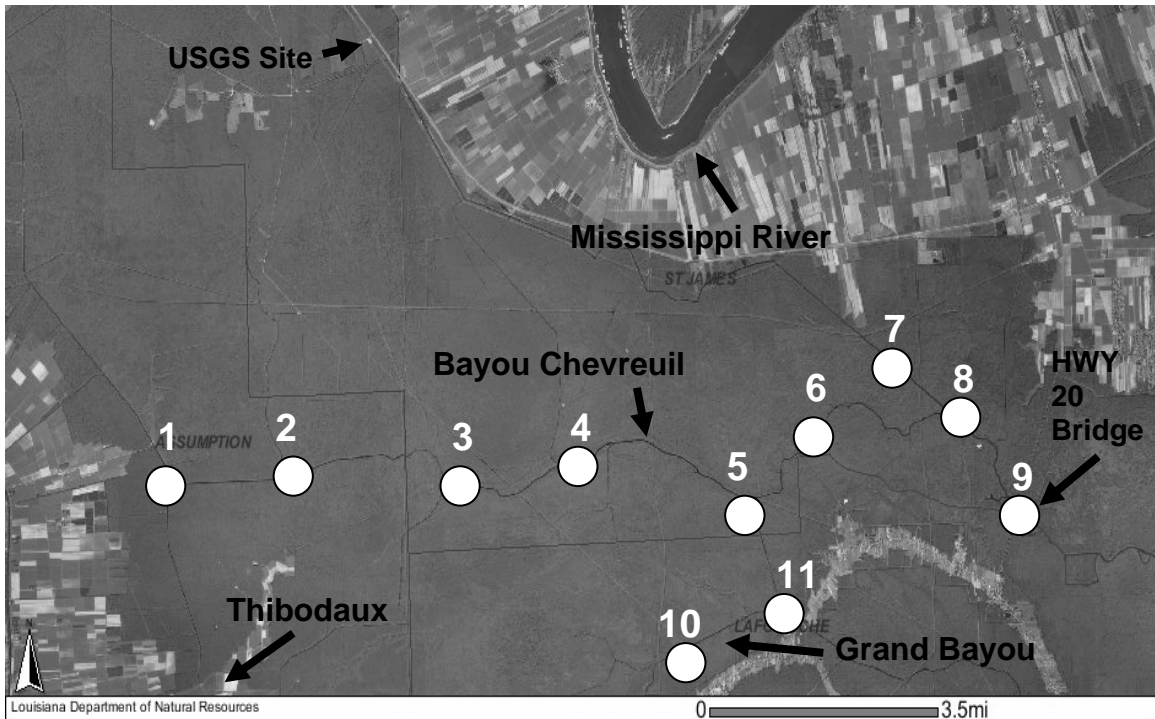
Nitrite-N concentration was measured using a modification of the azo-dye method (USEPA 1974). One hundred  $\mu\text{L}$  of azo-dye and 100  $\mu\text{L}$  of sample water were added to a spectrophotometer tube containing 3 mL of deionized water. The contents of the tubes were allowed to react for 10 minutes, and were then transferred to a spectrophotometer (Gensys 20 Thermo Spec) where concentrations were determined by comparing the sample absorbance at 540 nm to the absorbance of a 5 mg/L standard.

Nitrate-N concentration was measured using NitraVer® 5 Nitrate Reagent powder pillows. The contents of one reagent pillow were added to a cuvet containing 12.5 mL of deionized water and 12.5 of sample water. The cuvetts were shaken for one minute, and allowed to react. After 5 minutes the cuvetts were placed into a spectrophotometer (Hach DR220), and the nitrate-N concentration was measured in mg/L. Nitrate-N and Nitrite-N were combined to give  $\text{NO}_3+\text{NO}_2$ .

Phosphate concentration was measured using PhosVer® 3 Phosphate Reagent powder pillows. The contents of one reagent pillow were added to 25 mL of sample sample. The cuvet was shaken to disperse the reagent. After 2 minutes, the cuvetts were put into a spectrophotometer which measured the phosphate concentration in mg/L.

## **Statistical Analysis**

Means for all water quality parameters, and site specific differences were calculated using analysis of variance ( $\alpha = 0.05$ ; SAS 2003). Regression analysis was used to determine the relationship between distance (km) from the LA Hwy. 20 bridge and specific conductance ( $\mu\text{S}$ ) for sites 1-9 (SAS 2003).



**Figure 2.** Locations of the 11 study sites, Highway 20 bridge, and USGS site in the upper Barataria Estuary. GPS coordinates for each site are: Site 1; 29°55'8.52"N, 90°56'49.76"W: Site 2; 29°55'13.16"N, 90°54'56.92"W: Site 3; 29°55'1.25"N, 90°52'22.71"W: Site 4; 29°55'15.11"N, 90°50'49.62"W: Site 5; 29°54'50.73"N, 90°47'55.41"W: Site 6; 29°55'34.59"N, 90°46'49.14"W: Site 7; 29°56'31.61"N, 90°45'56.57"W: Site 8; 29°55'44.99"N, 90°44'48.27"W: Site 9; 29°54'38.97"N, 90°43'44.03"W: Site 10; 29°53'12.17"N, 90°48'52.06"W: Site 11; 29°53'35.61"N, 90°47'22.68"W.

**Table 1.** Distance (km) from Louisiana Highway 20 bridge to sites 1 – 9 in the upper Barataria Estuary.

<b>Site</b>	<b>Distance</b>
1	24.17
2	21.09
3	16.7
4	14.76
5	9.01
6	7.03
7	4.44
8	2.67
9	0

## RESULTS

Mean monthly rainfall was below the previous five-year monthly mean, for every month except for December 2006 (Figure 3). The mean ( $\pm$ SD) water level for the entire sampling period was  $177.5 \pm 26.9$  cm (Figure 4). Water levels remained between 140 and 200 cm from April 2006 to August 2006. From August 2006 to February 2007, the range of water levels increased, reaching levels  $>260$  cm and  $<140$  cm due to periods of heavy precipitation and drought, respectively. Based on personal observation, the upper Barataria Estuary floodplain is inundated at water levels  $>220$  cm. During this study period, the upper Barataria Estuary floodplain was inundated six times with the longest period of inundation (based on USGS water level  $>220$  cm) lasting 22 days from 21 December 2006 to 11 January 2007 (Table 2). The upper Barataria Estuary water level appears to be tidally influenced during low water periods (Figure 5). When water levels were low ( $<155$  cm), with minimal rain events ( $<5$  mm/day), water level rose and fell on a 24 hour tidal cycle. The maximum 24 hour water level change was approximately 5 cm. During high water periods ( $>250$  mm) water level gradually decreased as water was drained from the upper Barataria Estuary (Figure 6); and did not fluctuate on a 24 hour period.

Brown water was observed frequently in the upper Barataria Estuary. Due to the high occurrence of swamp/main channel mixing, there were often times no clear distinction between black and brown water; however waters with Secchi disk depths  $>70$  cm were considered black, and waters with Secchi discs depths  $<70$  were considered brown. Brown water dominated sites 1 and 7, and black water was most common at sites

10 and 11. Green water was not observed during this study in the upper Barataria Estuary.

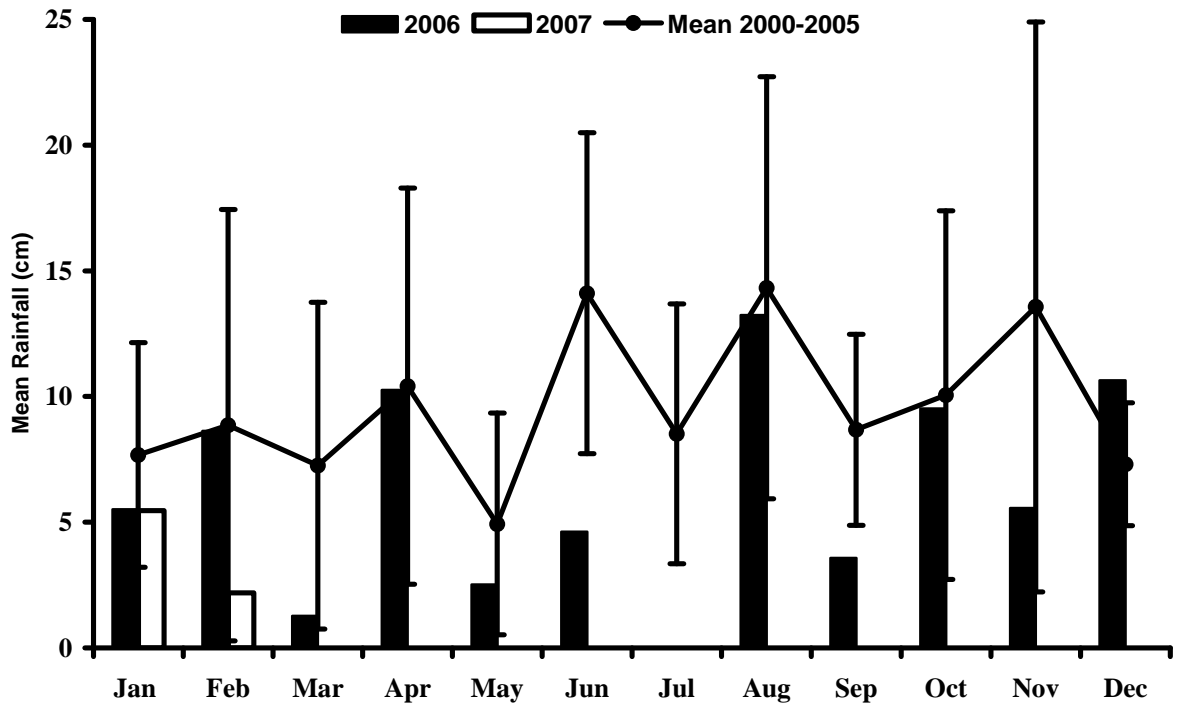
System-wide mean ( $\pm$ SE) water temperature for all sample dates was  $22.6 \pm 0.4^\circ\text{C}$ . The lowest observed temperature was  $8.5^\circ\text{C}$  at site 11 on 12 December 2006, and the highest observed temperature was  $31.8^\circ\text{C}$  at site 10 on 23 June 2006 (Appendix I). The lowest system-wide mean temperature was  $9.5 \pm 0.2^\circ\text{C}$  on 5 December 2006, and the highest system-wide mean temperature was  $30.8 \pm 0.2^\circ\text{C}$  on 23 June 2006 (Figure 7). There was no significant difference among sites for mean temperature for all sample dates combined (Figure 8). April water temperature in the upper Barataria Estuary was higher than previously reported April temperatures in the ARB (Figure 9). System-wide mean ( $\pm$ SE) DO concentration was  $2.40 \pm 0.11$  mg/L; with the lowest mean DO (all 11 sites combined) of  $0.38 \pm 0.06$  mg/L on 12 January 2006 (Figure 10). The highest observed DO was 13.99 mg/L at site 5 on 7 July 2006, and the lowest observed DO was 0.02 mg/L at site 7 on 14 November 2006 (Appendix I). There was no difference among sites for mean DO for all sample dates combined (Figure 11). System-wide mean specific conductance ( $\pm$ SE) was  $332.3 \pm 230.8$   $\mu\text{S}$  (Figure 12). Sites 6 – 9 had a higher mean specific conductance than site 1 (Figure 13), and there is a strong negative relationship ( $r^2 = 0.973$ ) between distance inland from Louisiana Highway 20 and mean specific conductance (Figure 14). System-wide mean ( $\pm$ SE) Secchi disk depth was  $42.84 \pm 1.29$  cm (Figure 15). Sites 1, 2 and 7 had lower mean Secchi disk depths (cm) than sites 4, 5, 6, 10, and 11 (Figure 16).

System-wide mean ( $\pm$ SE)  $\text{NO}_3 + \text{NO}_2$  concentration was  $0.81 \pm 0.39$  mg/L (Figure 17). There were no differences among sites for mean  $\text{NO}_3 + \text{NO}_2$  concentrations for all

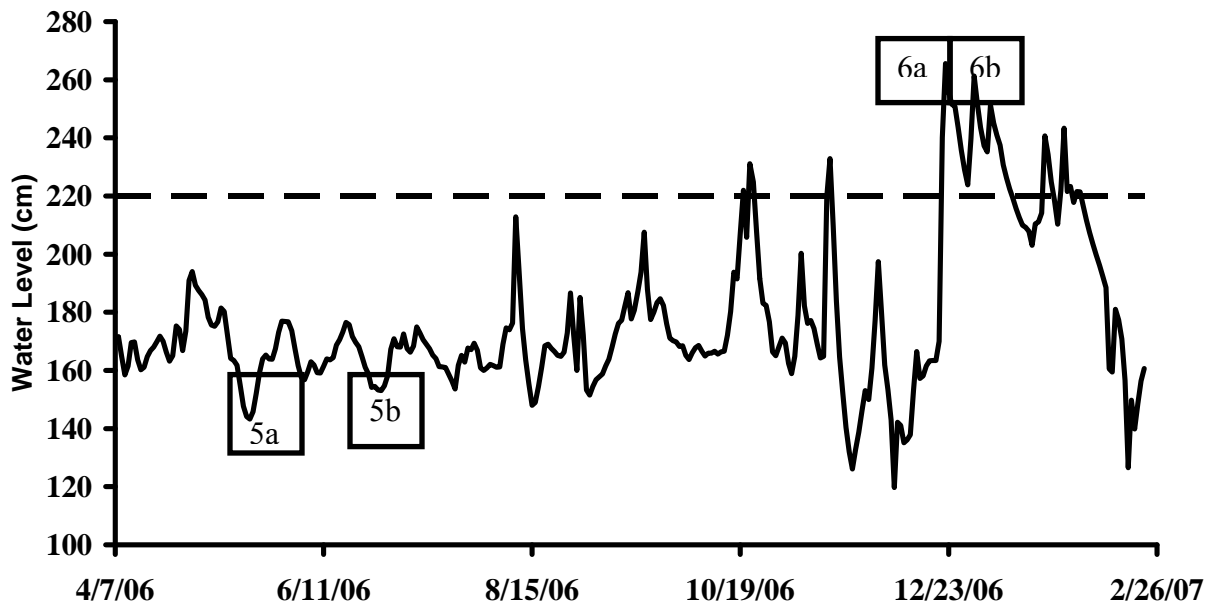
sample dates combined (Figure 18). System-wide mean ( $\pm$ SE) phosphate concentration was  $1.26 \pm 0.58$  mg/L (Figure 19). The mean phosphate concentration for all sample dates combined was higher for site 3 than site 11 (Figure 20).

**Table 2.** Period and duration (days) of floodplain inundation in the upper Barataria Estuary, based on water level greater than 220 cm. Water level data obtained from USGS station #07380401 located in St. James canal along Louisiana Highway 3127 near Donaldsonville.

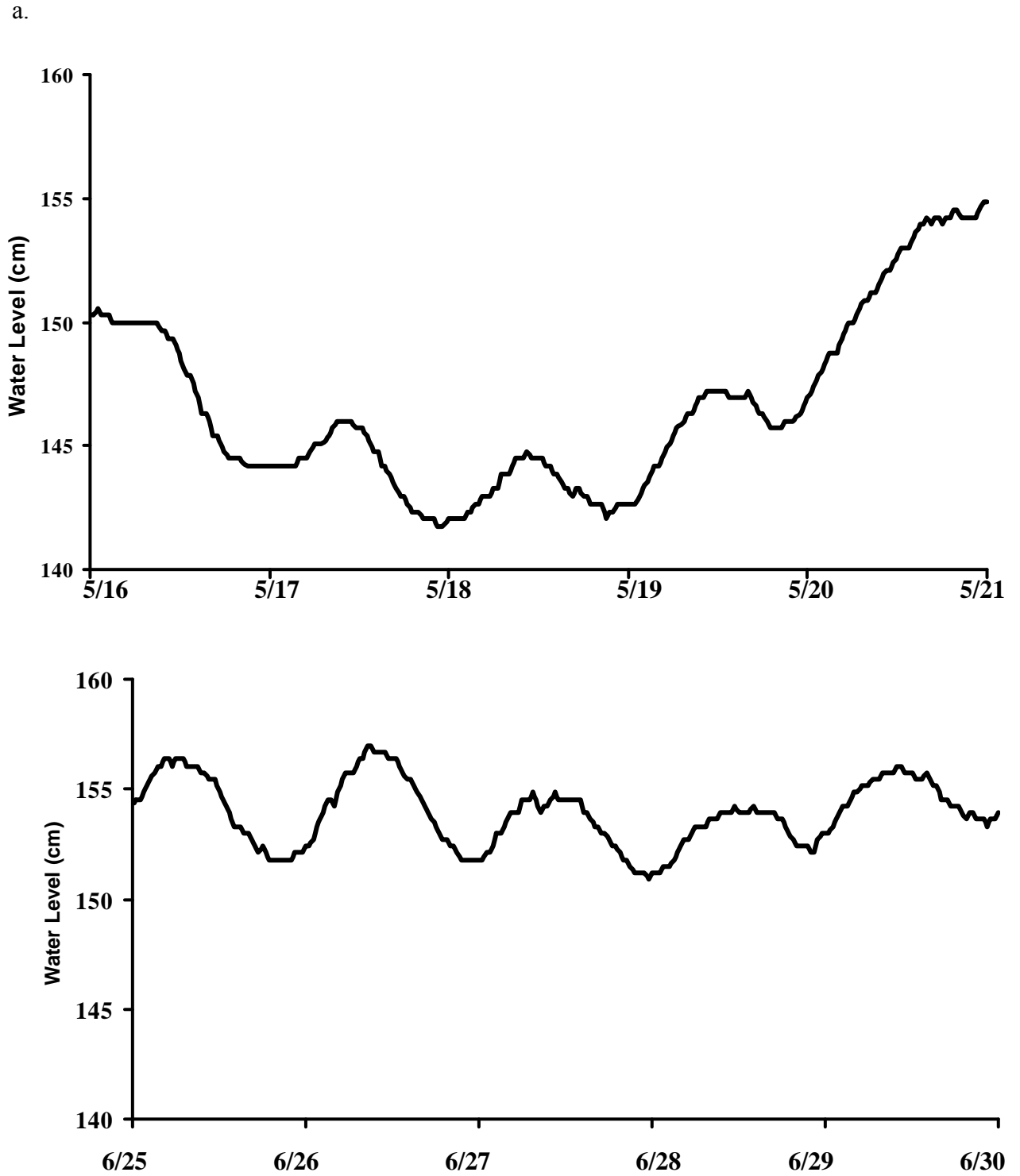
<b>Period of Inundation</b>	<b>Duration</b>
22 October 2006 – 23 October 2006	2
16 November 2006	1
21 December 2006 – 11 January 2007	22
22 January 2007 – 24 January 2007	3
27 January 2007 – 30 January 2007	4
1 February 2007 – 2 February 2007	2



**Figure 3.** Monthly rainfall means ( $\pm$  SD) for the USGS Gauge #07380401 in the upper Barataria Estuary. The solid line represents the 2000-2005 mean rainfall. Data is not available for July 2006.

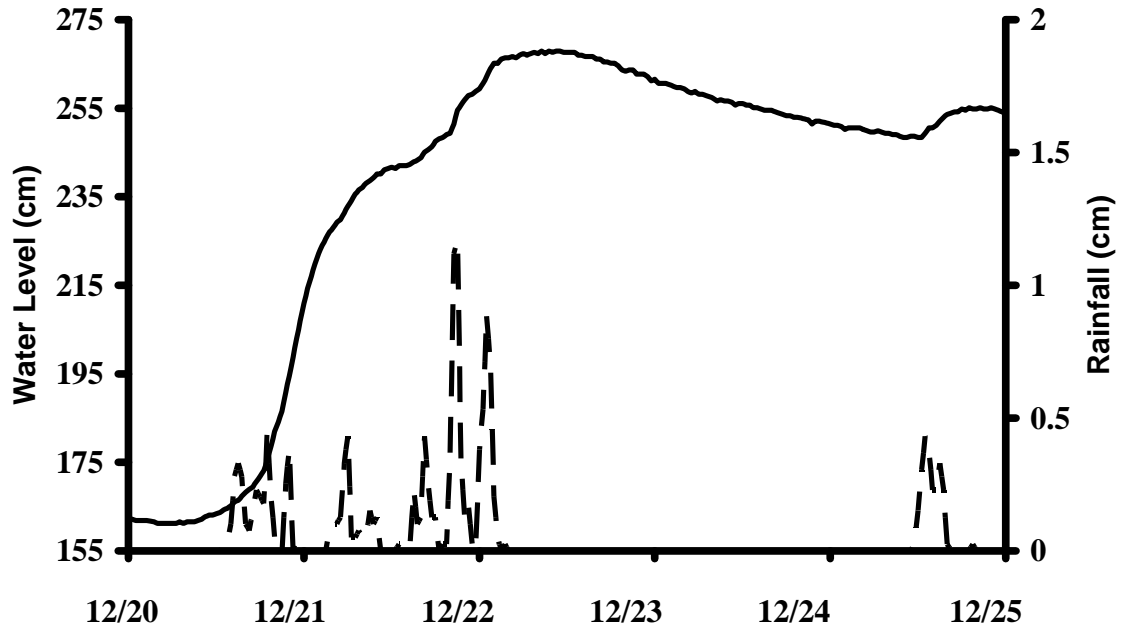


**Figure 4.** Mean daily water level for the upper Barataria Estuary from 7 April 2006 to 22 February 2007. Each labeled square outlines periods used to display 15 minute interval measurements of water level (Figures 4 and 5). The dashed line represents the water level in which the floodplain is inundated.

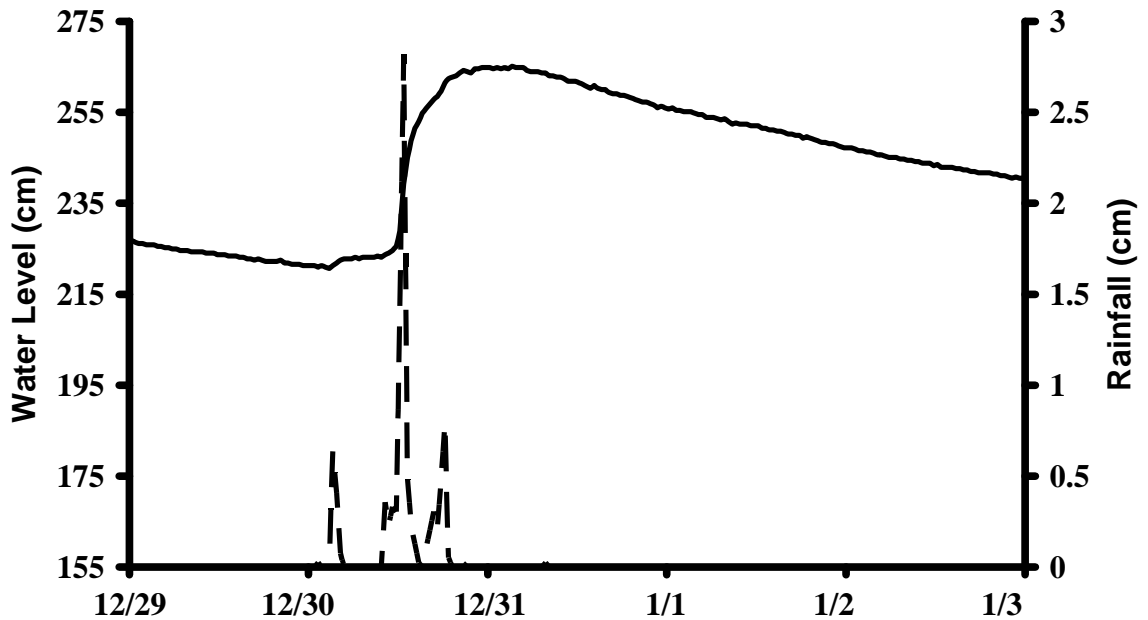


**Figure 5.** Water level measured in 15 minute increments in the upper Barataria Estuary for 17 May 2006 to 21 May 2006 (a) and 26 June 2006 to 30 June 2006 (b). Data obtained from USGS #07380401 located in St. James canal along Louisiana Highway 3127 near Donaldsonville

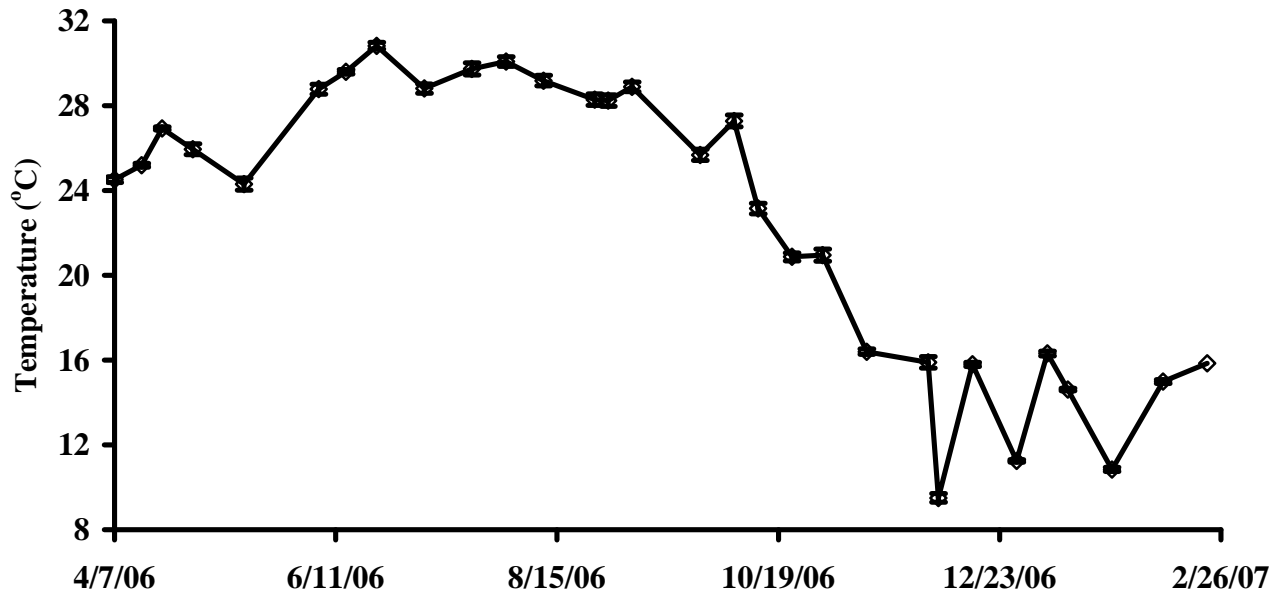
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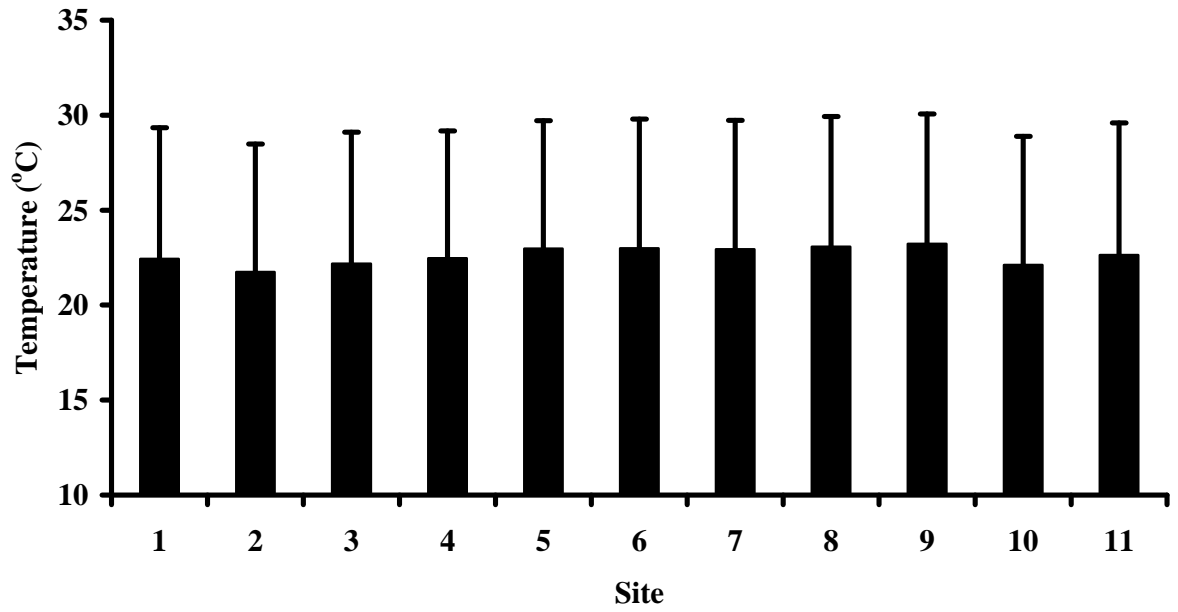
b.



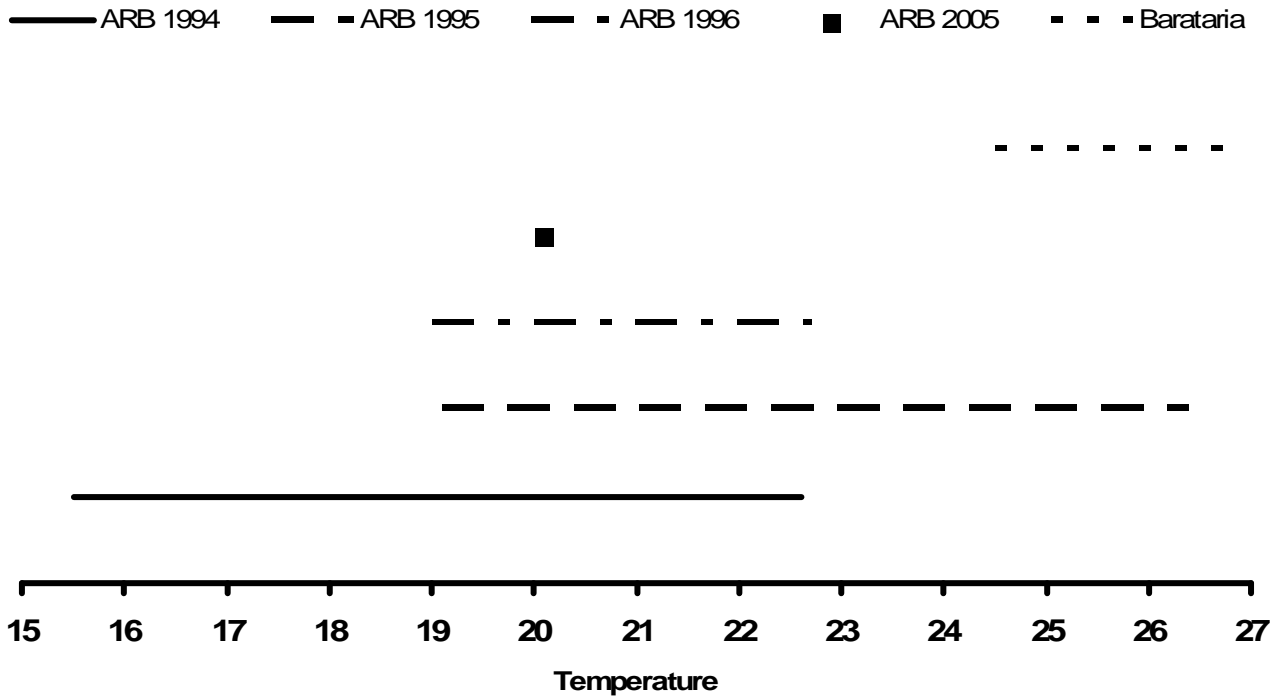
**Figure 6.** Water level (solid line) and rainfall (dashed line) measured in 15 minute increments in the upper Barataria Estuary for 20 December 2006 to 25 December 2006 (a) and 29 December 2006 to 3 January 2006 (b). Data obtained from USGS #07380401 located in St. James canal along Louisiana Highway 3127 near Donaldsonville.



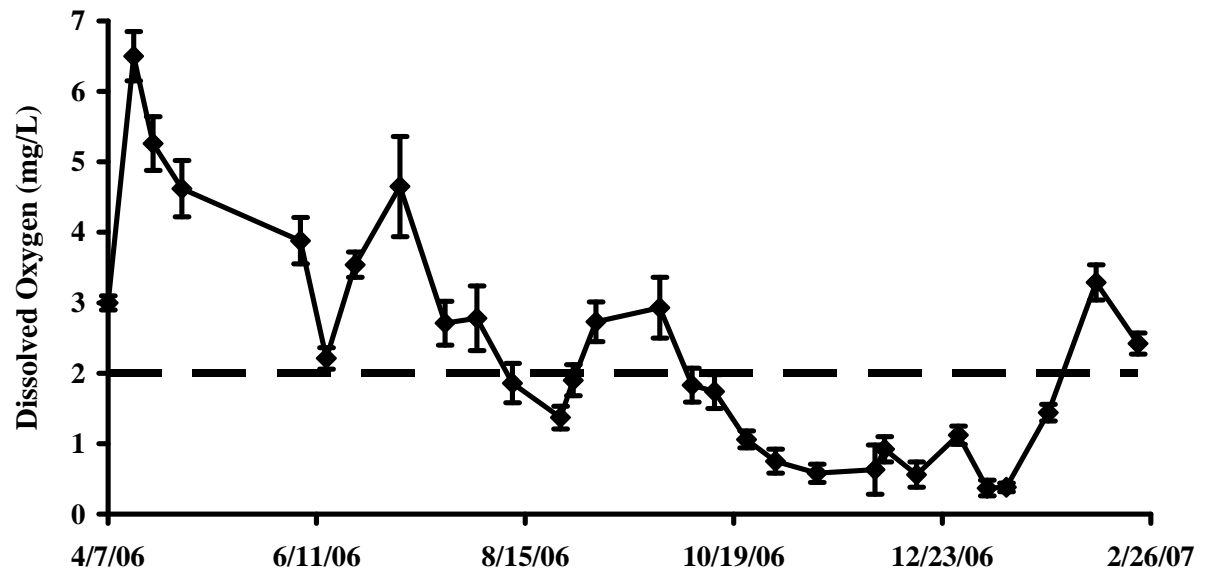
**Figure 7.** Mean ( $\pm$  SE) temperature for all sites combined in the upper Barataria Estuary for each sample date from 7 April 2006 to 22 February 2007 (N=30).



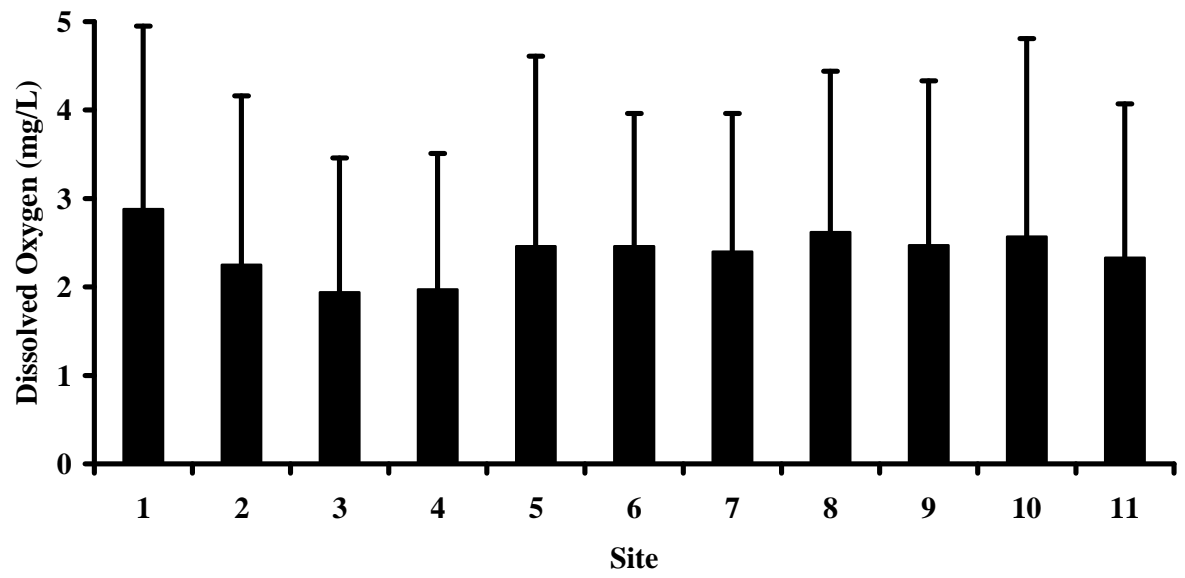
**Figure 8.** Mean ( $\pm$  SD) temperature for all sample dates combined (N=30) in the upper Barataria Estuary for each sample site from 7 April 2006 to 22 February 2007.



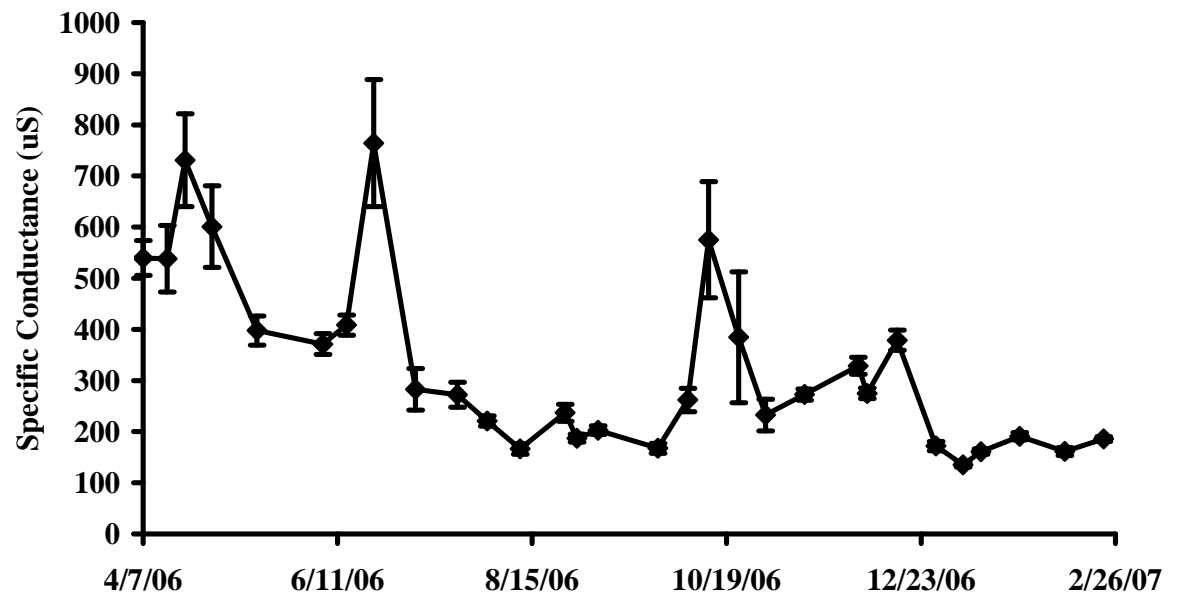
**Figure 9.** April water temperature range recorded in the Atchafalaya River Basin and the upper Barataria Estuary. Atchafalaya River Basin 1994, Landry 1997; Atchafalaya River Basin 1995, Landry 1997; Atchafalaya River Basin 1996, Fontenot 1997; Atchafalaya River Basin 2005, Bonvillain 2006.



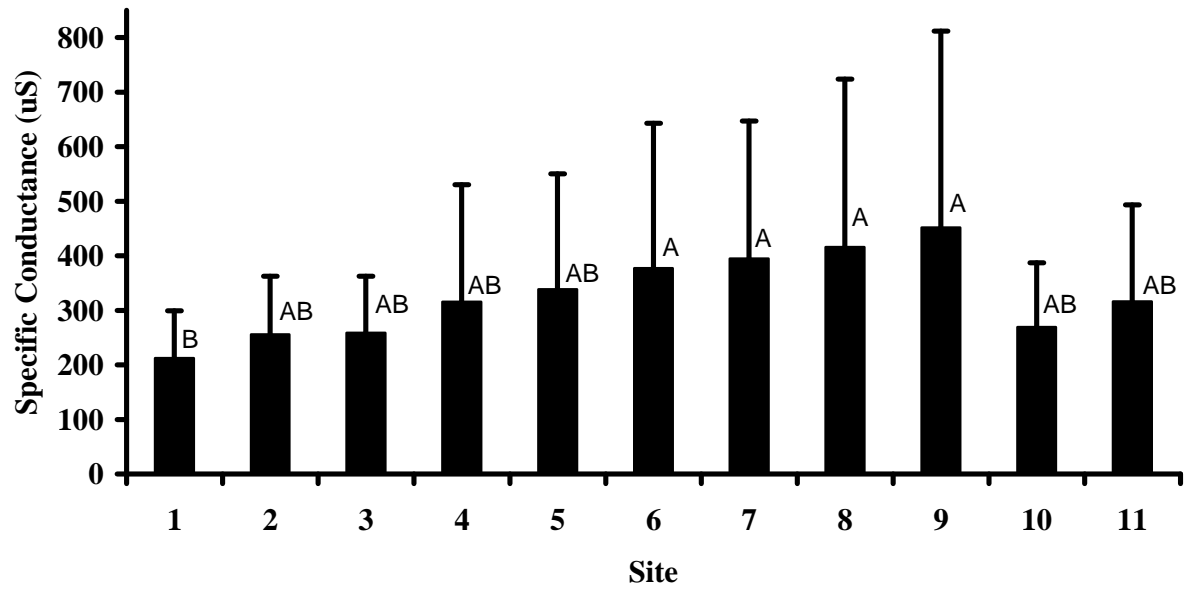
**Figure 10.** Mean ( $\pm$ SE) dissolved oxygen (mg/L) for all sites combined in the upper Barataria Estuary for each sample date. The dashed line marks the hypoxic level of 2.0 mg/L.



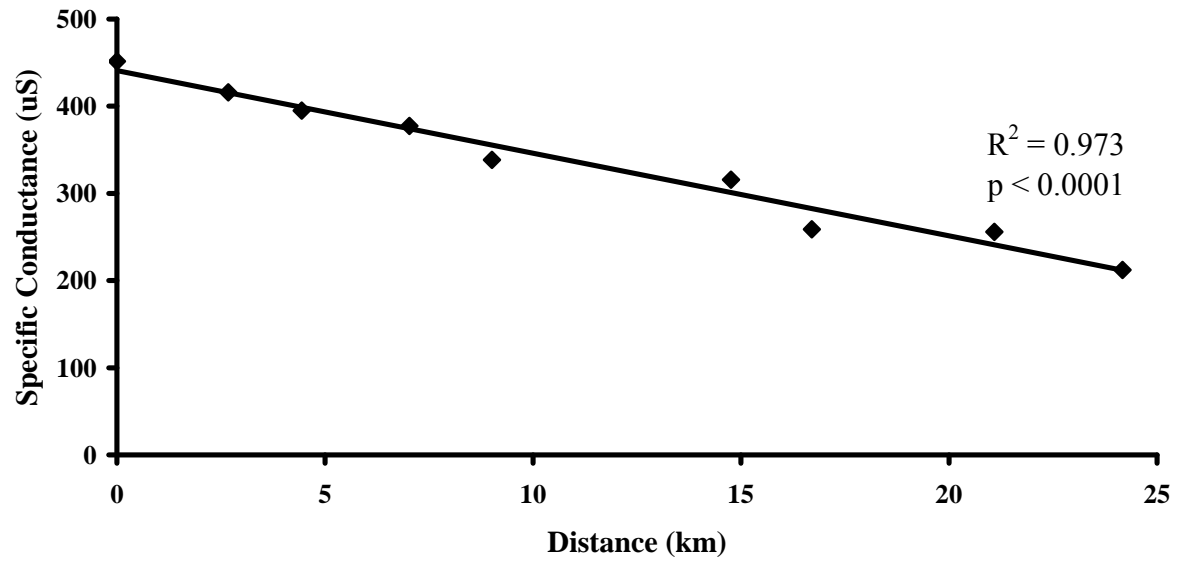
**Figure 11.** Mean ( $\pm$  SD) dissolved oxygen (mg/L) for all sample dates combined in the upper Barataria Estuary for each sample site.



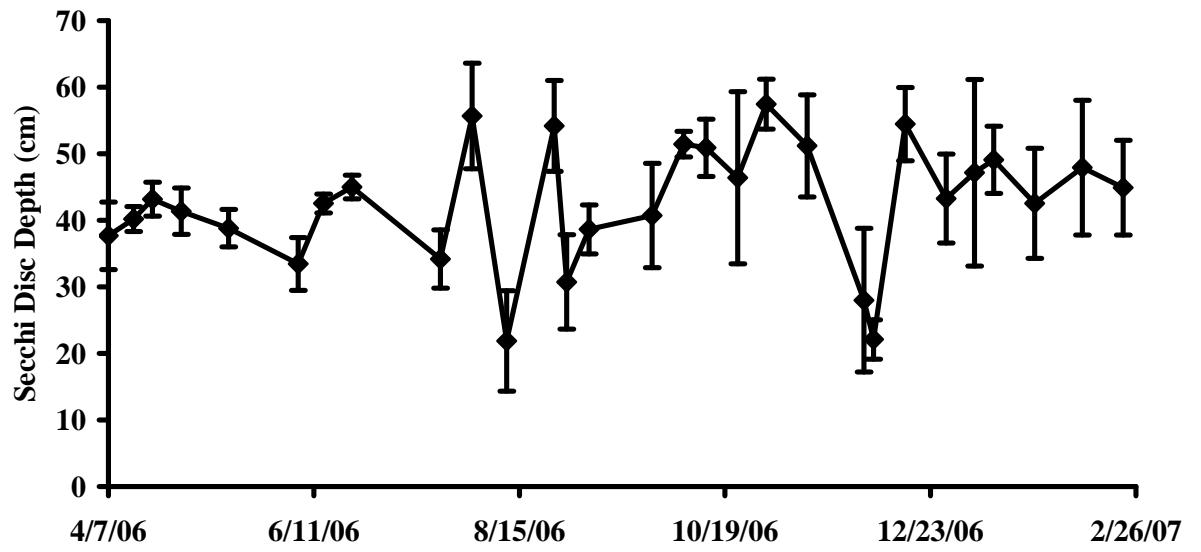
**Figure 12.** Mean ( $\pm$ SE) specific conductance ( $\mu$ S) for all sites combined in the Upper Barataria Estuary for each sample date.



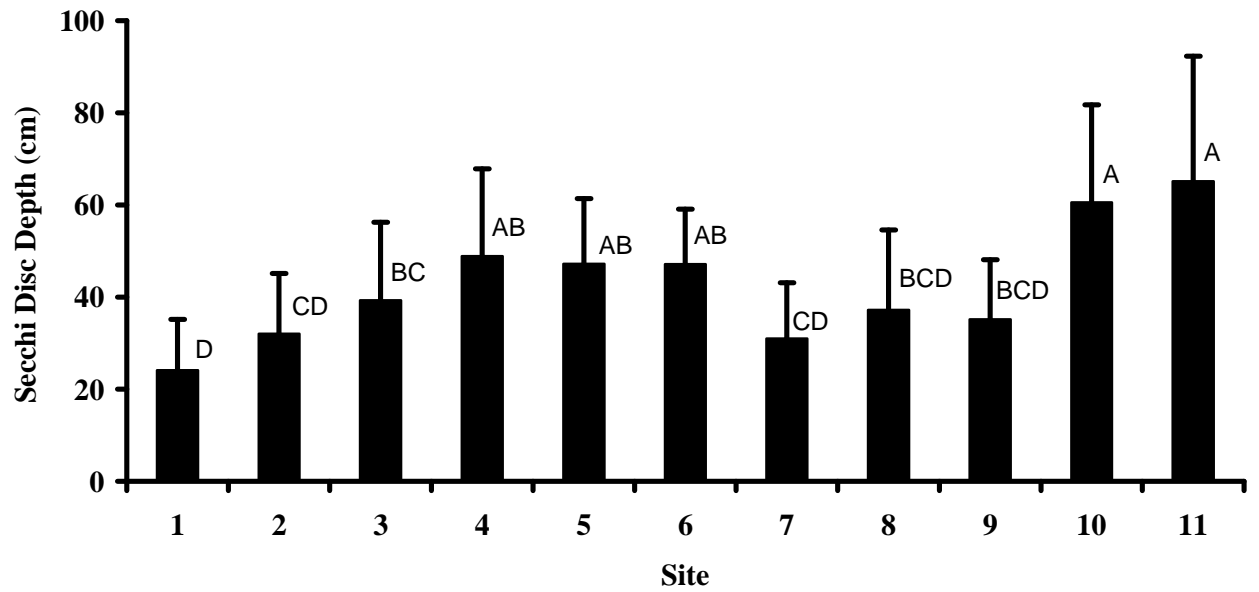
**Figure 13.** Mean ( $\pm$  SD) Specific conductance ( $\mu$ S) for all sample dates combined in the upper Barataria Estuary at each sample site. Means with a similar letter are not different.



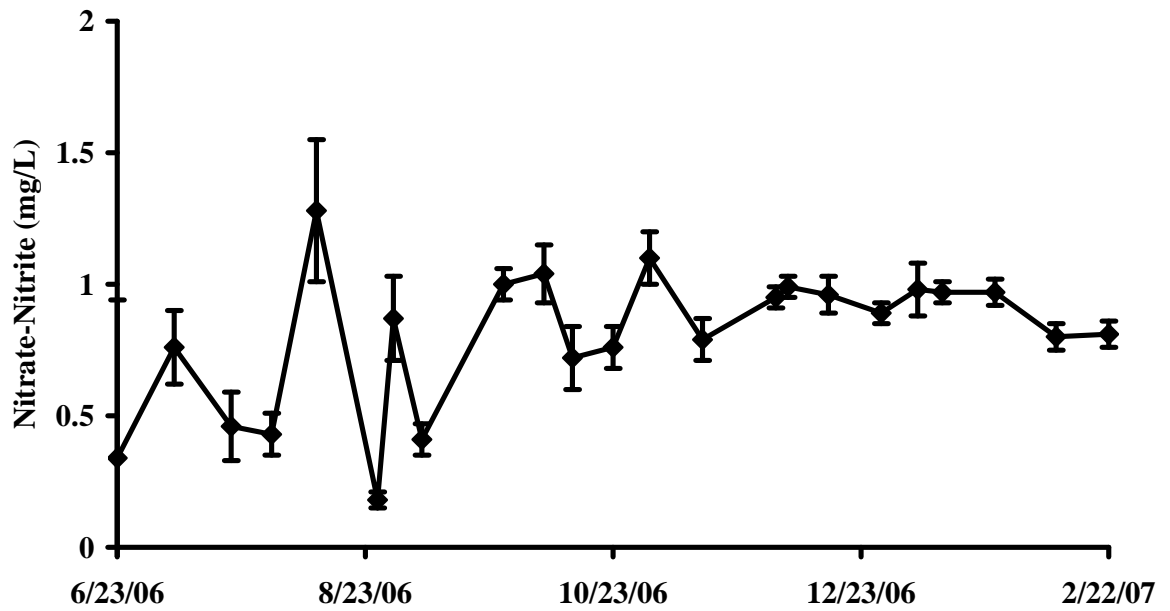
**Figure 14.** Relationship between distance (km) from Louisiana Highway 20 bridge and specific conductance (µS) for sites 1-9.



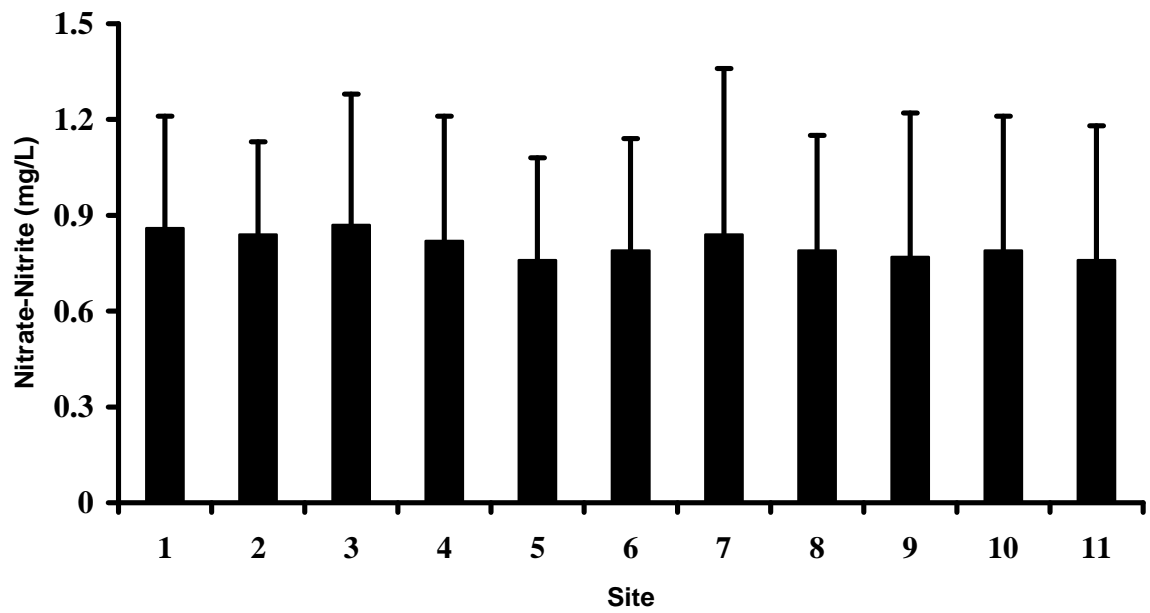
**Figure 15.** Mean ( $\pm$ SE) Secchi disk depth (cm) for all sites combined in the upper Barataria Estuary for each sample date.



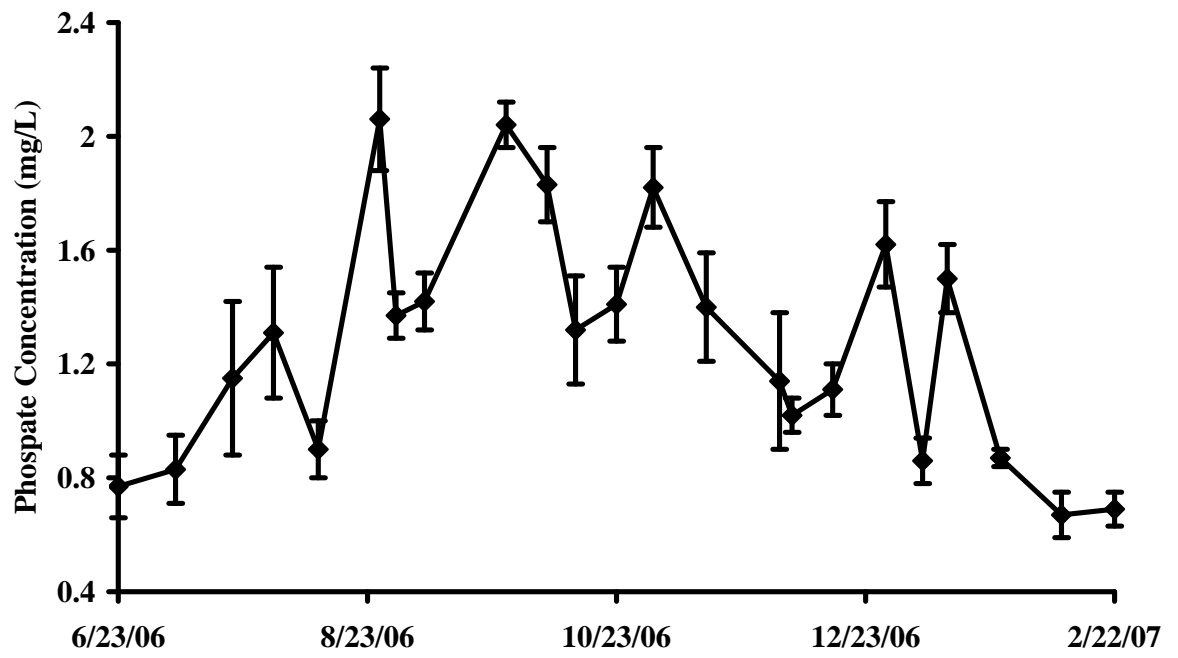
**Figure 16.** Mean ( $\pm$ SD) Secchi disk depth (cm) for all sample dates combined in the upper Barataria Estuary for each sample site. Means with a similar letter are not different.



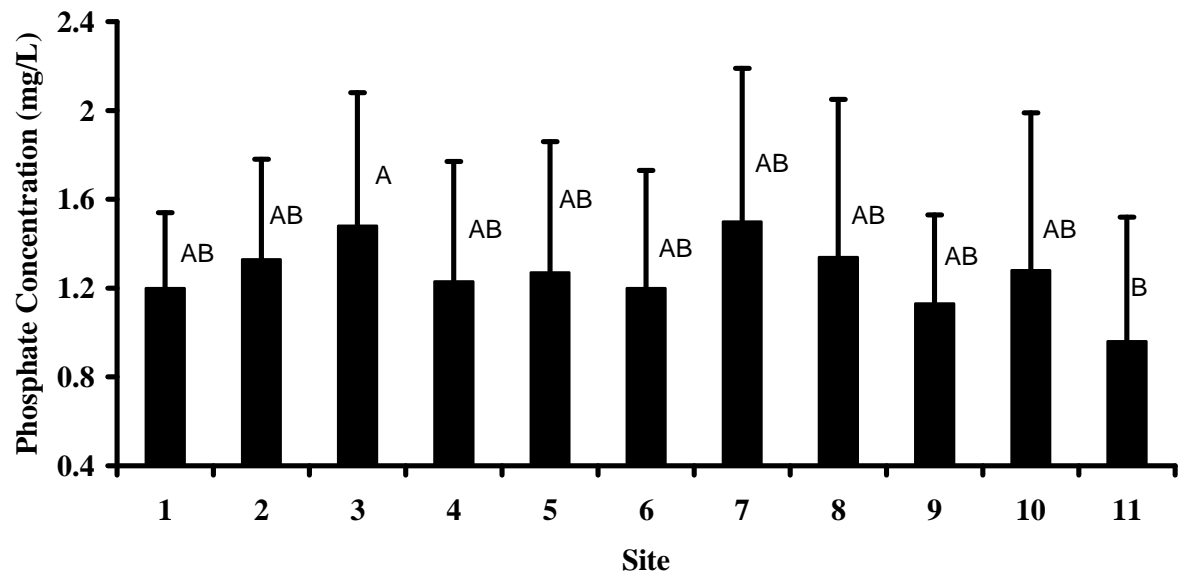
**Figure 17.** Mean ( $\pm$ SE)  $\text{NO}_3+\text{NO}_2$  concentration (mg/L) for all sites combined in the upper Barataria Estuary for each sample date.



**Figure 18.** Mean ( $\pm$ SD)  $\text{NO}_3+\text{NO}_2$  concentration (mg/L) for all sample dates combined in the upper Barataria Estuary for each sample site.



**Figure 19.** Mean ( $\pm$ SE) phosphate concentration (mg/L) for all sites combined in the upper Barataria Estuary for each sample date.



**Figure 20.** Mean ( $\pm$ SD) phosphate concentration (mg/L) for all sample dates combined in the upper Barataria Estuary for each sample site. Means with a similar letter are not different.

## DISCUSSION

Large river floodplains have high production and biota diversity due to predictable, seasonal flood pulses (Junk et al 1989). Many of the organisms inhabiting floodplains have developed adaptations that enable them to survive during and may even benefit from an adverse period of drought or flood, from these extremes (Junk et al. 1989). The change in water level during a large river flood pulse is gradual, because the drainage basins of large rivers cover a large geographic area. Therefore, the floodplain tends to be inundated for a long period, i.e., several weeks. In 2005, the floodplain of the ARB was inundated once and for more than 150 consecutive days (Bonvillain 2006). During the period of this study, the upper Barataria Estuary floodplain was inundated on 6 occasions and the longest period of inundation was 22 days. If fish are to use the inundated floodplain as spawning and foraging habitat, the floodplain needs to remain inundated during the typical spawning season. It is estimated that bowfin *Amia calva* require about 20 days of inundation, typically during the spring to spawn (Reighard 1900, 1903; Scott and Crossman 1973). The floodplains of the upper Barataria Estuary were inundated for more than 20 consecutive days, but during the winter, when it is not likely for most floodplain dependant fishes to spawn.

Because the upper Barataria Estuary receives no riverine input, high water periods occur during periods of extended local precipitation. Water level rapidly increases during periods of rainfall and gradually decreases as the upper Barataria Estuary drains. Rainfall for this study period was below average for the entire year except for December 2006 which is why we observed relatively low water except for high water periods in December and January. Even though rainfall was below average for January 2007, water

levels were still high due to the slow drainage rates of the upper Barataria Estuary. Water level in the upper Barataria Estuary appears to be tidally influenced during low water periods (Figure 5). Using a tidal range/distance inland relationship, Wiseman and Swenson (1989) estimated the tidal range of Lac Des Allemands to be 1.0 cm. This study area, located approximately 10 kilometers northwest of Lac Des Allemands, experienced a 5.0 centimeter tidal range during low water periods (Figure 5). As Louisiana coastal land continues to erode, more pronounced tidal influences may occur further inland. The Davis Pond freshwater diversion supplies freshwater water to the Barataria Estuary, but only flowed up to half of its capacity (approximately  $140 \text{ m}^3\text{s}^{-1}$ ) in the spring and winter of 2006. The lowest prolonged water levels were present in the upper Barataria Estuary in the summer and fall months. Because of the small gradient difference between the upper and lower Barataria Estuary, times of low water leave the upper estuary with the greatest chance of impact from the lower estuary entities. During this time, the Davis Pond freshwater diversion did not flow. Therefore, the Davis Pond freshwater diversion probably did not affect water quality in the upper Barataria Estuary.

Water temperature is ultimately influenced by varying amounts of sunlight during the different seasons of the year. In the ARB, water level rises during the spring when main stem river water enters the floodplain. Main stem river water originates from more northern regions and tends to be cooler than water already on the floodplain. Because the upper Barataria Estuary receives no riverine input, water temperature may increase sooner than water on an active large river floodplain, such as the ARB. Recorded water temperature in the ARB in April of 1995, 1996, and 2005 (Landry 1997; Fontenot 1997;

Bonvillain 2006) appeared to be lower than in the upper Barataria Estuary in April of 2006.

Perhaps the most evident consequences of the hydrologic modification and the introduction of anthropogenic runoff to the Barataria Estuary is decreased water quality (Rabalais et al. 1995). Cumulative effects of anthropogenic runoff can be described by integrative ecosystem measures such as oxygen concentration (Rabalais et. al 1995). Dissolved oxygen is essential for metabolism, and respiration in aquatic organisms, and can become depleted (hypoxic) in waters where decomposition rates of organic matter are high. Increased nutrient loading in water bodies can cause eutrophication, which may lead to decreased DO levels. Lack of sunlight available to primary producers in the water column through shading by surrounding trees may also decrease the amount of DO introduced to the water column. An increase in microbial respiration can also cause a decrease in DO. Dissolved oxygen levels were hypoxic for 52% of the sample dates in this study, and remained hypoxic for extended periods; 6 October 2006 to 25 January 2006 (Figure 8). In the ARB, hypoxic conditions are most likely to occur at temperatures  $>22^{\circ}\text{C}$  and are usually eliminated when temperatures decline in late fall (Bryan and Sabins 1979). However, extended periods of hypoxia in the upper Barataria Estuary were observed when temperatures were low ( $<20.0^{\circ}\text{C}$ ). Low DO is not expected during times of low temperature because of the decreased respiration rates. However, low DO in the upper Barataria Estuary occurred when the floodplain was inundated at low temperatures. It appears that floodplain inundation, and thus decomposition on the floodplain influenced hypoxic conditions more than high temperatures. Because hypoxic conditions in large river floodplains are somewhat predictable, some aquatic organisms have adapted

to live in such conditions. However, the occurrence of hypoxic conditions in the upper Barataria Estuary was unpredictable, and could arise during unexpected times when fish not adapted to these conditions are abundant, causing stress to these fish, and in extreme case, a fish kill.

Unlike the ARB, the upper Barataria Estuary did not exhibit similar seasonal occurrences of black, brown, and green water quality profiles. Black water was observed across the upper Barataria Estuary flowing from the floodplain, and into the main channels as flood waters recede. However, black water was mostly at sites 10 and 11. Sites 10 and 11 are located in Grand Bayou, which is a relatively small bayou more centrally located away from runoff sources. Sites 10 and 11 remained black for extended longer than the other sites, likely due to these sites' location, farther downstream from direct drainage of urban and agricultural areas. Most of the sediments from runoff (cause of brown water) will have fallen out of the water column upstream of sites 10 and 11. A study by Landry (1997) showed that black water in the ARB had a mean Secchi disk depth of 270 cm. Black water in the upper Barataria Estuary never exhibited Secchi disk depths higher than 150 cm (Appendix I), possibly due to a high concentration of organic matter from the floodplain. Unlike the ARB, which receives brown water pulses from riverine input, the upper Barataria Estuary receives brown water from the drainage of urban areas and agriculture fields. Low Secchi disk depth (<30 cm), characteristic of brown water, was evident at sites 1 and 7, which are in the closest proximity to urban areas and agriculture fields. This suggests that the upper Barataria Estuary receives sediments from agriculture drainage. Unlike the ARB, and other large river floodplains, green water was never observed in the upper Barataria Estuary during this study.

Although low Secchi disk depths were recorded during this study, it was due to high concentrations of suspended sediments, and not an abundance of phytoplankton.

Extended periods of high DO (>5.0 mg/L) were not observed in the upper Barataria Estuary likely due to the lack of primary production by phytoplankton.

Specific conductance was strongly negatively correlated with distance (km) upstream from the Highway 20 bridge. It appears that the source of specific conductance is from down estuary, not from agriculture and urban runoff. As coastal land erodes, and the upper Barataria Estuary becomes more tidally influenced during times of drought, specific conductance levels can be expected to rise, as down estuary saline water invades the upper Barataria Estuary.

Because the Barataria Estuary receives no direct riverine input, runoff from the surrounding watershed and atmospheric deposition are the dominant sources (54%) of nitrogen in the Barataria Estuary (Castro et al. 2003). If the major source of nitrogen in this area is from runoff, then we would expect to see higher nitrogen concentrations at sites closest to the runoff sources (sites 1 and 7); however, there was no difference in  $\text{NO}_3+\text{NO}_2$  among sites. The Barataria Estuary has a higher nitrogen input from atmospheric deposition of  $\text{NO}_3^-$  than other estuaries, which is likely due to industry and automobile combustion (Castro et al. 2003).  $\text{NO}_3+\text{NO}_2$  concentrations in the upper Barataria Estuary were three times higher than historical nitrogen concentrations in the ARB (Bryan et al. 1999), and are likely due to the Barataria Estuary's closer geographical location to the large number of industrial plants between Baton Rouge and New Orleans.

Unlike nitrogen, phosphate concentration seems to be linked to runoff in the upper Barataria Estuary. Site 3 had a higher concentration of phosphate than site 11. Site

3 has a near direct connection to drainage systems of an urban and agricultural area and likely receives runoff, where as site 11 lies farther away from runoff sources (Figure 2). Mean phosphate concentration was higher (up to 10 times) in the upper Barataria Estuary than reported means for the ARB (Bryan et al. 1999), possibly due to the prevalence and close proximity of agriculture and industry surrounding the upper Barataria Estuary (Braud et al. 2006).

In summary, water level in the upper Barataria Estuary is governed by rainfall, and thus does not exhibit the seasonal patterns of water levels expected for active large river floodplains. During low water times, water level was tidally influenced, even at the uppermost reaches of the estuary. Floodplain inundation was sporadic and of short duration. Hypoxia occurred for extended periods of time when temperatures were relatively low during this study. The source of specific conductance is from downstream, and levels may rise if Louisiana coastal land loss rates remain high and sea water continues to intrude north. Green water and thus extended periods of high DO was never observed during this study, probably due to the lack of a seasonal flood pulse and shading by trees. Nutrient concentrations were greater than concentrations reported for the ARB and were probably due to the prevalence of urban, industrial, and agriculture areas in the upper Barataria Estuary.

## **RECOMMENDATIONS**

Re-instating a spring flood pulse would flush the upper Barataria Estuary and may allow for predictable normoxic and hypoxic periods. A flood pulse would help to return the upper Barataria Estuary to a more productive large river floodplain, like the ARB. To build upon this study, I highly recommend the installation of continuous recorders that measure the parameters in this study that are deployed for at least a full year. This would allow for a complete and efficient collection of data. Continuous recorders can collect data that cannot be collected by field workers, such as short time intervals, and during inclement weather.

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## APPENDIX I

**Appendix 1.** Water quality parameters collected during the entire study period. The site number, date, time, temperature (°C; abbreviated Temp), dissolved oxygen (mg/L; abbreviated DO), specific conductance (µS; abbreviated Cond), Secchi disk depth (cm), nitrate+nitrite and phosphate concentrations (mg/L) are listed. A (.) indicates no data for this instance.

Date	Site	Time	Temp	DO	Cond.	Secchi	NO3+NO2	PO4
7-Apr-06	1	.	.	.	.	.	.	.
7-Apr-06	2	.	.	.	.	.	.	.
7-Apr-06	3	.	.	.	.	.	.	.
7-Apr-06	4	11:40	24.7	3.37	395.50	56	.	.
7-Apr-06	5	10:40	24.7	2.97	489.50	21	.	.
7-Apr-06	6	12:15	25.1	3.23	554.00	47	.	.
7-Apr-06	7	10:32	24.4	2.91	584.00	35	.	.
7-Apr-06	8	10:25	24.1	2.67	605.50	30	.	.
7-Apr-06	9	10:07	24.3	2.89	609.50	37	.	.
7-Apr-06	10	.	.	.	.	.	.	.
7-Apr-06	11	.	.	.	.	.	.	.
15-Apr-06	1	12:40	25.6	5.45	367.40	26	.	.
15-Apr-06	2	13:00	25.2	6.40	421.25	35	.	.
15-Apr-06	3	1:15	24.9	5.20	428.90	44	.	.
15-Apr-06	4	13:25	24.6	4.37	425.70	45	.	.
15-Apr-06	5	14:40	25.3	6.32	528.50	41	.	.
15-Apr-06	6	14:28	25.3	7.09	547.50	41	.	.
15-Apr-06	7	14:43	25.3	7.11	809.50	40	.	.
15-Apr-06	8	14:52	25.5	8.11	797.50	40	.	.
15-Apr-06	9	15:05	25.4	7.23	942.00	36	.	.
15-Apr-06	10	13:55	24.9	7.93	306.15	45	.	.
15-Apr-06	11	14:10	25.5	6.33	345.20	49	.	.
21-Apr-06	1	13:25	26.9	5.86	444.30	26	.	.
21-Apr-06	2	13:35	26.6	5.69	443.45	45	.	.
21-Apr-06	3	13:45	26.8	3.20	477.00	44	.	.
21-Apr-06	4	13:55	26.9	6.14	548.50	35	.	.
21-Apr-06	5	14:31	26.7	5.37	1025.50	51	.	.
21-Apr-06	6	14:43	27.0	3.69	1048.00	50	.	.
21-Apr-06	7	14:58	27.4	4.33	1047.50	35	.	.
21-Apr-06	8	15:05	27.3	6.05	1047.50	40	.	.
21-Apr-06	9	15:15	27.2	4.85	1053.00	46	.	.
21-Apr-06	10	14:13	26.9	7.71	427.40	54	.	.
21-Apr-06	11	14:22	26.7	5.02	479.00	49	.	.
30-Apr-06	1	15:11	28.0	7.35	280.60	19	.	.
30-Apr-06	2	15:25	25.8	6.47	393.90	41	.	.
30-Apr-06	3	15:40	25.5	5.81	377.10	39	.	.
30-Apr-06	4	15:49	24.4	4.02	393.50	55	.	.
30-Apr-06	5	16:26	26.2	3.89	605.00	51	.	.
30-Apr-06	6	16:37	25.9	4.07	912.00	50	.	.
30-Apr-06	7	16:50	25.7	3.16	857.50	24	.	.
30-Apr-06	8	16:58	25.9	3.84	792.00	34	.	.
30-Apr-06	9	17:06	26.0	3.67	1073.50	46	.	.

Date	Site	Time	Temp	DO	Cond.	Secchi	NO3+NO2	PO4
30-Apr-06	10	16:00	26.7	4.82	436.15	45	.	.
30-Apr-06	11	16:18	25.6	3.75	490.00	51	.	.
15-May-06	1	10:32	24.9	.	312.15	17	.	.
15-May-06	2	10:48	22.3	.	370.60	46	.	.
15-May-06	3	11:01	23.3	.	366.20	35	.	.
15-May-06	4	11:10	23.6	.	367.20	36	.	.
15-May-06	5	11:46	24.4	.	355.50	44	.	.
15-May-06	6	12:00	24.9	.	351.40	45	.	.
15-May-06	7	12:14	24.7	.	443.90	30	.	.
15-May-06	8	12:22	25.5	.	369.55	48	.	.
15-May-06	9	12:32	25.4	.	419.25	36	.	.
15-May-06	10	11:10	24.0	.	356.10	46	.	.
15-May-06	11	11:31	24.7	.	663.50	44	.	.
6-Jun-06	1	12:31	28.1	3.44	218.55	15	.	.
6-Jun-06	2	12:44	27.3	2.60	387.00	20	.	.
6-Jun-06	3	12:54	28.4	3.27	286.80	16	.	.
6-Jun-06	4	13:01	29.0	4.47	334.45	21	.	.
6-Jun-06	5	12:05	29.3	4.32	404.50	45	.	.
6-Jun-06	6	11:51	28.4	3.18	405.20	45	.	.
6-Jun-06	7	11:38	28.8	3.26	372.25	41	.	.
6-Jun-06	8	11:20	29.2	2.78	380.40	42	.	.
6-Jun-06	9	14:56	30.1	4.07	441.35	45	.	.
6-Jun-06	10	13:18	29.5	6.32	442.20	30	.	.
6-Jun-06	11	13:25	28.8	5.03	411.50	48	.	.
14-Jun-06	1	9:06	29.5	2.30	302.50	34	.	.
14-Jun-06	2	9:20	29.2	2.52	318.65	38	.	.
14-Jun-06	3	9:39	29.5	2.22	384.60	42	.	.
14-Jun-06	4	9:48	29.8	2.71	401.50	44	.	.
14-Jun-06	5	10:35	29.4	3.01	397.65	42	.	.
14-Jun-06	6	10:43	29.6	1.94	396.80	47	.	.
14-Jun-06	7	10:57	30.1	2.17	387.20	36	.	.
14-Jun-06	8	11:06	30.3	1.84	449.45	46	.	.
14-Jun-06	9	11:15	29.9	1.21	522.00	48	.	.
14-Jun-06	10	10:08	29.2	2.51	445.70	44	.	.
14-Jun-06	11	10:18	29.3	1.88	487.50	47	.	.
23-Jun-06	1	12:07	30.9	4.67	313.95	31	0.44	1.46
23-Jun-06	2	12:15	31.3	3.84	409.50	46	0.61	1.45
23-Jun-06	3	12:23	30.1	3.18	428.10	45	0.62	0.94
23-Jun-06	4	12:31	31.2	3.48	480.00	48	0.43	0.74
23-Jun-06	5	11:45	30.5	3.21	789.50	55	0.20	0.59
23-Jun-06	6	13:14	30.8	3.64	1021.50	47	0.40	0.54
23-Jun-06	7	11:24	30.9	2.58	613.50	42	0.20	0.73
23-Jun-06	8	11:15	31.2	2.87	1370.00	40	0.20	0.41
23-Jun-06	9	13:38	31.8	3.52	1582.50	47	0.01	0.59
23-Jun-06	10	12:43	30.7	4.47	558.00	46	0.40	0.49
23-Jun-06	11	12:50	30.1	3.56	839.00	48	0.22	0.51
7-Jul-06	1	12:44	28.9	3.60	133.55	.	1.48	1.37
7-Jul-06	2	12:52	27.7	2.35	137.65	.	1.02	0.99
7-Jul-06	3	13:00	28.0	2.30	175.40	.	1.32	1.25

Date	Site	Time	Temp	DO	Cond.	Secchi	NO3+NO2	PO4
7-Jul-06	4	13:06	28.4	2.90	190.35	.	0.80	1.35
7-Jul-06	5	12:07	28.8	10.37	259.95	.	0.40	0.91
7-Jul-06	6	14:12	29.4	5.10	269.90	.	0.40	0.89
7-Jul-06	7	14:22	29.1	2.95	274.10	.	1.30	0.72
7-Jul-06	8	14:28	29.9	5.70	291.50	.	0.53	0.53
7-Jul-06	9	14:35	30.0	6.71	360.50	.	0.72	0.59
7-Jul-06	10	13:19	28.3	4.67	435.15	.	0.20	0.23
7-Jul-06	11	13:26	28.9	4.56	580.50	.	0.20	0.33
21-Jul-06	1	11:56	29.2	3.52	163.00	19	0.60	0.69
21-Jul-06	2	12:08	28.1	1.20	310.90	10	0.42	1.38
21-Jul-06	3	12:15	29.1	1.71	219.70	26	0.20	0.87
21-Jul-06	4	12:22	29.5	1.45	220.85	59	0.60	2.75
21-Jul-06	5	12:50	29.3	1.93	208.15	35	0.60	2.65
21-Jul-06	6	12:58	30.9	3.15	210.75	31	1.60	1.82
21-Jul-06	7	13:08	31.2	3.55	435.60	43	0.20	0.75
21-Jul-06	8	13:14	30.7	4.33	368.65	26	0.20	0.50
21-Jul-06	9	13:19	30.5	2.20	308.45	31	0.40	0.59
21-Jul-06	10	12:37	28.9	3.26	252.25	54	0.20	0.48
21-Jul-06	11	12:44	30.0	3.50	295.20	42	0.00	0.20
31-Jul-06	1	.	.	.	.	.	.	.
31-Jul-06	2	.	.	.	.	.	.	.
31-Jul-06	3	13:51	29.0	0.44	208.55	96	0.20	1.55
31-Jul-06	4	13:41	29.4	1.24	211.75	95	0.40	1.84
31-Jul-06	5	13:31	30.4	2.08	237.00	50	0.40	1.17
31-Jul-06	6	13:20	30.9	3.68	222.05	46	0.61	1.16
31-Jul-06	7	12:55	29.8	3.22	246.10	40	0.73	2.75
31-Jul-06	8	12:45	30.5	2.99	235.85	58	0.62	0.99
31-Jul-06	9	12:35	30.1	3.13	270.05	30	0.04	1.20
31-Jul-06	10	14:20	29.7	3.13	188.45	46	0.20	0.89
31-Jul-06	11	14:05	31.1	5.11	169.65	40	0.67	0.24
11-Aug-06	1	.	.	.	.	.	.	.
11-Aug-06	2	.	.	.	.	.	.	.
11-Aug-06	3	.	.	.	.	.	.	.
11-Aug-06	4	16:37	28.3	0.63	116.40	9	1.91	0.67
11-Aug-06	5	16:26	29.4	1.30	156.10	17	1.07	0.88
11-Aug-06	6	16:18	30.2	2.23	205.30	35	0.20	0.69
11-Aug-06	7	16:07	28.6	1.44	151.30	8	2.52	1.43
11-Aug-06	8	16:00	28.9	2.03	174.95	16	0.85	0.86
11-Aug-06	9	15:50	29.2	1.45	186.20	10	1.70	1.21
11-Aug-06	10	16:56	28.9	2.81	148.10	10	1.54	0.84
11-Aug-06	11	16:48	30.3	2.98	192.05	70	0.47	0.64
26-Aug-06	1	.	.	.	.	.	.	.
26-Aug-06	2	.	.	.	.	.	.	.
26-Aug-06	3	.	.	.	.	.	.	.
26-Aug-06	4	.	.	.	.	.	.	.
26-Aug-06	5	10:10	27.4	0.92	199.65	65	0.20	2.69
26-Aug-06	6	10:04	27.8	1.56	211.75	54	0.20	1.95
26-Aug-06	7	9:49	29.1	2.06	296.60	44	0.22	1.69
26-Aug-06	8	9:42	29.0	1.28	273.00	82	0.02	2.47

Date	Site	Time	Temp	DO	Cond.	Secchi	NO3+NO2	PO4
26-Aug-06	9	9:34	28.5	1.22	242.00	40	0.22	1.50
26-Aug-06	10	.	.	.	.	.	.	.
26-Aug-06	11	10:17	28.1	1.11	199.05	40	0.24	2.08
30-Aug-06	1	15:46	29.3	0.99	160.20	11	1.34	1.47
30-Aug-06	2	15:39	29.3	0.92	146.50	15	0.92	1.71
30-Aug-06	3	15:30	29.5	1.28	227.85	35	0.42	1.34
30-Aug-06	4	15:24	28.4	1.32	199.65	47	0.43	1.31
30-Aug-06	5	15:12	28.6	2.41	182.95	51	0.43	1.36
30-Aug-06	6	15:05	28.5	2.24	187.20	39	0.62	0.84
30-Aug-06	7	14:51	26.7	2.45	170.50	4	1.74	1.76
30-Aug-06	8	14:45	28.1	2.55	192.30	5	0.87	1.32
30-Aug-06	9	14:35	27.8	2.10	181.35	5	1.74	1.41
30-Aug-06	10	16:08	27.5	3.08	232.15	65	0.40	1.44
30-Aug-06	11	16:13	27.4	1.59	179.85	61	0.63	1.08
6-Sep-06	1	17:44	29.6	3.71	135.05	17	0.40	1.33
6-Sep-06	2	17:37	28.7	1.74	226.15	39	0.20	1.04
6-Sep-06	3	17:31	28.9	2.67	177.20	35	0.21	1.78
6-Sep-06	4	17:20	28.9	1.59	185.45	49	0.21	1.20
6-Sep-06	5	17:03	29.3	2.98	201.70	50	0.60	1.17
6-Sep-06	6	16:50	28.8	3.08	211.80	41	0.40	1.42
6-Sep-06	7	16:39	28.9	2.41	217.65	20	0.67	1.52
6-Sep-06	8	16:24	28.8	3.01	223.80	34	0.41	1.24
6-Sep-06	9	16:13	30.0	4.71	225.50	35	0.20	1.10
6-Sep-06	10	18:08	27.1	1.59	223.90	54	0.60	1.87
6-Sep-06	11	18:03	29.1	2.58	202.85	51	0.60	1.94
26-Sep-06	1	13:08	27.0	5.05	139.00	40	0.63	1.87
26-Sep-06	2	13:02	25.9	2.70	141.00	28	0.92	2.17
26-Sep-06	3	12:55	25.8	2.72	152.70	42	0.83	2.26
26-Sep-06	4	12:49	25.8	2.47	140.60	27	1.05	2.09
26-Sep-06	5	12:25	25.4	1.81	127.60	27	1.06	1.69
26-Sep-06	6	12:19	24.8	2.21	146.15	32	1.07	1.64
26-Sep-06	7	12:09	27.0	5.13	223.65	21	1.31	2.38
26-Sep-06	8	12:03	26.2	4.19	198.85	21	1.31	2.43
26-Sep-06	9	11:56	25.6	.	194.85	33	1.06	2.02
26-Sep-06	10	12:38	24.1	1.61	196.90	69	1.01	2.08
26-Sep-06	11	12:30	25.1	1.52	180.65	108	0.81	1.86
6-Oct-06	1	15:39	26.9	1.99	162.70	56	0.42	1.45
6-Oct-06	2	15:32	26.7	2.68	200.80	62	0.62	1.54
6-Oct-06	3	15:23	27.3	1.84	246.50	45	1.62	1.66
6-Oct-06	4	15:15	27.6	0.70	238.15	60	1.44	1.45
6-Oct-06	5	14:51	29.0	2.19	242.45	49	1.23	2.06
6-Oct-06	6	14:46	27.9	1.78	248.05	55	1.03	2.18
6-Oct-06	7	14:37	27.1	2.47	292.05	44	0.84	2.75
6-Oct-06	8	14:31	27.2	2.13	326.90	46	1.05	1.89
6-Oct-06	9	14:23	28.0	2.84	452.60	45	0.67	1.48
6-Oct-06	10	15:04	25.3	0.53	248.10	50	1.25	2.29
6-Oct-06	11	14:57	27.4	0.98	222.65	54	1.23	1.34
13-Oct-06	1	13:21	23.0	1.44	179.45	42	0.40	1.61
13-Oct-06	2	13:16	22.2	1.40	222.90	45	0.86	2.10

Date	Site	Time	Temp	DO	Cond.	Secchi	NO3+NO2	PO4
13-Oct-06	3	13:09	22.8	1.14	258.45	50	1.03	1.15
13-Oct-06	4	13:01	22.8	1.63	468.10	67	0.60	1.13
13-Oct-06	5	12:35	23.4	2.20	595.00	56	0.40	0.91
13-Oct-06	6	12:30	23.5	2.55	904.00	52	0.44	0.70
13-Oct-06	7	12:20	24.1	2.63	1005.50	35	0.40	0.66
13-Oct-06	8	12:14	24.2	2.42	1046.00	46	0.56	1.53
13-Oct-06	9	12:07	24.4	2.64	1134.50	42	0.40	0.80
13-Oct-06	10	12:48	22.0	0.78	250.45	85	1.20	2.75
13-Oct-06	11	12:41	22.5	0.36	264.40	40	1.64	1.24
23-Oct-06	1	.	.	.	.	.	.	.
23-Oct-06	2	.	.	.	.	.	.	.
23-Oct-06	3	.	.	.	.	.	.	.
23-Oct-06	4	15:40	20.6	1.29	1223.50	90	0.40	0.93
23-Oct-06	5	15:06	22.1	0.77	446.90	52	0.66	1.12
23-Oct-06	6	15:01	21.0	0.72	298.35	27	0.89	1.74
23-Oct-06	7	14:50	20.8	1.58	128.70	10	0.85	2.06
23-Oct-06	8	14:45	20.8	1.30	146.65	10	1.02	1.31
23-Oct-06	9	14:37	21.1	1.15	189.10	12	1.06	1.38
23-Oct-06	10	15:24	20.6	1.09	193.00	74	0.60	1.62
23-Oct-06	11	15:17	20.2	0.57	451.65	96	0.61	1.12
1-Nov-06	1	15:19	22.8	2.27	177.25	32	0.80	1.31
1-Nov-06	2	15:09	19.8	1.16	205.45	40	0.60	2.12
1-Nov-06	3	15:02	21.8	0.83	219.90	62	0.80	2.71
1-Nov-06	4	14:54	21.3	0.31	349.15	60	1.00	1.92
1-Nov-06	5	14:30	21.4	0.64	386.90	75	1.21	1.50
1-Nov-06	6	14:26	20.5	0.46	404.75	64	1.21	1.64
1-Nov-06	7	14:16	21.0	0.96	341.10	55	0.80	2.59
1-Nov-06	8	14:10	20.5	0.50	447.55	61	1.44	1.71
1-Nov-06	9	14:03	21.7	0.60	473.40	57	1.20	1.51
1-Nov-06	10	14:43	19.7	0.38	224.25	71	1.47	1.71
1-Nov-06	11	14:36	20.1	0.19	329.35	55	1.60	1.29
14-Nov-06	1	12:43	16.8	0.04	230.30	17	0.69	0.82
14-Nov-06	2	12:34	17.1	0.52	247.50	20	0.40	1.03
14-Nov-06	3	12:23	16.1	0.12	247.35	31	0.60	2.39
14-Nov-06	4	12:13	16.3	0.59	291.35	69	0.60	1.14
14-Nov-06	5	11:40	16.3	0.92	296.95	70	0.80	1.09
14-Nov-06	6	11:33	16.5	1.10	305.50	65	0.80	1.09
14-Nov-06	7	11:21	16.7	0.02	258.05	31	0.60	1.66
14-Nov-06	8	11:13	16.3	1.18	325.30	50	1.03	2.75
14-Nov-06	9	11:05	16.9	0.28	321.80	40	0.82	1.18
14-Nov-06	10	11:55	15.7	0.68	238.90	75	1.32	1.30
14-Nov-06	11	11:45	15.9	0.97	236.65	95	1.01	0.99
2-Dec-06	1	.	.	.	.	.	.	.
2-Dec-06	2	.	.	.	.	.	.	.
2-Dec-06	3	.	.	.	.	.	.	.
2-Dec-06	4	.	.	.	.	.	.	.
2-Dec-06	5	.	.	.	.	.	.	.
2-Dec-06	6	14:14	15.9	1.64	352.75	60	1.07	0.63
2-Dec-06	7	14:02	15.4	0.08	360.55	22	0.88	1.63

Date	Site	Time	Temp	DO	Cond.	Secchi	NO3+NO2	PO4
2-Dec-06	8	13:45	15.7	0.24	308.85	16	0.93	0.83
2-Dec-06	9	13:32	16.7	0.59	293.10	14	0.93	1.48
2-Dec-06	10	.	.	.	.	.	.	.
2-Dec-06	11	.	.	.	.	.	.	.
5-Dec-06	1	15:16	10.5	1.45	230.15	13	1.08	1.25
5-Dec-06	2	15:08	9.9	0.18	229.80	15	1.08	1.00
5-Dec-06	3	14:59	9.0	1.10	252.30	19	1.06	1.29
5-Dec-06	4	14:50	9.2	0.87	269.70	20	1.09	0.98
5-Dec-06	5	14:25	9.3	0.95	275.50	20	1.08	1.00
5-Dec-06	6	14:18	9.3	1.83	277.35	20	1.08	0.94
5-Dec-06	7	14:06	10.1	0.13	328.80	21	0.88	1.24
5-Dec-06	8	13:59	9.8	0.74	303.70	23	1.07	0.89
5-Dec-06	9	13:51	10.3	0.09	299.50	17	0.88	1.02
5-Dec-06	10	14:36	8.5	1.11	245.40	50	0.89	0.89
5-Dec-06	11	14:28	8.8	1.72	313.10	25	0.66	0.67
15-Dec-06	1	11:00	15.7	2.29	271.10	16	0.63	0.83
15-Dec-06	2	11:10	15.4	0.49	368.55	40	0.83	0.94
15-Dec-06	3	11:20	15.9	0.44	383.70	62	1.28	1.34
15-Dec-06	4	11:28	15.8	0.30	370.60	55	1.01	0.77
15-Dec-06	5	11:37	16.0	0.38	385.10	65	1.04	1.67
15-Dec-06	6	12:05	16.2	0.50	386.65	75	1.00	0.84
15-Dec-06	7	12:19	15.2	0.58	533.00	40	0.62	1.20
15-Dec-06	8	12:13	16.3	0.59	405.95	65	1.02	0.82
15-Dec-06	9	12:28	15.8	0.06	403.65	41	0.82	1.17
15-Dec-06	10	11:50	15.8	0.27	308.75	65	1.31	1.18
15-Dec-06	11	11:41	15.9	0.34	350.45	75	1.00	1.41
28-Dec-06	1	12:43	11.1	0.57	132.35	25	1.04	1.31
28-Dec-06	2	12:51	11.3	0.85	135.25	30	1.04	1.31
28-Dec-06	3	13:00	11.3	0.77	135.30	30	1.06	2.44
28-Dec-06	4	13:13	11.2	0.81	186.20	40	0.81	1.16
28-Dec-06	5	13:22	11.4	1.00	189.15	46	1.01	0.94
28-Dec-06	6	13:51	11.5	1.06	189.90	50	0.83	2.08
28-Dec-06	7	14:07	11.0	1.65	197.90	25	0.81	1.65
28-Dec-06	8	14:00	11.2	1.59	186.50	30	0.81	2.43
28-Dec-06	9	14:17	11.1	1.55	185.00	30	0.86	1.62
28-Dec-06	10	13:35	11.7	0.79	136.00	85	0.70	1.54
28-Dec-06	11	13:26	11.4	1.70	216.05	85	0.80	1.34
6-Jan-07	1	12:43	16.8	0.05	116.40	11	1.29	1.10
6-Jan-07	2	12:52	16.3	0.08	128.55	14	1.08	0.95
6-Jan-07	3	13:02	16.3	0.07	133.05	15	1.04	1.10
6-Jan-07	4	13:20	16.1	0.43	150.55	50	0.80	0.80
6-Jan-07	5	13:28	16.2	0.54	150.00	55	0.80	0.83
6-Jan-07	6	.	.	.	.	.	.	.
6-Jan-07	7	.	.	.	.	.	.	.
6-Jan-07	8	.	.	.	.	.	.	.
6-Jan-07	9	.	.	.	.	.	.	.
6-Jan-07	10	13:42	16.6	0.70	127.85	110	0.60	0.65
6-Jan-07	11	13:35	16.0	0.74	140.10	75	1.23	0.57
12-Jan-07	1	12:06	15.1	0.16	127.95	21	1.22	1.23

Date	Site	Time	Temp	DO	Cond.	Secchi	NO3+NO2	PO4
12-Jan-07	2	12:14	14.3	0.12	185.45	29	1.00	1.44
12-Jan-07	3	12:25	14.5	0.19	162.35	35	1.20	1.65
12-Jan-07	4	12:34	14.7	0.27	159.95	55	1.00	1.29
12-Jan-07	5	12:42	14.7	0.45	158.15	58	1.00	1.57
12-Jan-07	6	13:08	14.7	0.43	158.95	60	1.00	1.40
12-Jan-07	7	13:20	14.4	0.47	186.65	41	0.83	1.63
12-Jan-07	8	13:29	14.6	0.64	173.50	49	0.80	1.88
12-Jan-07	9	13:35	14.5	0.76	168.55	47	0.80	1.09
12-Jan-07	10	12:51	14.8	0.25	147.40	70	0.80	2.42
12-Jan-07	11	12:45	14.7	0.49	140.85	75	1.01	0.90
25-Jan-07	1	12:13	11.6	1.20	169.80	21	1.03	0.95
25-Jan-07	2	12:06	11.3	1.12	173.55	21	1.21	0.85
25-Jan-07	3	11:55	10.8	0.91	187.05	31	1.22	0.89
25-Jan-07	4	11:42	10.7	1.08	189.25	45	1.00	0.83
25-Jan-07	5	11:15	10.7	1.25	187.85	40	1.00	0.87
25-Jan-07	6	11:08	10.6	1.46	187.25	44	1.00	0.88
25-Jan-07	7	10:57	10.8	2.08	242.75	24	0.80	0.99
25-Jan-07	8	10:48	10.8	1.94	224.75	23	1.00	0.98
25-Jan-07	9	10:38	10.9	2.12	199.00	29	1.00	0.8
25-Jan-07	10	11:28	10.8	1.23	174.60	99	0.60	0.89
25-Jan-07	11	11:20	10.4	1.52	166.70	91	0.80	0.63
9-Feb-07	1	10:57	15.1	5.68	149.00	20	1.11	0.79
9-Feb-07	2	11:06	14.6	3.39	152.85	28	1.02	1.27
9-Feb-07	3	11:14	14.8	3.16	151.65	34	1.00	0.8
9-Feb-07	4	11:23	15.1	2.86	150.85	44	0.80	0.79
9-Feb-07	5	11:30	15.2	2.82	150.10	43	0.85	0.64
9-Feb-07	6	11:55	15.4	3.22	148.85	49	0.80	0.64
9-Feb-07	7	12:13	15.0	3.10	220.35	32	0.61	0.64
9-Feb-07	8	12:03	15.3	3.43	200.95	31	0.80	0.47
9-Feb-07	9	12:23	15.4	2.56	170.85	45	0.62	0.5
9-Feb-07	10	11:45	14.6	3.23	142.95	57	0.63	0.6
9-Feb-07	11	11:37	14.7	2.78	135.40	144	0.60	0.27
22-Feb-07	1	11:33	15.8	3.11	180.20	26	0.90	0.68
22-Feb-07	2	11:42	15.9	3.41	181.75	30	1.22	0.73
22-Feb-07	3	11:51	15.6	1.99	182.85	30	0.80	0.75
22-Feb-07	4	12:01	15.8	1.95	181.10	39	0.80	0.67
22-Feb-07	5	12:10	15.9	2.02	180.40	49	0.80	0.67
22-Feb-07	6	12:41	16.1	2.27	180.10	50	0.80	0.62
22-Feb-07	7	12:54	16.5	2.65	225.90	25	0.80	0.57
22-Feb-07	8	12:48	16.1	2.61	194.65	30	0.80	1.19
22-Feb-07	9	13:05	15.7	2.54	193.15	39	0.80	0.66
22-Feb-07	10	12:26	15.4	2.05	176.15	75	0.60	0.69
22-Feb-07	11	12:19	15.7	2.12	166.30	101	0.60	0.37

## **BIOGRAPHICAL SKETCH**

Marcel Estay was born on April 23, 1983, in Raceland, Louisiana where he grew up attending Raceland lower, upper, and junior high schools. After graduation from Central Lafourche High School in 2001, he enrolled in Nicholls State University to major in Agriculture Business. He was awarded the aid of the TOPS program as well as several other scholarships. In his senior year of college, Marcel was awarded with the Outstanding Agricultural Production award. In May of 2005, Marcel graduated with a bachelor degree in Agricultural Business with a concentration of Agricultural science. He also acquired minors in Animal Science, and Plant Science. In the summer of 2005, Marcel was accepted into the Nicholls State University Master's degree program in Marine and Environmental Biology. The majority of Marcel's graduate work included a teaching assistantship and research on the water quality in the upper Barataris Estuary. Marcel plans to continue working in the environmental biology field after graduating in 2007.

## CURRICULUM VITAE

**Marcel Estay**

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### **EDUCATION:**

**M.S. Marine and Environmental Biology, Fall 2007.** Nicholls State University, Thibodaux, Louisiana, 70310. Thesis title: Assessment of Water Quality in the Upper Barataria Estuary.

**B.S. Agricultural Business with a concentration in Agricultural Science, Spring 2005.** Nicholls State University, Thibodaux, Louisiana, 70310.

### **TEACHING EXPERIENCE:**

Fall 2005 – Spring 2007: Teaching Assistant, Nicholls State University, Department of Biological Sciences. Duties included teaching up to two labs per week, weekly lab set up, and grading lab reports and exams.

### **RESEARCH EXPERIENCE:**

Assesment of water quality in the upper Barataria Estuary

### **SKILLS:**

Large vehicle and boat operation, water quality monitoring (Temperature, DO, salinity, specific conduction, Secchi disk depth, Nutrient concentration), gill net sampling, biological monitoring station construction, ATV operation, GPS, GIS, wetland plant identification, wetland delineation

## **HONORS AND AWARDS:**

Maintained a 4-year Sugar Industry Scholarship  
Louis P. Ledet Scholarship  
Robert Boudreaux Memorial Scholarship  
Alumni Federation Scholarship  
Rienzi Agricultural Scholarship  
Awarded Alpha Lambda Delta as a freshman  
Outstanding Agricultural Production award

## **WORK EXPERIENCE:**

May 1999 – Present: Louisiana Department of Natural Resources / Coastal Restoration Division Thibodaux, Louisiana. Produced maps of DNR projects using ArcGIS and related programs, experience with various forms of data collection and analysis, operation and calibration of continuous recorder instruments and hand-held instruments for salinity, temperature, and specific conductance, assisted with the construction of a prototype Coast-wide Reference Monitoring System study site, maintenance of boats, vehicles, and field equipment, fostered my knowledge of vegetation, marsh types, and other scientific processes.

## **MEMBERSHIP AND SERVICES:**

Louisiana Chapter of the American Fisheries Society  
Nicholls State University Biology Society

## **SCIENTIFIC PRESENTATIONS:**

- 2006. Estay, M.S., and Q.C. Fontenot. Assessment of Water Quality in the Upper Barataria Estuary. 1 February 2006. Joint Meeting of the Mississippi and Louisiana Chapters of the American Fisheries Society.
- 2006. Estay, M.S., and Q.C. Fontenot. Assessment of Water Quality in the Upper Barataria Estuary. Nicholls State University, Calypseaux Expedition. Cocodrie, Louisiana.