Interactions among Hydrology, Sediment and Vegetation in Accreting Wax Lake Delta: Physical and Biogeochemical Implications for Coastal Louisiana Restoration

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INTERACTIONS AMONG HYDROLOGY, SEDIMENT AND VEGETATION IN ACCRETING WAX LAKE DELTA: PHYSICAL AND BIOGEOCHEMICAL IMPLICATIONS TO COASTAL LOUISIANA RESTORATION

A Thesis

Submitted to the Graduate Faculty of the
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by

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B.S., Coastal Carolina University, 2013
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ABSTRACT

River discharge pulses, wind, waves, tides, and the presence of dense vegetation are factors that interact and regulate the transport and retention of sediment in coastal regions. In particular, vegetation structural and physiognomic traits promote fine sediment trapping during tidal and river flow, maintaining the balance between soil elevation and relative sea level rise on coastline stability and land building.

Mike Island, located within Wax Lake Delta, Louisiana, USA, is part of a deltaic system created by a man-made freshwater diversion (1941) and one of few coastal areas where land is expanding in coastal Louisiana as result of pulsing river sediment discharge. Acoustic and optical sensors at upstream and downstream locations in Mike Island were deployed for 30-60 days during spring and late summer in 2015 to evaluate spatiotemporal changes in turbidity, waves, tides, current speed and direction. Sediment traps were installed 30 cm above and on the sediment surface to identify spatiotemporal differences in sediment texture and deposition. During a flood stage, most of the island is dominated by overbank flooding and high discharge from a secondary channel located upstream. When vegetation biomass was low, the downstream station received more wave influence than the upstream station. Current speeds during the spring deployment were approximately 23 cm/s at the upstream station and only 6 cm/s downstream. During peak productivity in August-October, current speeds decreased markedly in early September 2015 due to the presence of dense vegetation interference. Spatial and temporal differences in total inorganic nitrogen (TIN) and orthophosphate (PO$_4^{3-}$) nutrient concentrations in overlying and soil surface water were evident and indicate complex nutrient availability patterns controlling vegetation production. Surficial sediments (0-5 cm)
collected in April and August (2014) were comprised of approximately 20% sand and 80% mud. Bulk density (BD) in sediment cores increased with depth (50 cm) at the downstream location while BD in the upstream location peaked at shallower depths (<20 cm), indicating differences in sediment deposition history and rates. This study contributes toward the long-term goal of developing and parameterizing biophysical models to manage and recommend freshwater and sediment diversions in Louisiana wetland restoration programs.
1. INTRODUCTION

1.1 The Mississippi and Atchafalaya Systems

The Mississippi River drains an area of $3.4 \times 10^6$ km$^2$, making it the fourth largest drainage basin and the seventh largest sediment discharge in the world (Blum and Roberts, 2012). This large river system and sediment input has a direct influence on the northern Gulf of Mexico. The Mississippi River discharge is characterized by a seasonal and interannual variability (Allison et al., 2012) with the highest river discharge during the spring and the lowest during the late summer and fall (Mossa and Roberts, 1990; Cotton et al., 2006; Silva et al., 2009; Kolker et al., 2014; Bevington et al., in review). Seasonal pulsing of water discharge leads to a change in sediment discharge and water level in the delta (Mossa and Roberts, 1990; Li et al., 2001; Cotton et al., 2006). When river discharge is low, tides can penetrate into the Mississippi River channel approximately 200 km upstream but only 50 km during high discharge (Allison et al., 2012). Overall, these discharge and tidal variations can lead to changes in the dominant physical forcings which directly influence the downstream sediment transport, delta formation, and ecosystem dynamics (Cotton et al., 2006; Bevington et al., in review).

Over the past 7000 years, the Mississippi River has changed its main course six times with deltas forming during each avulsion every 1000-2000 years (Day et al., 2007). As each delta grows, the distance to the river mouth becomes longer and the river changes its course to find the shortest path and steepest gradient to the northern Gulf, abandoning the previous delta lobe. The most recent delta lobe of the Mississippi River is the Balize delta (modern birdfoot Mississippi delta), which formed approximately 550 years ago (Day et al., 2007). This lower basin of the Mississippi River has been managed in order to maximize flood control,
navigation and the utilization of sediment and water from the river to combat coastal wetland loss (Allison et al., 2012).

Following the historic Mississippi River flood in 1927, the Flood Control Act of 1928 was implemented, requesting the U.S. Army Corps of Engineers to construct various flood control structures. Since 1928, dams and levees have been implemented along the Mississippi River to reduce damage from flood events. However, the influence of engineering projects in the lower Mississippi has severely altered natural fluvial processes. In the early 20th century, between 400 and 500 million tons of sediment per year were delivered via the Mississippi River (Blum and Roberts, 2012). Since 1950, however, there has been about a 50% decrease in the sediment load due to the trapping of sediment within >50,000 reservoirs in the Mississippi basin (Blum and Roberts, 2012). This significant reduction in the sediment supply delivered to the Gulf of Mexico threatens the coast with exacerbated land loss (Paola et al., 2011; Khalil and Raynie, 2015).

If the Mississippi River were to change course naturally, the next primary delta lobe would be in the Atchafalaya Bay, considering its short distance to the shoreline and steepest gradient (Roberts et al., 2003; Day et al., 2007). In 1941, the U.S. Army Corps of Engineers constructed the Wax Lake Outlet, diverting water from the Atchafalaya River to the northern Gulf of Mexico to suppress flooding in Morgan City of Louisiana (Roberts et al., 2003; Wellner et al., 2005; Jones, 2016). As a result, subaqueous land began to form in 1952 as the sediment began to fill in the Atchafalaya Bay creating the Wax Lake Delta (WLD) (Wellner et al., 2005). The current diverted discharge from the Mississippi to the Atchafalaya is managed via the Old River Control Structure, which was constructed in 1963. The Old River Control Structure diverts
30% of the combined flow of the Mississippi and Red Rivers to the Atchafalaya River and 70% of the combined flow down the channel toward the birdfoot Balize delta (Mossa and Roberts, 1990; Wellner et al., 2005; Allison et al., 2012). As much as 44% of the total annual suspended sediment load and 80% of the sand load is trapped between the Old River Control Structure and the mouths of the Mississippi and Atchafalaya Rivers (Allison et al., 2012), causing a 9% reduction in the sediment load in the Atchafalaya River basin before reaching its mouth (Xu, 2010).

1.2 Coastal Restoration and Relevant Processes

Coastal Louisiana (LA) is a complex environment regulated by the influx of water, sediment, nutrients and carbon from the Mississippi and Atchafalaya Rivers (Blum and Roberts, 2012). This coastal environment faces several complex processes in sustaining land with a rising sea, including reduced sediment supply, subsidence, saltwater intrusion, coastal eutrophication, oil and gas extraction, among others (Salinas et al., 1986; Paola et al., 2011; Rosen and Xu, 2013).

Across coastal LA, there has been approximately 4,877 km² of marsh loss since 1932 (Couvillion et al., 2010; Rosen and Xu, 2013; Couvillion et al., 2016; Figure 1). This loss can have negative implications on the surrounding ecosystems. Marsh loss also increases when saltwater intrusion occurs, causing freshwater marshes to be converted to open water and brackish and intermediate marshes to migrate landward (Salinas et al., 1986).

Wetlands serve as a protective barrier for the coast from storm events, dissipating the surge energy before reaching inland (Anderson et al. 2011; Khalil and Raynie, 2015). Losing
Figure 1. Map of land loss and gain across coastal LA over 100 years (obtained from USGS) with Wax Lake Delta and Atchafalaya Delta highlighted in the green box.

these wetlands also means losing an area of flood protection, a storm surge barrier, and an important habitat for economically important species. Due to the high value of LA wetland resources for both the state and the entire nation, the protection and restoration of coastal LA has been a priority to many political and scientific movements, such as the creation of the Coastal Protection and Restoration Authority (CPRA) in 2006.

Engineers and coastal scientists have supported the use of diversions and local dredging to either protect or restore coastal Louisiana (Allison and Meselhe, 2010; Paola et al., 2011; Nittrouer et al., 2012; Xu et al., 2016). However, there is an initiative to implement more “non-intrusive” and natural forms of shore protection, such as the use of vegetation (Augustin et al., 2009). The use of vegetation as a form of coastal protection has many benefits such as reducing storm surge, improving water quality, providing habitat for several economically important fish and shellfish species, and regulating water level (Augustin et al., 2009). The Coastal Protection and Restoration Authority (CPRA) of Louisiana produces a Coastal Master Plan every five years.
that outlines restoration projects proposed for the coming years. Two of the most commonly proposed project types are *marsh creation* and *sediment diversions* (Figure 2), which focus on the creation of marsh through sediment dredging and the transport and retention of sediment to a receiving basin to build land, respectively (Khalil and Raynie, 2015). The success of these projects depends heavily on the plant-sediment interaction and the trapping efficiency of vegetation to build land.

![Figure 2. Proposed and ongoing coastal restoration projects in coastal LA (CPRA, 2012).](image)

Nutrients, such as nitrogen and phosphorus, are essential drivers of wetland primary productivity. The relative concentration and bioavailability of these nutrients partially determine wetlands species composition and biomass across salinity gradients. Runoff from farmland in the upstream Mississippi contains fertilizers, contributing a large amount of nitrogen and phosphorus to the lower stream of Mississippi River. In 2014, 1.1 million metric tons of nitrogen and 160,000 tons of phosphorus were released to the Gulf of Mexico via the
Mississippi and Atchafalaya Rivers (EPA Report, 2015). Thus, nutrient loading due to increasing human activities along the river basin can have a major role in controlling marsh production and vegetation spatial distribution.

Although nitrogen and phosphorus are essential for plant growth, excess nutrients can lead to negative effects. One of the largest hypoxic (dissolved oxygen < 2 mg/L) events occurs annually in the northern Gulf of Mexico during the warm months of the year (Rabalais et al., 2007). The seasonal development of hypoxia in the northern Gulf is thought to be the result from a combination of eutrophication that arises from excessive nutrient loading from the Mississippi River watershed in the spring and temperature- and salinity-driven water column stratification during the summer (Rabalais et al., 2007). This hypoxic zone can be detrimental to the ecological communities that thrive in this system.

Wetland systems, such as the recently created WLD, can serve as an effective nutrient sink to reduce the amount of nitrogen and phosphorus that are currently discharged into the Gulf (Nichols, 1983; Day et al., 2004; Fisher and Acreman, 2004; Hunter et al., 2009; Twilley and Rivera-Monroy, 2009; Henry and Twilley, 2014; O’Connor and Moffet, 2015; Twilley et al., 2016). When the nutrient-rich water enters the WLD, there are several processes that can reduce the flux exiting into the Gulf. For example, the vegetation that inhabits the wetlands can use the nutrients for growth. In addition, the nutrients that are bound to sediments may settle out and deposit within the WLD.

Nutrient inputs into this deltaic wetland can experience several fates, including vegetation uptake, deposition and burial, oxidation or reduction within the sediment and export to the Gulf of Mexico (Figure 3). Nitrogen input entering the Louisiana coastal region is
in the form of NO$_3^-$ from upstream runoff due to the use of fertilizers with high concentrations of N and P. In contrast, nitrogen fixing microbes have the ability to fix N$_2$ from the atmosphere. Once NO$_3^-$ reaches the wetland, plants may uptake this nutrient and assimilate it into their tissues. It may also flow into the sediment surface layer, be transported down to anoxic regions of the sediment and be reduced to NH$_4^+$. In contrast, NH$_4^+$ may be oxidized back into NO$_3^-$ if the area is aerobic.

Figure 3. Cycling of nutrients within a wetland system (The Wetland Initiative), modified from Kadlec and Knight (1996).

Phosphorus is also transported into the system in the form of inorganic PO$_4^{3-}$ in runoff. Further, the net phosphorus input is directly influenced by sediment transport since it is estimated that up to 90% of the phosphorus is associated with suspended solids (Froelich, 1988). The dissolved phosphorus that enters the system is subject to a two-step sorption process, where the phosphorus can be adsorbed on to the sediment particles and then over
time, it can diffuse to the interior of the particle (Froelich, 1988). Once the phosphorus is deposited with the sediment, it may be assimilated by the plants, deposited into the soil, or remineralized (Figure 3). In the Mississippi River, the nitrogen (2 ppm) and phosphorus (50 ppb) levels (Turner and Rabalais, 1991) reaching the Gulf of Mexico are considered very high and can support a very productive ecosystem.

The major source of carbon to the system is the uptake of CO$_2$ for photosynthesis and release of CO$_2$ back into the system during decomposition and respiration (Figure 3). The largest reservoir of carbon in a deltaic wetland system is the sediment (Reddy and DeLaune, 2008). If the sediment is exposed to aerobic conditions, then methane will become oxidized and will release CO$_2$ into the atmosphere. These processes are likely to change seasonally with changes in productivity and will influence the nutrient composition in the water, sediment and plant tissues.

Wetland vegetation can attenuate waves, reduce current speeds, protect the shoreline from storm surge, reduce turbidity and promote sediment deposition (Leonard and Luther 1995; Nepf et al., 1997; Nepf, 1999; Nepf and Vivoni, 2000; Madsen et al., 2001; Cotton et al., 2006; Augustin et al., 2009; Corenblit et al., 2009). The velocity within a vegetated area is reduced through drag and frictional force (Nepf et al., 1997; Temmerman et al., 2005; Cotton et al., 2006). When a current enters a vegetated bed, the velocity is dampened by an order of magnitude and decreases more with increasing vegetation density (Leonard and Luther 1995; Nepf et al., 1997; Corenblit et al., 2009). Some studies suggest a reduction of velocity by vegetation by a factor of 2 to 2.5 (Corenblit et al., 2009; Cotton et al., 2006). The direction of flow can also be influenced by the presence of vegetation (Leonard et al., 2002). The ability of
plants to attenuate current and wave energy is influenced by the plant characteristics such as stem density, geometry, buoyancy and local hydrodynamics (Augustin et al., 2009; Anderson et al., 2011).

The velocity profile can be influenced differently by emergent and submerged vegetation types (Leonard and Luther, 1995; Temmerman et al., 2005). Emergent vegetation affects the entire water column and attenuates waves 50 to 200% more than submerged vegetation (Augustin et al., 2009; Anderson et al., 2011). Velocity profiles in submerged vegetation conditions have an area where the flow is unobstructed by vegetation. Therefore, submerged vegetation generally has less influence on wave attenuation than emergent (Augustin et al., 2009; Anderson et al., 2011).

Decreased current velocity and wave energy has implications for associated sediment deposition and retention (Leonard and Luther, 1995; Nepf, 1999; Madsen et al., 2001). Reduced flow leads to an increased residence time of water in a vegetated area, which promotes fine sediment deposition (Leonard and Luther, 1995; Nepf et al., 1997; Nepf, 1999; Cotton et al., 2006; Henry and Twilley, 2014). Increased spatial coverage of fine sediment has been found to be associated with vegetative growth (Cotton et al., 2006; Henry and Twilley, 2014; Smith, 2014). In addition, vegetation biomass adds organic matter to the soil, which is eroded easily due to its low bulk density but may accumulate over time. However, vegetation also traps finer mineral particles, such as silts and clays, which contribute to overall net accretion (Madsen et al., 2001). Wetland sediments hold most of the phosphorus and nitrogen that rooted macrophytes require for growth (Madsen et al., 2001), thus forming a positive feedback loop between vegetation growth and sediment deposition (Paola et al., 2011). However, when
vegetation dieback occurs due to cold weather, saltwater intrusion, or prolonged inundation, the sediment becomes non-vegetated and more erodible. Furthermore, this erosion leads to deeper water depths, making it difficult for vegetation to re-establish.

Vegetation not only promotes sediment deposition but also has a stabilizing effect, creating land that is less likely to be converted to open water, which has strong implications for coastal restoration (D’Alapaos et al., 2007; Rosen and Xu, 2013). The contribution of organic matter from plant productivity and trapping of inorganic sediment enhances marsh resilience by enhancing accretion (Schile et al., 2014). Vegetation cover is a key factor in determining long-term geomorphic development of marshes (Nepf et al., 1997).

1.3 Wax Lake Delta

Even though the Mississippi sediment supply was reduced, there has been sediment transported to the Atchafalaya Bay via the Wax Lake Outlet (WLO) to build land; however, this was not the original purpose of WLO (Roberts, 1998). This land became subaerial in 1973 (Roberts et al., 2003; Wellner et al., 2005; Jones, 2016), creating the Wax Lake Delta (WLD). Although the Wax Lake Outlet was man-made, the WLD has continued to self-organize and grow naturally (Figure 4) without the need for dredging or leveeing since 1973 (Wellner et al., 2005; Jones, 2016). Kolker et al. (2014) studied 7Be radionuclide of core sediment and reported 0-5 cm of flood sediment deposit in WLD after 2011 Mississippi River flood (Figure 5); these flood accumulations can be approximately converted to ~0-2 cm/year of annual sediment accumulation rate. In addition, Smith (2014) studied an island in WLD and reported estimated average deposition rates ranging from 3.7 to 6.9 cm/year.
Figure 4. History of subaerial growth of WLD from 1983 to 2002 (Wellner et al., 2005). Mike Island is marked in the year 2002.
Figure 5. Penetration depth (in cm) of $^7$Be sediment cores from Wax Lake Delta (from Kolker et al., 2014). Mike Island is marked.

The WLD is a dynamic area that is largely influenced by seasonal river pulses, tides, winds, and cold fronts (Figures 1 and 4) (Mossa and Roberts, 1990; Roberts et al., 2015). This area provides a unique opportunity to explore the local hydrology and sediment transport in an accreting delta. The area of study is Mike Island, which is located within the middle of the WLD (Figure 6). Morphologically, Mike Island is an interdistributary bay between two primary channels. The northern part of Mike Island has a small secondary channel that serves as an entry point for water, sediment and nutrients from a primary channel to the interior of Mike Island (Figure 6) (Hiatt et al., 2015). Approximately 23-54% of the flow from the primary channel enters the island via secondary channels and overbank flooding (Hiatt et al., 2015). During a flood stage, the majority of island can be dominated by overbank flooding and
elevated discharge from the secondary channel. Tidal influence has been shown to be a dominant force for sediment input and deposition on Mike Island (Bevington et al., in review) as well as a determinant factor in the flow direction within the secondary channel (Hiatt et al., 2015). Overall, there is an increase in connectivity between the primary channels and the island interior moving from the apex toward the Gulf, thus making this a unique yet complex area to study (Hiatt et al., 2015).

Figure 6. Location of the two stations used in this project, Mike1 and Mike3 (from Google Earth). Primary channel, secondary channel and interdistributary bay are marked in the map.
Ambient minimum temperature is one of the driving forces of vegetation presence not only in the WLD but along coastal Louisiana. During the winter months, the average temperature is between 6-22° C. Even though nutrients are still present in the water column, the temperature is too cold (<15° C) for plant growth (Figure 7). However, as the temperatures rise in conjunction with the excess of nutrients available, vegetation can grow extensively (Figure 7).

![Figure 7](image)

**Figure 7.** Seasonal difference in vegetation biomass on Mike Island (Taken by Edward Castañeda-Moya).

The seasonal dichotomy in vegetation biomass on Mike Island is very distinct (Figure 7). During winter, when vegetation is sparse and in patches, there is an uninterrupted flow. The velocity profile only becomes influenced by the friction with the sediment within the bottom boundary layer. During the summer, the vegetation becomes dense and widespread, slowing down the currents and resulting in an increased water residence time. As the water slows down, the finer grain particles settle out. This deposition of inorganic particles and contribution of organic matter from the vegetation can lead to net accretion.
There is a clear zonation of wetland vegetation along an elevation gradient in Mike Island (Figure 8). The flooding regime and salinity drive the presence or absence of a given species in a location (Paola et al., 2011). This elevation gradient has been noted at Mike Island, as there is a distinct shift from *Salix nigra* (willow trees) along the levees (higher elevation) to *Nelumbo lutea* in areas of low elevation (Carle et al., 2015; Hiatt et al., 2015) (Figure 8).

Vegetation in the areas of higher elevation, such as *Salix nigra*, is present all year; however, vegetation in lower elevations is seasonally present (Henry and Twilley, 2014).

Figure 8. Vegetation species across an elevation gradient at Mike Island of Wax Lake Delta (Carle et al., 2015).
1.4 Motivations and Scientific Questions

There are a number of wetland and deltaic-geomorphologic studies on land loss, sea level rise and coastal subsidence along the Louisiana coast. Nutrient cycling, plant growth and decay, local hydrology and morphology have been studied extensively by biogeochemists, ecologists, and geologists as well. However, there is a gap in the knowledge of the interactions among hydrology, sediment and vegetation in accreting deltas in coastal Louisiana to inform future restoration measures such as freshwater and sediment diversions. The mechanisms that control the plant-sediment interaction and relative contributions of drivers such as wind, wave, tide, current and river are not yet fully understood.

Although the general relationship of the plant-sediment interaction is understood (Leonard and Luther 1995; Nepf et al., 1997; Nepf, 1999; Madsen et al., 2001; Cotton et al., 2006; Augustin et al., 2009; Corenblit et al., 2009), few studies have been performed on coastal Louisiana deltaic plains. The seasonal vegetation growth and decomposition rates greatly influence water velocity and turbidity in marsh islands, leading to rapid changes on sediment roughness and viscosity of bottom boundary layer. In addition, vegetation growth can promote or inhibit overbank flooding on these deltaic islands (Hiatt et al., 2015). These parameters are essential but are often simplified in hydrodynamic and sediment dynamics models currently being used by the Louisiana CPRA. In fact, time-series high resolution bottom boundary layer observation in growing deltas is rather limited. Xu et al. (2016) reported that the success of future Louisiana large diversions is highly dependent on the retention of mud (<63 μm; phi >4) since >80% of Mississippi River sediment falls in this category. If artificial planting is used as a “non-intrusive” method in combination with marsh natural creation or sediment diversions,
vegetation can potentially uptake nutrients, slow down velocity, trap mud, and enhance mud retention to build more land (Paola et al., 2011). Thus, the study of plant–sediment interaction has both management and economic implications to coastal Louisiana restoration plans.

Deltaic wetlands are an important interface between the land and the ocean as it serves as an area of efficient nutrient removal (Nichols, 1983; Day et al., 2004; Fisher and Acreman, 2004; Hunter et al., 2009; Twilley and Rivera-Monroy, 2009; Henry and Twilley, 2014; O’Connor and Moffet, 2015; Twilley et al., 2016). Future large Louisiana diversions can bring not only water and sediment but also carbon and nutrients to Louisiana estuaries and wetlands. There have been concerns on the possible new hypoxia development in Louisiana estuaries after the openings of large diversions (Turner et al., 2002; Turner et al., 2004; Bargu et al., 2011). Thus understanding the nutrient cycle (particularly the nutrient removal along the water-sediment interface) is critical to the ongoing biogeochemical modeling effort by the CPRA.

The overarching goal of this study is to investigate interactions among hydrology, sediment and vegetation to improve our understanding of physical and biogeochemical processes in the water column, water-sediment interface and sediment (0-50 cm) in the accreting WLD. Specific scientific questions addressed in this study are: (1) What are the grain size distribution and organic matter content of suspended, surficial (sediment surface) and down-core sediments at an upstream and downstream location within a naturally created interdistributary bay (Mike Island) in WLD? Coarser materials will be deposited at the upstream location due to the proximity to the higher energy secondary channel. Coarser materials will settle out first as flow exits the secondary channel and finer materials will be deposited downstream. Organic matter is likely to be greater downstream due to the high mineral input
from the secondary channel upstream. (2) What are the roles of wind, river discharge, wave, tide and vegetation in controlling sediment transport between an upstream and downstream location on Mike Island, and how do these roles change in contrasting seasons and during events like river floods and cold fronts? During spring, when river discharge is high and vegetation biomass is low, the river discharge will be a dominant driver in sediment transport. The upstream location will be more influenced by river discharge while the downstream location will be more influenced by wave influence. Tidal influence will be more obvious when river discharge is low. River floods and cold fronts will bring a new complexity to sediment transport and will likely transport large amounts of sediment to the delta top. (3) How do the vegetation richness, aboveground biomass, and nutrient content vary between upstream and downstream locations within Mike Island? Due to the elevation gradient present between the upstream and downstream location, more species will likely be found upstream than downstream. Biomass may vary based on the species diversity found at each location. Nutrient content is expected to be similar due to the short distance between the upstream and downstream locations and multiple entry points for nutrient-laden water to enter the island interior. (4) How does the plant-sediment interaction impact the nutrient cycle at these two locations? Specifically, is there a difference in the nutrient concentration of porewater and overlying water at upstream and downstream locations when vegetation is present? When vegetation is present, lower concentrations of nitrate and orthophosphate will be present in the overlying water if the currents are slow enough for uptake by plants. Ammonium is expected to be high in the porewater with vegetation due to remineralization. (5) How do bulk density, nutrient content (mainly P and N) and total carbon change in preserved core sediments
sampled from upstream and downstream locations? Since there is a different depositional age and rate between the upstream and downstream locations, it can be expected that the depth profiles of bulk density, nutrient content and carbon content reflect the higher mineral input upstream.
2. METHODS

2.1 Study Site

During the past decade there have been extensive geological and biogeochemical studies in the WLD area. Time-series velocity, water level, turbidity and nutrient data have been collected at six platform stations on Mike Island that are monitored through the National Science Foundation’s Frontiers in Earth System Dynamics (FESD) project (PI: Robert Twilley). Two of the above six platforms were chosen for this study (Figure 6). One station is Mike1 which is located at northern Mike Island, near the secondary channel where pulsing river discharge enters the island. The other station is Mike3 which is about 1.5 km south of Mike1 and located within the interior of the island (Figure 6). Due to time and resource limitations, the majority of this study’s research effort is on these two stations, and they will be compared extensively. In a typical high river discharge condition, the river flows into Mike Island, passes the upstream station (Mike1) before reaching the downstream station (Mike3). This flow direction, however, can be reversed when the river discharge is low and flood tidal currents are high from the Gulf of Mexico or during storm events (O’Connor and Moffett, 2015). In addition to six platforms, there was a monthly survey grid of 30 stations used in Mike Island implemented for the FESD project. As explained below, surficial sediments were collected in these 30 stations to study spatial grain size variation as well.

2.2 Wind and Discharge Data

Data collected from nearby National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS) stations were used to quantify wind and river forces influencing Mike Island. River discharge and gauge height were from the USGS Wax Lake...
Outlet station, in Calumet, located approximately 20 km upstream of Mike Island (29°41'52" N, 91°22'22 W) (Figure 9). Wind speed and direction data were downloaded from NOAA’s National Data Buoy Center (NDBC) station located at Amerada Pass (29°26'58" N, 91°20'17" W), approximately 12 km southeast of Mike Island (Figure 9).

Figure 9. Map of the NOAA and USGS stations where wind and discharge data were collected in relation to the two platforms on Mike Island.

2.3 Field Methods

2.3.1 Time-Series Observation

An array of acoustic and optical sensors was deployed during two seasons, spring and summer of the year 2015. The objective of these deployments was to identify spatiotemporal
variations in water level, velocity, turbidity, and waves. The spring deployment took place from
March 29 to May 2, 2015, when the river discharge was high and vegetation biomass was
relatively low. The summer deployment was from August 28 to October 22, 2015, when river
discharge was considerably lower, and vegetation biomass was at its peak.

Prior to field deployment, all instrument parameters were set up in the Sediment
Dynamics Lab at Louisiana State University (LSU) and programmed to begin recording variables
at an estimated time of deployment the following day. For all acoustic instruments, proper
compass calibrations were completed prior to deployment in the field. All of the instruments
were then wrapped with plastic bags to prevent biofouling during deployment, but did not
interfere with the acoustic and optical windows.

At the Mike1 station, an x-platform was deployed with a SonTek Acoustic Doppler
Velocimeter (ADV) Argonaut, Campbell Scientific Optical Backscatter Sensor (OBS) 5+, and an
Ocean Sensor Systems wave gauge (Figure 10). During both deployments at Mike1, the ADV
Argonaut was deployed downward-looking on the x-platform, at a position where the current
velocity was measured 15 cm above the x-platform frame. The average ADV burst duration, or
the time that the instrument collects current data, is 60 seconds. The 60 seconds of data were
used to represent the sampling interval of 3600 seconds, or 1 hour; thus, there were 60
seconds of data collected at the beginning of each hour of the deployment. The ADV Argonaut
takes three dimensional velocity measurements in order to identify local current speed and
direction at a point 10 cm below the acoustic transmitter (at 25 cm). The OBS 5+ was oriented
downward-looking, with the optic window facing upstream and 15 cm above the x-platform
frame. The duration of sampling for the OBS 5+ was 60 seconds, for every 3600 seconds
interval, similar to the ADV Argonaut. The purpose of deploying the OBS 5+ is to quantify turbidity near the sensor. The wave gauge was deployed during both deployments positioned with the pressure sensor downward-looking and 15 cm above the x-platform frame. The sampling rate was set at 10 Hz and the burst duration was 20 minutes, thus measuring 12,000 data points during 20 minutes of each hour. The wave gauge provided high-resolution pressure data on changes in wave characteristics such as wave height, wave period, and significant wave height. A similar array of acoustic and optical sensors was deployed at Mike3 to compare hydrology and sediment transport.

At the Mike3 platform, a small tripod was deployed with a SonTek ADV Ocean, Campbell Scientific OBS 3A, and an Ocean Sensors System wave gauge (Figure 11). During both deployments, the ADV Ocean was deployed downward-looking, with the acoustic transmitter located approximately 33 cm above the wood board attached to the bottom of the tripod. The
transmitter has three receivers to give a measure of three-dimensional velocity \((u, v, w)\). There is an 18 cm blank distance between the transmitter and the point of measurement; therefore, the velocity is measured 15 cm above the bed. The ADV Ocean was programmed to sample at a rate of 1 Hz for duration of 1024 seconds, providing 1024 samples per burst at the beginning of one hour. The OBS 3A was deployed during both seasons as downward-looking, with the optic window both facing upstream and at a position 15 cm above the wood board. The OBS 3A was deployed at a sampling rate of 1 Hz and power of 50%. The burst duration for the OBS 3A was 60 seconds for every one hour burst interval. The purpose of deploying the OBS 3A was to measure temperature, salinity and turbidity. Another wave gauge was deployed using a setup similar to that of Mike1.

![Figure 11. Tripod deployed at Mike3 during both deployments with instruments including an ADV Ocean (sensor and external battery), OBS 3A, and Wave Gauge.](image)

Following retrieval of both the tripod and x-platform, all instruments were brought back to the lab to download and analyze data collected during the deployment.
2.3.2 Water Sampling

Water bottles of 2000 mL were used to collect in-situ water samples near the sediment surface and in the middle of the water column at Mike1 and Mike3 during several collection periods. The water was collected for total suspended solid (TSS) analysis in March, May, August and October of 2015, which represent the start and end of each sensor deployment.

Overlying water approximately 10 cm above the water-sediment interface and porewater at 30 cm below the interface were collected at Mike1 and Mike3 in vegetated and non-vegetated areas during several field trips. Hereafter they will be referred to as overlying and porewater, respectively. Vegetated areas were targeted areas that had visible aboveground biomass during collection in March 2015. Non-vegetated areas did not have visible aboveground biomass during collection; however, they are likely still influenced by vegetation presence. This distinction between vegetated and non-vegetated areas remains for subsequent analyses. Two centrifuge tubes of 50 mL were collected at each one of these locations. This water was filtered in the field and stored in labelled, plastic scintillation vials. The vials were then stored in the lab freezer upon return to LSU and sent to the lab for analysis of \( \text{NO}_2^- \), \( \text{NO}_3^- \), \( \text{NH}_4^+ \), and \( \text{PO}_4^{3-} \) within 1-3 days of collection.

2.3.3 Sediment Sampling

Trap, surficial grab and core sediments were all collected for this study. During the spring deployment, a prototype sediment trap was deployed at Mike1 and Mike3 platforms that consisted of two 10-cm diameter PVC caps and drain inserts placed on opposite sides of a 2.5-cm diameter PVC pipe (Figure 12). One sediment trap was flushed with the sediment-water interface and the other was located 30 cm above the interface. During the summer
deployment, triplicate sediment traps were deployed at Mike1 and Mike3. At the end of each deployment, the sediment traps were stored in the cold room (4°C) until further analysis.

![Sediment trap](image)

**Figure 12.** Sediment trap used for collection at the sediment-water interface and 30 cm above the bed.

Surficial sediment samples were collected using a shovel at a survey grid of 30 stations across northern Mike Island for grain size analysis. Approximately the top 5cm of sediment was collected during April and August 2014. A small portion of each of these homogenized grab samples was used for grain size analysis.

Push cores made of PVC material (internal diameter= 10 cm; length= 50 cm) were used to collect intact sediment cores at both upstream (Mike1) and downstream (Mike3) locations in vegetated and non-vegetated patches. There were three push cores taken at Mike1, with two in
non-vegetated areas and one in a vegetated patch. Three push cores were also taken at Mike3 later in the year, with all three in vegetated areas.

Russian cores (internal diameter= 5.4 cm, length 50 cm) were also taken at Mike1 and Mike3 in vegetated and non-vegetated areas. Two Russian cores were collected at vegetated and non-vegetated areas at both Mike1 and Mike3. The intact sediment section was 50 cm long and 5.4 cm wide. After collection, the cores were transported back to LSU and stored in the cold room (4°C) until further analysis.

2.3.4 Vegetation Sampling

On August 25, 2015, vegetation aboveground biomass was estimated by clipping all aboveground biomass within a standard 0.25 m² quadrat. Three quadrats were taken at Mike1 and Mike3, respectively. Vegetation was stored in the cold room (4°C) until further analysis.

2.4 Laboratory Methods

2.4.1 Water

The water bottles for TSS measurements were transported back to LSU and stored in the cold room (4°C). The water was filtered through a pre-weighed Whatman 125 mm filter to collect any suspended material in the sample. The filters were then dried and weighed after 48 hours. The initial weight of the filter was subtracted from the filter with sample to determine the total suspended solids within a known volume of water (mg/L).

NO₂⁻, NO₃⁻, NH₄⁺, and PO₄³⁻ concentrations in the overlying water and porewater were determined by LSU Wetland Biogeochemistry Analytical Services (WBAS) via segmented flow analysis using a Flow Solution IV AutoAnalyzer (OI Analytical, College Station, Texas). Only
results from May and October were used in statistical analyses due to missing porewater data in both March and August. However, these months represent seasonal differences.

2.4.2 Sediment

The sediment within the trap was recovered and placed into a beaker to estimate the volume of sediment or slurry, homogenized, and then was separated into two smaller beakers for loss-on-ignition and nutrient analysis and a small amount was placed in a centrifuge tube for grain size analysis. The sediment was weighed before and after being placed in the drying oven for at least 48 hours. One beaker was used for loss-on-ignition and the other was ground and packed for nutrient analysis. The material was placed in the muffler furnace at 550°C for 2.5 hours to eliminate any organic matter (Heiri et al., 2001).

The push cores were split into 5 cm increments and analyzed for sediment grain size after homogenizing the sample. A small amount of each core slice or plugs (~1 g) was placed into a centrifuge tube and about 20 mL of 35% hydrogen peroxide was added to the sediment to eliminate any organic matter. The centrifuge tubes were placed in beakers of water on the hot plate at 65°C until bubbling seized within the tube. To ensure that all organic matter had been removed, an additional 10 mL of hydrogen peroxide was added to each centrifuge tube. After the reaction was complete, the centrifuge tubes were brought to the same volume using distilled water and were placed in the centrifuge. The supernatant (excess liquid) was then poured out, leaving the sediment at the bottom. A small amount of distilled water was added to the centrifuge tube and a vortex mixer was used to disaggregate the particles before analysis. When prompted, the sediment-water mixture was poured into the collection chamber of the Beckman Coulter LS 13 320 Laser Grain Size Analyzer to provide a distribution of grain
sizes using laser diffraction and refraction properties. Then the fractions of sand (>63 μm; phi < 4), silt (4–63 μm; phi is 4–8) and clay (<4 μm; phi > 8) were determined. The mud size discussed in this study is the summation of silt and clay class sizes.

The Russian cores were solely used for nutrient analysis while the push cores were used for grain size and nutrient analysis. All of the Russian cores were cut into 5 cm intervals and weighed before being placed in the drying oven for at least 48 hours. The push core slices were divided further by using a piston corer to extract three plugs for either grain size or nutrient analysis. For grain size analysis, the sediment does not need to be dried so the plugs or the slice without the plugs were stored in the cold room (4°C) until grain size analysis was completed. The remainder of the slice was placed in the drying oven (at 60°C) until a constant weight was met to determine bulk density. After reaching a final dry weight of the core slice, the bulk density of the slice was calculated using the measured dry weight divided by the calculated volume of the slice or plugs. The dried sediment was then ground with a Wiley mill grinder to 40 μm and transferred to individual glass scintillation vials. A small amount of sediment (9.0–13.5 mg) was transferred from the scintillation vial to a small tin capsule that was folded into a small square, weighed, and stored in a plastic tray for nutrient analysis by LSU WBAS. Percent of total carbon and nitrogen for each sample was measured using a Costech 1040 CHNOS Elemental Combustion system (Costech Analytical Technologies, Inc. Valencia, California). Additionally, the sediment was analyzed for total phosphorus (TP) using 1 M HCl for the digestions, following the methods described by Aspila et al. (1976). The sediment was diluted at 10x prior to using an Auto-Analyzer (see above Water section of Laboratory Methods) to perform the colorimetric procedure to determine TP. Loss-on-ignition was completed at 550°C.
for 2.5 hours for all sediment samples analyzed for TP to remove organic matter prior to analysis (Heiri et al., 2001).

2.4.3 Vegetation

The vegetation was sorted into genus and species (when possible) within each collected quadrat. Within each species, the roots, stems, leaves, fruits, and flowers were separated into individual paper bags and weighed before and after drying until a constant dry weight was met. The dry weight was documented to estimate aboveground biomass during peak production months (August-October) at Mike1 and Mike3. All vegetation samples were ground using a Wiley mill grinder through a 40 um mesh and stored in separate glass scintillation vials. The ground vegetation was packed into tin capsules (similar to sediment preparation) for percentage of total carbon and nitrogen using a Costech 1040 CHNOS Elemental Combustion system (Costech Analytical Technologies, Inc. Valencia, California). Additionally, total phosphorus was measured for vegetation, using a 1 M HCl solution for the digestion, following the methods of Aspila et al. (1976). All vegetation, except one sample, was run at a dilution of 50x. One sample (Colocasia leaf from upstream) was run at a 70x dilution because TP was higher than the standard curve; therefore, it could not guarantee accurate results.

2.5 Data Analysis

Data collected from the acoustic and optical sensors during the field deployment were plotted and analyzed primarily using MATLAB software. Due to the large number of wave gauge data points, a specialized Wave ToolBox developed by Drs. Jim Chen and Arash Karimpour from LSU, OCEANLYZ, was used to analyze the data using Fast Fourier transform (downloaded from http://download.cnet.com/Oceanlyz/3000-2054_4-75833686.html). The ADV Argonaut data file
included the signal-to-noise ratio (SNR) for each data point, which can be used as a proxy to check data quality. A quality assurance/quality control assessment was performed on the raw data so that any data point that had a SNR less than 20 was not used in the analysis. The ADV Ocean data file included a quality coefficient for three velocity components for all 1024 samples per burst. If at least 60% of the 1024 sample points within a burst were of good quality, then the burst was used in the analysis; those bursts with less than 60% were not used in the analysis.

2.6. Statistical Analysis

Two-factor analysis of variance (ANOVA) tests were run on all data to determine the significance using SAS JMP Pro 12 software. For the sediment trap data, the trap location (upstream, downstream), the collection location (water column, sediment surface), and their interaction were the fixed factors to determine differences in TN, TC, TP, and bulk density. The nutrients collected in the water were analyzed by location (upstream, downstream), month of collection (May, October), vegetation presence (yes, no) and water collection (overlying, porewater), and their interactions. In addition, seasonal differences were analyzed among overlying and porewater inorganic nutrients. The water nutrient data were log-transformed and evaluated for normality and samples size previous to statistical analyses (Tolotti et al., 2012). The response variables for the water nutrients were total inorganic nitrogen (TIN= NO$_2^-$ + NO$_3^-$ + NH$_4^+$) and PO$_4^{3-}$. Statistical analyses were run on the Russian cores. Soil variables were also analyzed by soil depth. The fixed factors in this analysis were location (upstream, downstream) and vegetation presence (yes, no) as well as their interaction. The response variables for soil core nutrients were TP, TN, and TC. Vegetation differences were only analyzed
on the two species that were present at both upstream and downstream locations: *Eichornica crassipes* and *Nelumbo lutea*, where location was considered also a fixed factor. The response variables for vegetation included TN, TC and TP. Tukey honest significant difference (HSD) tests were run on significant interactions where appropriate. All significant results were determined by an alpha value of 0.05.
3. RESULTS

3.1 Water Column Processes

Discharge from the Atchafalaya River shows a distinct seasonal pattern, with high discharge during the spring and early summer months and low discharge during the fall and winter (Figure 13). During 2015, river discharge was at a higher magnitude than previous years and extended into late July. During the spring deployment, the river was in a flood stage, with a discharge of approximately 5500 m$^3$/s measured at the Calumet station (Figure 13). The gage height at Calumet during the spring deployment was 1.8 meters, relative to NAVD88 (North American Vertical Datum of 1988), with a small variation during the deployment. Relative water level ranges at both Mike1 and Mike3 during the spring deployment were between 0.2 and 0.5 m, with larger variations during the middle to end of April 2015 (Figure 14C). Although Mike1 and Mike3 are in phase most of the time (Figure 14C), during some lower water levels Mike3’s tidal ranges were larger than those recorded in Mike1 (Figure 14D).

Wind data were collected from a NOAA buoy station in Amerada Pass. During the spring deployment, the majority of the wind speed remained between 4 and 5 m/s (Figure 14A). However, around April 26, wind speed reached a maximum of 14 m/s. The wind direction during the spring deployment shifted mostly from southeast to southwest. During the middle to end of April 2015, there are larger shifts in wind directions. These enhanced wind speeds and changes in wind direction correspond with a storm event that passed through coastal Louisiana during this time.
Figure 13. River discharge and gage height measured at the USGS gauging station, Calumet; the deployment periods are outlined in purple.

Figure 14 (A-D). Wind and relative water elevation data from the April 2015 deployment where (A) Wind speed and direction collected from Amerada Pass, (B) water level data from USGS Discharge Station at Calumet relative to NAVD88, (C) Mike1 (blue) and Mike3 (red) relative water level variations, and (D) difference in relative water level between Mike1 and Mike3; Note the increase in wind speed and relative water level during late April 2015.
Another strong seasonal change on Mike Island is the presence and density of wetland vegetation. During the winter, vegetation was sparse and occurred in patches. However, during the summer the vegetation was dense and widespread, likely influencing the local hydrodynamics and sediment transport, along with the dispersion of flow across the island. The seasonal difference in vegetation biomass and density is clear on LANDSAT images that correspond closely with the deployments (Figure 15). Low intensity of reflectance by vegetation is clear in the image taken during the first deployment in April 2015. Even during periods of low biomass, there is still vegetation present along the northern edges of Mike Island, due to a higher elevation along these levees where a willow forest (Salix nigra) dominates this habitat. The upstream to downstream flow is clear in this image of the interdistributary bay. However, this flow is not as clear in the image taken from peak biomass in August 2015 (Figure 15b), which could be due to lower river discharge and the extensive growth of vegetation throughout the island.

Figure 15 a-b. LANDSAT images processed using data from USGS and analyzed by the Earth Scan Laboratory at LSU showing vegetation cover on Mike Island during (a) low productivity, taken on April 19, 2015 and (b) peak productivity, taken on August 25, 2015.
Wave parameters were collected at Mike1 and Mike3 during both deployments. The wave height at Mike1 during the spring deployment was very small and usually less than 1 cm (Figure 16A). There are some small peaks in wave height up to 4 cm. The wave heights at Mike3 during the spring deployment are larger than Mike1 and during some times, an order of magnitude higher than Mike1. Wave heights remained below 5 cm during the majority of the deployment but there was a period in late April 2015 when the wave height exceeded 20 cm, corresponding with the storm event (Figure 16A).

During the spring deployment, the current speed at Mike1 was on average 23 cm/s (Figure 16B). At Mike3, the ADV Ocean failed due to a battery problem and no data were collected. However, a 2-dimensional ADV was deployed at Mike3 for the FESD-NSF project, and its velocity data were then used for this study. The average current velocity at Mike3 was 6 cm/s (Figure 16C).

The different physical forces described above can influence the sediment dynamics within the system. Using an OBS, a proxy of turbidity (in Nephelometric Turbidity Unit-NTU), was measured at Mike1 and Mike3 during both deployments. At Mike1 during the spring, turbidity remained relatively stable with a few peaks, until the storm in late April, when there were several large peaks (Figure 16D). There are several large peaks in turbidity at Mike3 during the spring. However, the majority of the NTU values remained relatively stable (Figure 16E).

During the summer deployment, the river discharge was much lower at approximately 1000 m$^3$/s. The gage height measured during this deployment fluctuated around 1 meter, with a strong variation that mimics tidal signal. There is a drop in gage height at Calumet noted during October 1 (Figure 17B). During the summer, the river discharge was much lower and...
Figure 16 (A-E). (A) wave height at Mike1 (blue) and Mike3 (red), (B) current velocity at Mike1, (C) current velocity at Mike3, (D) turbidity at Mike1, (E) turbidity at Mike3; Note the enhanced wave height, current speed at Mike3 and turbidity during late April 2015.

thus had a smaller impact on the local hydrodynamics at Mike1 and Mike3. However, Mike1 was still more influenced by riverine discharge than Mike3. The water level at Mike1 during the summer oscillated around a range of 0.6 m with a variation that mimics a tidal signal (Figure 17C). A drop in water level of about 80 cm is evident around October 1, 2015, which corresponds to a cold front event. At Mike3, the water level followed a similar tidal oscillation, with a drop in water level also during October 1 (Figure 17D).

During the summer deployment, wind speeds were mostly between 3 and 4 m/s, with a few larger peaks not to exceed 8 m/s (Figure 17A). Wind direction during the summer shifted from northeast to northwest in a clockwise manner over a 7 day period. There was a strong shift in wind direction on October 1, 2015 from the northeast to northwest over a single day, which was linked to the cold front (Figure 17A).
Figure 1 A-D. Wind and relative water elevation data from the Sept.-Oct. 2015 deployment where (A) Wind speed and direction collected from Amerada Pass, (B) water level data from USGS Discharge Station at Calumet relative to NAVD88, (C) Mike1 (blue) and Mike3 (red) relative water level, and (D) difference in relative water level between Mike1 and Mike3; Note the drop in water level in early October 2015.

Water temperature during the spring deployment did not show much variation. However, during the summer deployment, there was a drop in temperature of about 8°C after October 1, 2015 (Figure 18 A). This drop in temperature occurred during the same time as the drop in water level on October 1 during the passage of a cold front.

Wave height at Mike1 during the summer was close to 0 m throughout the majority of the deployment. There were several peaks but they do not exceed a maximum of 4 cm (Figure 18B). Wave height at Mike3 during the summer was also very small, approximately 0.1-0.2 cm (Figure 18B).

During the summer, the average current velocity collected by the ADV Argonaut at Mike1 was approximately 13 cm/s (Figure 18C). The ADV Ocean successfully collected data during the first 30 days of the summer deployment. The ADV Ocean shows some intriguing
velocity data during the first week of summer deployment, where there were velocities up to 30 cm/s and then the values drop to near 0 cm/s on September 6, 2015 and remain low throughout the rest of the deployment (Figure 18D). There are a few periods where velocity may reach 5 or 10 cm/s but is distinctly different from the first week of this summer deployment.

The turbidity values collected at Mike1 during the summer were usually lower but there were several peaks throughout the deployment (Figure 18E). The turbidity data collected from Mike3 during summer do not vary much throughout the deployment (Figure 18F). However, there was one sharp increase in turbidity on September 6, 2015 that coincides with a drop in velocity at Mike3.

Figure 18 (A-F). (A) water temperature, (B) wave height at Mike1 (blue) and Mike3 (red), (C) current velocity at Mike1, (D) current velocity at Mike3, (E) turbidity at Mike1, (F) turbidity at Mike3; Note the large velocity drop and increase in turbidity on September 6th and large drop in temperature in early October 2015.
TSS values generally decreased from March to October. However, there were extremely high values measured in the surface water in October at Mike1, which may have been due to disturbance prior to sampling. All values can be found in the Appendix Table A1.

3.2 Water-Sediment Interface

3.2.1 Overlying Water and Porewater

Overlying water was collected at Mike1 and Mike3 in both vegetated and non-vegetated areas in March, May, August, and October of 2015. Due to logistics limitations and sampling difficulty, porewater was sampled in March at Mike1 at both vegetated and non-vegetated areas but only in the vegetated area for Mike3. Porewater was collected in May and October at both Mike1 and Mike3 in vegetated and non-vegetated areas. No porewater data were collected in August due to sampling time restrictions. Inorganic nitrogen was analyzed as total inorganic nitrogen (TIN) and represented by the sum of \( \text{NO}_3^- \), \( \text{NO}_2^- \) and \( \text{NH}_4^+ \).

The total inorganic nitrogen (TIN) concentrations showed a significant three-order interaction: month of collection (May, October), location (upstream, downstream), and compartment (overlying, porewater) (p=0.0062**) (Figure 19, Table 1). Despite this interaction, there is a significantly higher TIN in the porewater in October at Mike1 (115.4 uM) and Mike3 (101.5 uM) than in the other collection dates or compartments.

The difference in TIN concentration between the surface and porewater was significant at all sites and seasons except during May 2015, at the downstream location. The large contributions of TIN in the porewater are attributed to high concentrations of \([\text{NH}_4^+]\) (78.6 ± 9.5 uM), while \([\text{NO}_3^-]\) is the main contributor to TIN (22.5 ± 3.6uM) in the
Figure 19. TIN concentrations (uM) separated by site location; Season is by color (May= blue, October= red) and compartment is indicated by design (overlying= solid, porewater= diagonal); Standard error bars are presented with the Tukey HSD group by letter above

Table 1. ANOVA source table for the Total Inorganic Nitrogen (TIN) concentrations; the following notation is used to indicate levels of significance * <0.05, **<0.01, ***<0.001

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overlying water. Although vegetation presence was not significant in a three-order interaction, it was significant in a two-order interaction with compartment and month (p<0.0001***and p<0.0025**, respectively) (Table 1).

Orthophosphate showed a significant two-order statistical interactions between location (upstream or downstream) and the month of collection (May, October) (p=0.0004**) (Table 2). During May 2015, there was no significant difference in PO$_4$$^{3-}$ concentrations between upstream and downstream locations. However, during October, the upstream location had significantly higher concentrations of PO$_4$$^{3-}$ (Figure 20). Downstream concentrations did not vary significantly between seasons.

Table 2. ANOVA source table for the PO$_4$$^{3-}$ data; the following notation is used to indicate levels of significance * <0.05, ** <0.01, *** <0.001

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The location of water collection and vegetation presence had a significant interaction in determining the $\text{PO}_4^{3-}$ concentrations ($p=0.0188^*$) (Table 2). The largest concentration of $\text{PO}_4^{3-}$ across location and vegetation presence was in the non-vegetated area at the upstream location (Mike1). There was no significant difference in $\text{PO}_4^{3-}$ concentration between vegetated and non-vegetated areas downstream whereas the concentration in vegetated locations upstream was significantly greater than non-vegetated areas (Figure 21).

The other interaction that was significant in determining $\text{PO}_4^{3-}$ concentrations in the water were the factor “compartment” (i.e., overlying water and porewater) and vegetation presence ($p=0.0331^*$) (Table 3). There was a significant difference between the overlying and porewater regardless if the location was vegetated or non-vegetated (Figure 22). Overall mean $\text{PO}_4^{3-}$ was higher in the overlying water ($1.25 \pm 0.16 \text{ uM}$) than in the porewater at 30 cm soil depth. Therefore, vegetation in the time frame of this study did not seem to influence $\text{PO}_4^{3-}$ concentrations.
Figure 21. PO$_4^{3-}$ concentrations by location; vegetation presence is marked by color (vegetated= red, non-vegetated=blue); Standard error bars are presented with the Tukey HSD group indicated by the small letter.

Figure 22. PO$_4^{3-}$ concentrations by compartment; vegetation presence is marked by color (vegetated= red, non-vegetated=blue); Standard error bars are presented with the Tukey HSD group indicated by the small letter.
3.2.2 Surficial Grain Size

Thirty grab samples were analyzed from across a spatial pattern on Mike Island during two seasons to describe the distribution of grain size in the top 0-5 cm of sediment layer. In April 2014, the average grain size was in the range of silt (~6 phi, 16 μm). The composition of sediment collected in the grab samples was a mixture of approximately 23% sand, 58% silt, and 19% clay. The surficial map shows an area in the northern part of Mike Island highlighting a sandy deposit (Figure 23A). This coarser deposit was confirmed in the field during collection; it had a gritty texture and was collected near the secondary channel. Standard deviation of the grain size is a mathematical representation of the sediment sorting, i.e., a measure of the range of grain size distribution and the magnitude of the spread or scatter around the mean size (Xu et al., 2014). The standard deviation of surficial sediment was high, indicating a poorly sorted sediment mixture (Figure 23B). Skewness is a definition of the degree of asymmetry in a grain size histogram; positively skewed samples reflect grain sizes that are skewed to the positive end of the phi scale, which corresponds to finer grain sizes. The skewness followed the morphology of the island, with a more symmetrical distribution collected near the secondary channel and more finely skewed distribution near the southern part of the island, near Mike3 (Figure 23C). Kurtosis is the ratio between the spread in the middle part and the spread in the tails of the distribution curves. The kurtosis measurement was usually between 1 and 1.2, which corresponds to a more peaked distribution, with a distinct mode (Figure 23D).
In August 2014, the surficial grain size distribution was very similar to April 2014 with a mixture of approximately 20% sand, 62% silt and 18% clay. The surficial map of mean grain size shows finer sediment being collected along the bank of the secondary channel (Figure 24A). The standard deviation is high, indicating a poorly sorted mixture (Figure 24B). The entire spatial distribution is finely skewed, with more skewed values toward the edges of the sampling grid (Figure 24C). The kurtosis values are indicative of a more leptokurtic distribution, with a more defined mode on the left side of the sampling distribution (Figure 24D).

Grain size can be reported in phi as above or in mm or µm for easier comparison across disciplines. The conversion of mm to phi can be found in Equation 1.

\[
\phi = -\log_2 D \text{ (mm)}
\]

Equation 1
The difference in the spatial distributions shows that overall sediment in April 2014 was approximately 10 µm coarser than sediment collected in August 2014 (Figure 25). The area in April where sand was found was targeted a few meters beyond the grid point and may also be present in August. However, the overall difference of 10 µm in surficial grain size between April and August remains.

3.2.3 Sediment Trap

The prototype sediment traps used in April 2015 at Mike1 and Mike3 to capture sediment 30 cm above the sediment-water interface as well as along the sediment surface, were successful at trapping sediment (Figures 26 and 27).
Figure 25. Surficial grain size distribution (µm) during April and August 2014, with the last panel representing the difference in grain size between the two collections.

Figure 26. Sediment collected in a trap located 30 cm above the bed at Mike1, retrieved on May 2, 2015.

During spring 2015, the sediment traps were deployed on March 28 and retrieved on May 2, 2015. Since there was only one trap apparatus deployed at Mike1 and Mike3, only the values and general trends will be reported here. No statistics were performed on these traps and the differences noted between May and October may not be reliable due to the sample
Figure 27. Sediment collected in a trap located at sediment-water interface at Mike1, retrieved on May 2, 2015.

Material collected 30 cm above the sediment surface had a slightly higher bulk density than at the sediment-water interface. However, a larger difference was evident in the bulk density values between Mike1 and Mike3. Bulk density values were 1.5 and 1.4 g/cm³, respectively for the water column and sediment surface at Mike1. However, at Mike3, bulk density values were only 0.53 and 0.47 g/cm³ for the water column and sediment surface (Figure 28).

Since the sediment trap was successful during the spring deployment, triplicate sediment trap devices were installed at both Mike1 and Mike3 for the summer deployment. A similar trend is noted in the bulk density values during the summer deployment. Average BD values at Mike1 were 1.25 g/cm³ for the sediment collected 30 cm above the sediment-water interface while BD at the sediment surface was 1.15 g/cm³. At Mike3, the average bulk density values were much lower, with 0.23 (30 cm above the sediment-water interface) and 0.03 g/cm³.
(sediment surface) (Figure 28); the low values (i.e., 0.23 and 0.03 g/cm$^3$) might be associated with sediment slurry and excess water contained in the traps after sampling.

Organic matter content was estimated from loss-on-ignition which complement the BD values estimated above. During the spring (April 2015) deployment, the amount of OM collected in the traps was slightly higher in the water column than at the sediment surface. However, the clear difference is observed between Mike1 and Mike3, where a higher OM% was measured in the sediment traps at Mike3 (6-7%) than at Mike1 (1.8%) (Figure 29).

During the summer (September-October, 2015), a similar OM value was observed in the sediment traps. Overall, the amount of organic matter found in the sediment traps collected in October 2015 was slightly higher at both Mike1 and Mike3 than during May. At Mike1, average organic matter was between 2.9% and 2.7% in the water column and sediment surface, respectively. At Mike3, average organic matter was 11.0% and 8.5% in the water column and sediment surface, respectively (Figure 29).
Figure 29. Percent of organic matter (OM%) estimated in sediment traps and deployed at Mike1 and Mike3 during May and October 2015; Averages and standard error bars are shown for October only due to sample size.

The sediment collected in the traps was also analyzed for nutrient content. Large variation exists due to differences in location and season. At Mike1, the TP was higher (578.1 ± 2.3 µg/cm³) than at Mike3 (438.8 ± 10.6 µg/cm³) during the spring deployment. At Mike1, TP values were 580.4 and 575.8 µg/g P for the water column and sediment surface, respectively. However, at Mike3, values were 428.2 in the water column and 449.4 µg/g P for sediment surface (Figure 30).

During the summer, a similar pattern was observed for the TP concentration in sediment traps. At Mike1, average TP values were similar to those in May, with 565.8 ± 29.4 and 579.6 ± 28.5 µg/g P in the water column and sediment surface, respectively. However, at Mike3, average values were 91.9 ± 22.1 and 198.8 ± 61.3 µg/g P for the water column and sediment surface, respectively (Figure 30).
Figure 30. Total phosphorus (µg/cm³) values determined in the sediment traps collected in May and October 2015; Averages and standard error bars are presented for October only due to sample size.

The trap sediment was also analyzed for total nitrogen (TN) content. In May, TN values were 6.34 mg N/cm³ in the water column and 6.68 mg N/cm³ at the water-sediment interface at Mike1. At Mike3, 10.95 mg N/cm³ was determined in the sediment collected at 30 cm above the sediment-water interface while at the sediment surface TN content was 13.25 mg N/cm³ (Figure 31).

During October, there was slightly higher TN found in the sediment surface than in the water column. At Mike1, average TN values were 10.91 mg N/cm³ and 11.51 mg N/cm³ for the sediment trapped in the water column and the sediment-water interface, respectively. At Mike3, the average TN values were lower with only 3.35 mg N/cm³ trapped in the water column and 7.54 mg N/cm³ at the sediment surface (Figure 31).
Figure 31. Total nitrogen (mg/cm$^3$) values in sediments collected in sediment traps in May and October 2015; Averages and standard error bars are presented for October only due to sample size.

Total carbon (TC) was analyzed for the trap sediment collected during the April deployment as well as September-October. During the first collection in May 2015, the sediment traps at Mike1 showed TC values of 84.02 and 92.98 mg C/cm$^3$, for the water column and sediment surface, respectively. At Mike3, TC values were 10.95 mg C/cm$^3$ in the water column and 13.25 mg C/cm$^3$ at the sediment surface (Figure 32).

In October, the average TC was calculated for the triplicate sediment traps. The average TC content of the traps at Mike1 was 123.4 mg C/cm$^3$ in the water column and 120.2 mg C/cm$^3$ at the sediment surface. At Mike3, the average TC content of the traps were lower than at Mike1, with only 32.2 mg C/cm$^3$ trapped in the water column and 78.4 mg C/cm$^3$ trapped at the sediment-water interface (Figure 32).
Figure 32. Total carbon (mg/cm$^3$) values measured in sediments collected in sediment traps in May and October 2015; Averages and standard error bars are presented for October only due to sample size.

Sediment collected in sediment traps was analyzed for grain size distribution. In May, the dominant grain size trapped at Mike1 was fine sand and coarse silt in both the water column and sediment surface (Figure 33). At Mike3, the distribution of sediment trapped was more poorly sorted, with the largest contribution being from silt in both the traps in the water column and at the water-sediment interface (Figure 33).

During the September-October deployment, a similar pattern in grain size was found. At Mike1, the dominant grain size was fine sand, as it was in May (Figure 34). However, at Mike3, a bimodal distribution is noted, with a primary mode in silt and secondary mode in sand (Figure 34).
Figure 33. Sediment grain size distribution (µm) of sediment collected in the traps during March 28-May 2, 2015 with Mike1 (blue) showing a peak in fine sand and Mike3 (red) having silt as the largest contribution.

Figure 34. Sediment grain size distribution (µm) of sediment collected in the traps during August 28-October 2, 2015 with Mike1 (blue) showing a peak in fine sand and Mike3 (red) having a bimodal distribution with silt and sand.

3.3 Vegetation

3.3.1 Aboveground Biomass

Three 0.25 m² quadrats were used to sample vegetation at Mike1 and Mike3 at the beginning of the summer deployment on August 28, 2015. This size quadrat was used as a
standard size for aboveground vegetation harvest (Kirby and Gosselink, 1976). At Mike3, only two species were sampled in the quadrat, *Eichornia crassipes* and *Nelumbo nucifera* while at Mike1, several species were identified and harvested. All genera, vegetation structure and their corresponding aboveground biomass values are included in the Appendix (Table A2). Overall, there was a greater range of biomass at Mike1 with greater diversity of species (8 identified species). The average total biomass of the three quadrats from Mike1 was $631.24 \pm 247.83$ g/m$^2$. At Mike3, the average total biomass of the three quadrats was $997.17 \pm 72.08$ g/m$^2$. Large variations are present due to various species and structural components. Since only the roots of floating or uprooted plants were sampled, root values are not indicative of belowground biomass. The largest contributor to total biomass in each quadrat was the stems. Although depending on the species, leaves, fruit and flower structures had a large contribution to biomass as well.

Integrating tissue nutrient concentrations across all structural components show a N:P ratio greater than 16 (Redfield ratio, Koerselman and Meuleman, 1996). This N:P ratio was observed in all vegetation genera tissue identified in this sampling collection (Figure 35).

![N:P Ratio Chart](chart.png)

Figure 35. N:P ratio of the integrated tissues of each genera found at the upstream and downstream location
3.4 Sediment Cores

3.4.1 PVC Cores

Mean grain size was calculated for each 5 cm sediment slice from the PVC cores. From the upstream location (Mike1), one core from the non-vegetated area and the core from the vegetated patch were analyzed for grain size with depth. However, comparisons between the vegetated and non-vegetated areas do not accurately show impacts of vegetation due to the possibility of vegetation influence in previous years. The core taken in the non-vegetated area was 46 cm long and the core in the vegetated patch was 30 cm long. Grain size in the vegetated core was not calculated for the first 5 cm due to high water content. Overall, the trend for grain size with depth in the vegetated area follows a similar pattern to that of the non-vegetated core (Figure 36). No comparison can be made at the surface layer but the sediment in the vegetated patch is finer than that in the non-vegetated area (Figure 22). Maximum grain size was found in both cores at 10 cm depth.

Figure 36. Mean grain size (µm) profile with depth of cores sampled in vegetated (red) and non-vegetated (black) areas at Mike1.
At the downstream location (Mike3), all cores were taken in vegetated areas since they were taken during peak biomass in August and there were only vegetated areas. Grain size was analyzed in all three cores. The cores showed relatively similar grain sizes with depth. However, Core 1 in Mike3 had very coarse sand in the surface layer, which may be an outlier or residual organic matter that did not react completely with the H₂O₂. The trend shows a general grain size fining upwards trend in all three cores taken at Mike3 (Figure 37).

![Mean grain size profile](image)

**Figure 37.** Mean grain size (µm) profile with depth of cores sampled in vegetated areas at Mike3 in August 2015.

### 3.4.2 Russian Cores

The bulk density (BD) of the Russian cores was calculated at 5 cm increments. The area used for bulk density of the Russian core slices was calculated carefully due to the specific core shape using a half circle shape with an additional triangular shape. Radius (r), triangle base (b)
and triangle height (h) are used in the calculation. The area of the half circle was calculated (πr²) and then added to the area of the triangle (0.5b×h) to get a surface area of 12.8 cm², which was then multiplied by the depth of the slice (d = 5 cm), and divided by the dry weight of the slice to get the bulk density (g/cm³). Two cores were sampled at each upstream and downstream location, including vegetated and non-vegetated areas. Since these cores were taken in late March 2015, little vegetation was present on the island. Therefore, these vegetated patches were targeted for sampling. Bulk density at Mike1 ranged from 0.2-1.2 g/cm³ (Figure 38).

Figure 38. Bulk Density with depth of vegetated (red) and non-vegetated (blue) areas at Mike1

BD at Mike3 ranged from 0.3 to 1.4 g/cm³ (Figure 39). At Mike3, there was little difference in bulk density between vegetated and non-vegetated areas except around 30 cm depth, where bulk density at the vegetated area was higher than the non-vegetated area (Figure 39).
Organic matter (%) was analyzed via loss-on-ignition. At the upstream station (Mike1), OM% ranged from 2 to 6% for non-vegetated areas and from 5 to 10% for vegetated areas (Figure 40). There is about a 3% difference in organic matter between vegetated and non-vegetated areas at Mike1 up to 25 cm when values are relatively similar.
At the downstream station (Mike3), a trend similar to Mike1 was observed in the organic matter between vegetated and non-vegetated cores. The organic matter at the vegetated area ranged from 1 to 9% and the organic matter at the non-vegetated area ranged from 1 to 6% (Figure 41). There was about 2% more organic matter in the surface of the core taken in a vegetated area. There was a major difference in OM% below 30-35 cm where the lowest OM% was observed corresponding to the downstream site.

![Organic Matter Depth Graph](image)

Figure 41. Organic matter with depth of vegetated (red) and non-vegetated (blue) areas at Mike3

Soil total carbon (TC) was analyzed at 5 cm increments in the Russian cores. At the upstream location, TC ranged from 10 to 160 mg/cm³ with more variation between vegetated and non-vegetated areas at depths from 25-40 cm. The overall trend in TC concentration showed a similar concentration down to approximately 25 cm where TC values began to decrease with depth (~50 mg/cm³); the core obtained in the vegetated site showed slightly higher TC concentrations ranging from 25 to 40 cm (Figure 42).
Figure 42. Total carbon with depth of vegetated (red) and non-vegetated (blue) areas at Mike1

At the downstream location, more variability between vegetated and non-vegetated cores was observed at shallower depths, particularly in the depth range from 10 to 25 cm. The TC values ranged from 50-210 mg/cm³ at Mike3 in both vegetated and non-vegetated areas (Figure 43).

Figure 43. Total carbon with depth of vegetated (red) and non-vegetated (blue) areas at Mike3

Soil total nitrogen (TN) concentrations with depth were very similar to those of TC. The overall trend in TN values was the same until about 25 cm depth where TN began to decrease sharply with depth. However, the vegetated core had a higher concentration of TN from 25 to
40 cm but also showed decline, although at smaller rate (Figure 44). At Mike1, the values for TN range from 0 to 12 mg/cm$^3$ (Figure 44).

Figure 44. Total nitrogen with depth of vegetated (red) and non-vegetated (blue) areas at Mike1

TN concentrations ranged from 4-15 mg/cm$^3$ at Mike3 in both vegetated and non-vegetated areas (Figure 45). The values show high variability down to 30 cm, but overall more TN concentrations were higher at the downstream location.

Figure 45. Total nitrogen with depth of vegetated (red) and non-vegetated (blue) areas at Mike3

At Mike1, the soil total phosphorus (TP) range was from 120-800 µg/cm$^3$ (Figure 46).

High variability in concentration was observed in the vegetated core from 10-25 cm, while most
of the variability was detected from 25-40 cm in non-vegetated core. The overall general pattern is a significant increase of TP with depth.

![Graph showing total phosphorus (TP) with depth of vegetated and non-vegetated areas at Mike1.](image)

**Figure 46.** Total phosphorus with depth of vegetated (red) and non-vegetated (blue) areas at Mike1

At Mike3, a similar pattern of increasing concentration with depth was measured. However, at the non-vegetated area, there was a decrease in TP after 35 cm depth. The TP concentration in the cores sampled at Mike3 ranged from 50 - 680 μg/cm³ (Figure 47). Large variability was present in both cores, especially at depths greater than 35 cm.

![Graph showing total phosphorus (TP) with depth of vegetated and non-vegetated areas at Mike3.](image)

**Figure 47.** Total phosphorus with depth of vegetated (red) and non-vegetated (blue) areas at Mike3
4. DISCUSSION

4.1 Water Column Processes

Mike Island is a dynamic system and is subject to several hydrodynamic forcings, including waves, tides, and currents, along with other factors such as vegetation biomass, river discharge, and wind. Therefore, it becomes very complex when trying to decipher the cause and effect of the data spatiotemporal trends (Geleynse et al., 2015).

During the spring, it is evident that the river discharge is at its highest point and is likely to have a strong influence downstream. The secondary channel located at the northern end of Mike Island serves as an entry point for the river discharge to enter the interior of the island, where Mike1 is located. Since the channel is narrow, the flow recorded by the ADV Argonaut at Mike1 during the spring is relatively high (Figure 16). However, at Mike3, flow is much smaller, possibly due to the dispersion of flow after the water exits the narrow secondary channel and disperses across the island (Hiatt et al., 2015). In the primary channels, the average velocity tends to decrease moving toward the bay (Hiatt et al., 2015) so this reduction of flow between the upstream and downstream location is seen within the island as well. Mike1 is not as greatly influenced by waves from the Gulf of Mexico as Mike3, as supported by the overall smaller wave height measured at Mike1 (Figure 16). This was expected due to the closer proximity of Mike3 to the Gulf of Mexico. Turbidity values at Mike1 were very low until 3 days in late April 2015. At Mike3, there were several large spikes in turbidity throughout the deployment (Figure 16). However, some of the large spikes are questionable. There are no documented large changes in wave height, current speed, or wind speed to explain these large increases in
turbidity. However, it is clear that resuspension is playing an important role depending on the level of disturbance due to cold fronts and tropical storms.

As confirmed using long term weather records, a strong wind-driven storm passed through the Louisiana coast on April 27, 2015, which was linked to the responses seen at Mike1 and Mike3. During this event, there was an increase in wind speed, water level, wave height, current velocity and, as a result of a more energetic environment, an increase in turbidity (Figure 16). The increase in turbidity and water level lasted a few days and then returned to a background value while the remaining parameters returned to a baseline value immediately following the passage of the storm. The sediment that was re-suspended during the storm might take a few days to settle out, prolonging increased turbidity conditions.

Even though river discharge remained higher than usual through the year of the study (2015), it was much lower during the summer deployment, thus having a smaller influence on Mike Island local hydrodynamics. Along with river discharge being much lower in the summer, the vegetation is at its peak biomass and productivity. The water velocity at Mike1 during the summer deployment remains fairly high, although comparatively lower than during the spring deployment. Since the river discharge is not as high during the summer, there is not as strong of a flow entering the island through the secondary channel, thus contributing to lower velocity at Mike1 during this season. During this period, the vegetation does not have a strong influence on flow at Mike1 because the channel was not completely colonized by plants when compared to the remainder of the island area. *Eichhornia crassipes* (water hyacinth) was present in the secondary channel, but its biomass and density was not enough to hinder flow during instrument deployment. However, at Mike3, interesting velocity data were collected from the
ADV Ocean (Figure 18). During the first week of the summer deployment, velocity was higher (~30 cm/s) than the velocity recorded at Mike1 during the spring (~23 cm/s). Around September 6, 2015, there was a large reduction in velocity with a concurrent increase in turbidity. Since this is an unlikely occurrence, the quality of the ADV Ocean velocity data was first confirmed (Figure 48). Bursts that had less than 60% good quality data points for u, v and w vectors were not used in the analysis. However, the majority of the data quality is near 90-100% (Figure 48).

Figure 48. ADV Ocean Quality of u,v and w velocity vectors with a threshold of 60% noted in blue.

Furthermore, the heading, pitch and roll and the battery of the instrument were also analyzed (Figure 49). If there was a large change in these parameters, it is likely that there was something that disturbed the orientation of the instrument. In addition, battery level must be above a threshold of 13 volts to ensure that the instrument was working properly. The instrument never dropped below this threshold during the deployment (Figure 49), thus adding confidence to the velocity numbers measured by the instrument.
Figure 49. Heading, pitch, and roll of the ADV Ocean data as well as the battery level throughout the deployment in 2015.

Previous studies show the possibility of vegetation presence creating a channel, where velocity is maintained between the vegetation but suppressed within (Madsen et al., 2001). It is possible that the vegetation at Mike3 created an “artificial vegetated channel” where the enhanced flow passed the ADV Ocean located on the tripod. However, on the 6th of September, the velocity dropped off to near 0 cm/s for 5 days (Figure 18). This velocity then increased around September 13, 2015 and then decreased again after two days. Revisiting other parameters collected during this large drop in velocity at Mike3, a sharp increase in turbidity was also noted (Figure 18). However, there is no increase in wave or wind to trigger this apparent enhanced turbidity.

Another parameter that can be retrieved from the ADV Ocean instrument is the distance from the sampling volume to the sediment-water interface which is recognized as a sudden change on acoustic impedance. During the deployment, this parameter is extremely variable and there is a large decrease in distance from the sampling volume to the sediment.
surface on September 6, 2015, when concurrently velocity drops and turbidity increases (Figure 50). It is possible that the ADV Ocean instrument was measuring the distance from the sampling volume to a plant-water interface which is also acoustic impedance, thus contributing to the variability noted in the data set during this period.

![Graph showing distance from sensor to bed over time]

Figure 50. Variation in the distance between the sampling volume and the sediment-water interface may be due to a measurement of the distance between the sampling volume and the plant-water interface.

A large drop in velocity does not correspond with a large increase in turbidity in a regular setting. One explanation is that the ADV Ocean instrument experienced interference during the measurements that collected velocities near 0 cm/s. Vegetation has been shown to have a strong influence on velocity, especially when it is dense and widespread. However, it does not seem to be feasible that a large amount of vegetation can grow and reduce flow speeds in a matter of hours. It is possible that a dense floating mat of vegetation, such as *Eichornia crassipes*, which occupies large surface water extensions of the island, particularly at Mike3, was tangled in the tripod (Figure 51). Another possibility is that a growing seedling near the ADV Ocean instrument was susceptible to swaying from the changes in current direction. This growing vegetation may be laid down in the direction of the ADV transmitters, causing
strong interference (Figure 51). If the vegetation was in line with the area of acoustic measurement, the resulting velocity would be near 0 cm/s.

Figure 51. Diagram showing the possibility of vegetation interfere with acoustic signal.

Another set of noticeable differences in the data occurred on October 1, 2015. The strong shift in the wind direction, a drop in water level and temperature and an increase in turbidity (Figure 18) can be attributed to a cold front, which was confirmed by a historical weather map. The passage of the cold front did not appear to affect the water velocity much but the data collection during this time was limited due to battery depletion or recording quality below the set threshold.

As a result of this study, a conceptual model was created to help explain how vegetation is expected to influence flow in an idealized situation with no wind, wave, or tide influence.
However, this conceptual model is not based on actual data that was collected during this study. Rather, fluid dynamics and some results from Hiatt et al. (2015) are used. In Mike Island, the different geomorphology and interaction with environmental drivers do influence the hydrodynamics within the island. However, in Figure 52, only two processes are considered: river discharge that enters the island only via the secondary channel in northern Mike Island and vegetation. When there is little to no vegetation and a relatively high river discharge, the largest velocity vector would be found within the secondary channel due to the restriction of flow. As the water exits the secondary channel, the water begins to spread across the island (Figure 52A). However, in some cases, vegetation can form an “artificial vegetated channel,” where flow will be re-directed to areas of no vegetation, creating an area of sustained flow (Figure 52B). Any water that enters the vegetated patches will be greatly reduced due to frictional resistance. Peak vegetation biomass will not hinder the flow within the secondary channel due to less colonization of submerged and emergent vegetation within the channel. Once the flow exits the secondary channel, the flow will disperse as it did in a situation with no vegetation. However, the vegetation may slow the velocity down even more than it would through the dispersion of flow across the island interior (Figure 52C).

An additional conceptual model is proposed that includes more semi-realistic and more quantitative processes derived from all of the measured drivers in my study in order to characterize three events observed and recorded during the instrument deployments and soil and vegetation sampling. In late April, there was a confirmed storm event that was tracked with enhanced wind speeds, large wave heights at Mike3 of 0.2 m and peaks in turbidity (Figure 53A). In addition, this storm brought a tornado, which can be confirmed in our wind direction
Figure 52 (A-C). Conceptual model ignoring wind, wave, and tidal influence, looking at the effect of vegetation density on the velocity within Mike Island assuming only one source of flow being the secondary channel near Mike1.

data, which shows wind rotation during this time. During this storm event, the largest tidal range of 0.4 m was also identified. The enhanced flows during this storm were likely maintained due to the lack of vegetation on the island during this time. The second event that was registered in the data set was the velocity reduction that occurred on September 6, 2015 when the largest discrepancy in velocity values between Mike1 and Mike3 were observed (Figure 53B). Tides were registered at both Mike1 and Mike3 during this event, but wave heights were very small at both Mike1 and Mike3. The small wave heights were likely attributed to the widespread and dense distribution of vegetation across the island during this time, which has been noted in other studies as well (Anderson et al., 2001; Madsen et al., 2001; Temmerman et al., 2005; Augustin et al., 2009). The third event that was captured by my instruments was the passage of a cold front on October 1 (Figure 53C). During this event there were dense
vegetation and reduced river discharge. The smallest tidal range was measured during this time at Mike1 of 0.25 m and the smallest wave heights of 0 m were found at Mike1. There was a decrease in water temperature of about 8°C during this time, a strong shift in wind direction from southerly winds to northwesterly winds, as well as a 0.8 m reduction in water level. Cold fronts are common meteorological events in coastal Louisiana and it is likely that more than one passed throughout my study area during our deployment (Li et al., 2001; Roberts et al. 2015; Bevington et al., in prep.).

Figure 53 (A-C). Semi-quantitative conceptual model using the data we collected during our deployments to characterize three distinct events that occurred being (A) storm event, (B) velocity drop due to possible vegetation interference and (C) cold front.

Mike Island is a complex system driven by several factors including wind, wave, river, tide, and vegetation. In addition, the influence of events on the island can be very pulsing and extreme. Storms can transport sediment from offshore back to the delta top. In non-vegetated
Mike Island, such as the situation seen during spring 2015, with low vegetation and high river discharge, the river and wind-driven waves drive sediment transport from Mike1 to Mike3 locations. During the summer months, the colonization of vegetation likely establishes a “vegetated channel”, which constricts flow to the middle of the island (Madsen et al., 2001). Since the interior of the island is deeper than the edges, this may influence the speed of the current that is directed to the middle of the island. In addition, when river discharge was low, and vegetation biomass was high, waves were very small, but tidal variations were still present. However, the vegetation seems to be a dominant factor controlling sediment transport in conjunction with the momentum of the flow within the confined secondary channel spreading across the delta top. Although tides can still penetrate through the dense vegetation and cause resuspension, vegetation indeed slows the water currents and attenuates waves, prolonging water residence time in an area, thus promoting significant fine sediment deposition as registered in my sediment traps (Leonard and Luther 1995; Nepf et al., 1997; Nepf, 1999; Nepf and Vivoni, 2000; Madsen et al., 2001; Cotton et al., 2006; Augustin et al., 2009; Corenblit et al., 2009; Henry and Twilley, 2014). The ability of the vegetation to enhance sediment trapping is one essential way to continue land building in the Wax Lake Delta and in other areas where sediment diversions are planned in the future in coastal Louisiana.

4.2 Water-Sediment Interface

The overlying and porewater nutrient results show several interactions among month, location, vegetation presence, and compartment (i.e., overlying water and pore water). The [PO$_4^{3-}$] was plotted against the [TIN] for the overlying water and porewater to explore additional patterns (Figure 54). In the overlying water, a very distinct pattern was present. In
May 2015, both the upstream and downstream locations had very similar PO$_4^{3-}$ and TIN concentrations, showing a small range of approximately 28-40 µM for TIN and 0.9-1.7 µM for PO$_4^{3-}$. This pattern was apparent in both sampling points (replicates) within each location (upstream, downstream) (Figure 54). However, during October 2015, there is a divergence in PO$_4^{3-}$ and TIN concentrations in the overlying water, indicating either a different source or a change in biogeochemical processes; in this particular case, higher concentrations were measured upstream while lower concentrations were recorded downstream (TIN: 47.2 (upstream), 3.88 uM (downstream); PO$_4^{3-}$: 2.65 (upstream) 0.79 uM (downstream). Further, overlying PO$_4^{3-}$ concentrations in October were almost double the concentrations measured during May 2015. This difference could be explained by increasing remineralization occurring at the end of the growing season. Downstream, overlying TIN concentrations are much lower in October than during May 2015, but PO$_4^{3-}$ concentrations remain similar. The PO$_4^{3-}$ concentrations in the porewater do not vary between seasons but TIN does. The majority of the TIN in the porewater is NH$_4^+$, which generally increases with higher remineralization rates occurring at the end of growing season. This major seasonal variation in TIN and PO$_4^{3-}$ concentrations between locations and porewater versus overlying water indicates significant differences in TIN transport and use within the system, with higher NO$_3^-$ in the overlying water and NH$_4^+$ in the porewater. Overall high PO$_4^{3-}$ concentrations in the pore water are important to plant productivity and show significant availability during the growing season; however, may become limiting depending on the concentration of nitrogen in the system. Based on these spatial patterns in TIN and PO$_4^{3-}$ concentrations, it is apparent that net fluxes across the sediment, plant uptake, and transformations within the sediment need further study.
However, inorganic nutrient patterns in the water column and the sediment could be proposed to explain their interaction with vegetation presence and productivity. The divergence of the nutrient concentrations observed in the overlying water during October 2015 (Figure 54) is a result of several factors. During May 2015, river stage is high and vegetation biomass is low. Therefore, the water entering the island via the secondary channel that flows from upstream to downstream carries similar nutrients concentrations. As water flow diffuses across the island, other external inputs such as overbank flooding act as an additional source of nutrients to the downstream location. The lack of vegetation early in the year (spring) maintains a homogenous flow moving downstream without a large reduction in water velocity. However, during October (rainy season), marking the end of the vegetation growing season,
river stage is lower and vegetation biomass is high. The water flow from the primary channel upstream still enters the island upstream via the secondary channel, as indicated by the higher nutrient concentrations in this location (Figure 54). As the flow moves downstream, however, the vegetation can slow water flow (Leonard and Luther 1995; Nepf et al., 1997; Corenblit et al., 2009). Additionally, this reduction in water velocity promotes sediment deposition. It has been reported that about 90% of the inorganic phosphorus entering an estuarine/coastal system is bound to sediment particles (Froelich, 1988). As water flow decreases downstream due to the presence of dense vegetation and flow dispersion, sediment (i.e. and adsorbed PO$_4^{3-}$ in sediment) may become deposited, thus decreasing the potential availability of PO$_4^{3-}$ in overlying water downstream as indicated by the high concentrations throughout the year. TIN uptake by plants can help explain the difference in concentrations between upstream and downstream in October 2015 in my study area. When water residence time is prolonged due to a reduction in velocity, the vegetation can utilize inorganic nutrients in the overlying water and facilitate the exchange of TIN and PO$_4^{3-}$ between the overlying water and the sediment by diffusion.

Both TIN and PO$_4^{3-}$ concentrations in porewater were more spatially variable than in the water column as show in Figure 55 where both sampling points (replicates) are shown. During May, there is significantly lower TIN in the porewater than during October (p<0.001*** (Table 3; Figure 55). However, no significant differences were present between concentrations of PO$_4^{3-}$ across location or month.
Table 3. ANOVA source table of the TIN concentrations in the porewater; the following notation is used to indicate levels of significance * <0.05, ** <0.01, *** <0.001

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>F Ratio</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
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<td>Month</td>
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<td>21.156</td>
<td>&lt;.0001***</td>
</tr>
<tr>
<td>Location</td>
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<td>0.3264</td>
</tr>
<tr>
<td>Month*Location</td>
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<td>3.937</td>
<td>0.0571</td>
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<tr>
<td>Error</td>
<td>28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As mentioned above, the significantly higher TIN concentrations in October 2015 than in May 2015 can be attributed to higher remineralization and microbial activity at the end of the growing season. In addition, this higher concentration in October could be due to net decomposition or flux of nitrate into the sediments. Again, there was a significantly higher amount of NO₂⁻ + NO₃⁻ (N+N) in the overlying water than the surface water (see results, Figure 19), thus promoting a concentration gradient and net flux from the overlying water into the porewater.

![Figure 55. Concentrations of PO₄³⁻ and TIN in porewater at upstream (square) and downstream (x’s) locations during May (blue) and October (red); Standard error bars are present in both x and y dimensions](image-url)
sediments. This potential high N+N flux into the sediments can contribute to the higher TIN concentrations in October as well. The high and low N+N concentrations in the water column and pore water, respectively, and the high NH$_4^+$ concentration measured in the pore water indicated a very active N transformation and uptake, where ammonification and dissimilatory nitrate reduction to ammonia might be critical transformations in the N cycling in Mike Island.

The sediment traps deployed in different seasons representing different river stages were used to characterize the material that is suspended in the water column or being transported along the water-sediment interface. To summarize, a higher bulk density, lower organic matter, higher TP, higher TN, higher TC, and coarser material were all found upstream. The higher bulk density and lower organic matter complement one another and support the conclusion that there is more mineral sediment deposition upstream. In addition, more nutrients (TN, TP) and carbon (TC) were trapped at the upstream location. This process is plausible due to the influx of water flow from the secondary channel at this location. Coarser materials were also trapped upstream, which follows the expected outcome where coarser materials, which are heavier, settle out more quickly than fine materials.

The surficial grain size data show sediment approximately 10 µm larger collected in April than August 2014. Although the sand spot identified in the discrete grain size analyses in the northern part of the island was targeted during April, the difference of 10 µm still remains across the overall points sampled across the grid (see Figure 25). This difference in grain size may be attributed to higher river discharge during the spring season that brings in coarser materials during the flood season. In addition, vegetation growth and increasing density during the summer might promote fine sediment deposition, which is a process observed in other
studies (Leonard and Luther 1995; Nepf et al., 1997; Nepf, 1999; Nepf and Vivoni, 2000; Madsen et al., 2001; Cotton et al., 2006; Augustin et al., 2009; Corenblit et al., 2009; Henry and Twilley, 2014). The combination of 80% mud and 20% sand found in this study has been confirmed in other studies done in WLD as well (DuMars, 2002; Roberts et al., 2003; Wellner et al., 2005).

4.3 Vegetation

The vegetation on Mike Island follows an elevation gradient, where more species were found to inhabit an area of higher elevation (Mike1) than lower elevation (Mike3) during quadrat sampling in August 2015. Only *Nelumbo* and *Eichornia* were found in my sample quadrats at Mike3, which were also found at Mike1. However, this difference in elevation and overlying nutrient concentrations during the end of growing season (Figure 54) did not significantly alter the nutrient concentration in the plant tissues between locations. All taxonomic genera show N:P ratios that were higher than the value of 16 (Redfield ratio) (Koerselman and Meuleman, 1996), suggesting phosphorus limitation (Figure 56). Compared to unfertilized systems, there is a large concentration of N and P in the tissues of this vegetation, which suggest a eutrophic environment where even under high N availability (e.g. >40 uM NO₃⁻), P can become limiting (Koerselman and Meuleman, 1996) (Figure 57). This excessive nutrient availability is reflected in vegetation tissues and is three to six times greater than those found in an unfertilized, control plots in wetland communities. Although there are large pulses of both nitrogen and phosphorus to the system, eventually, phosphorus may become limiting due to excess nitrogen input.
Figure 56. Tissue concentrations of N and P of all genera (different symbols) found in upstream (blue) and downstream (red) locations; N:P=16 is marked.

Figure 57. Nutrient contents of unfertilized, control plots from 40 European wetland types; from Koerselman and Meuleman, 1996

Vegetation has been found to significantly influence current speed and wave attenuation (Leonard and Luther 1995; Nepf et al., 1997; Nepf, 1999; Cotton et al., 2006). At the beginning of growing season in Mike Island, it is plausible that the enhanced current velocities noted in the beginning of the September-October deployment can be associated to
the formation of a vegetated channel. Madsen et al. (2001) found that flow could be re-directed from areas that are vegetated to those less vegetated, thus creating a channel where flow is maintained in a non-vegetated area. However, as the vegetation continues to grow, this channel will fade or disappear.

There is evidence that during peak biomass in August, wave height is greatly diminished by vegetation presence due to the very small wave heights noted at Mike1 and Mike3 compared to April when vegetation biomass is low (Figures 16 and 18). However, this is a complex system where multiple factors influence the magnitude of wave influence. The ADV Ocean current velocity data show large decreases in velocity at Mike3. It is possible that vegetation has a strong influence on the current velocity in this area, which is supported by several other studies (Leonard and Luther 1995; Nepf et al., 1997; Nepf, 1999; Cotton et al., 2006). However, it is also possible that the vegetation became entangled in the tripod, or a new plant interfered with the acoustic and optical signals, leading to the large decrease in velocity and coinciding increase in turbidity. Dense mats of floating vegetation (e.g. *Eichhornia crassipes*) had to be removed during retrieval of the instruments in October, so it is likely that there was an effect of vegetation on our data collection.

4.4 Cores

The TN and TC profiles with depth for both upstream and downstream locations followed a similar pattern. In order to further investigate this relationship, I evaluated the relationship between TN versus TC (Figure 58). A linear relationship between the two variables (mean concentration value over depth) shows a coefficient of determination ($r^2$) of 0.89 (Figure 58). As the amount of TIN entering the system increases, the amount of
productivity increases within this range of concentrations (Henry and Twilley, 2014). The increase in productivity is reflected in the increasing concentration of TC. The coupling present between TN and TC is expected due to the biological control of their concentrations rather than geochemical (Craft, 1997). In addition, there appears to be a spatial difference in the TN and TC concentrations between upstream and downstream with a distinct separation at the extremes with some mixing in between. The variability in this is expected since I am using the mean value integrated over depth. In the upstream location, there were generally lower TN and TC concentrations while in the downstream location, I observed higher concentrations (Figure 58). It is clear that a coupling exists since the trap data suggests less organic material was trapped upstream. The large influx and deposition of mineral matter upstream is likely a large contributor in this difference in N and C concentrations.

Figure 58. TN vs TC in sediment collected using Russian cores in the upstream (blue) and downstream (red) locations; linear regression, $r^2=0.887$
In order to evaluate differences in the total amount of TC, TN, and TP at each location under vegetation presence, a storage value for each treatment combination was estimated at 50 cm. First, analyzing total carbon, vegetation presence was not a significant factor influencing the carbon storage (Figure 59). However, this is expected due to the targeting efforts of finding vegetated and non-vegetated areas in March when vegetation biomass is low. In previous seasons, it is very likely that area was colonized or influenced by vegetation presence and is influenced by the contribution of buried organic carbon (peat) (Paola et al., 2011). Therefore, I did not expect a significant difference between vegetated and non-vegetated areas.

However, location was a significant factor in explaining differences in carbon storage, where significantly higher carbon storage was calculated upstream at Mike1 (p=0.0011**) (Table 4). The increased soil TC at Mike1 may be a result of quick burial of organic matter by the large influx of mineral material and plant material before further accumulation of mineral sediment over time. The upstream location is in closest proximity to the source of nutrients being transported by the secondary channel. As I mentioned previously, TN has a linear relationship with TC, indicating the importance of N in driving plant (macrophyte) productivity (Craft 1997). The larger influx of nutrients upstream via the secondary channel could contribute to higher productivity and more carbon storage. In fact, the differential age (spatial) of the island, with older areas at the northern end and younger areas moving southward, may influence carbon storage as well (Johston, 1991).
Figure 59. Total carbon storage at 50 cm depth at upstream (blue) and downstream (red) locations in vegetated and non-vegetated areas.

Table 4. ANOVA source table for carbon storage; Location was the only significant effect; The following notation is used to decipher various levels of significance * <0.05, ** <0.01, *** <0.001

<table>
<thead>
<tr>
<th>SOURCE</th>
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<th>F Ratio</th>
<th>Prob &gt; F</th>
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<td>0.0011**</td>
</tr>
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<td>7.4605</td>
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<tr>
<td>Error</td>
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<td></td>
</tr>
</tbody>
</table>

A similar pattern was observed in the case of TN storage at 50 cm, where vegetation presence was not a significant factor but location was significant (p=0.0022**) (Figure 60), (Table 5). As mentioned before, the higher soil TN upstream could be due to the proximity of the source or a faster turnover time within the sediment.

Table 5. ANOVA source table for nitrogen storage; Location was the only significant effect; The following notation is used to decipher various levels of significance * <0.05, ** <0.01, *** <0.001

<table>
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</tr>
<tr>
<td>Vegetation Presence</td>
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<td>0.4237</td>
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<td>Location*Vegetation Presence</td>
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<td>0.0874</td>
</tr>
<tr>
<td>Error</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the case of soil TP storage at 50 cm depth, neither vegetation presence nor location was significant factors. Phosphorus storage downstream, although not significant, still appears to be slightly less than upstream (Figure 61).
4.5 Implications to Coastal Restoration

The data presented here are essential to help better understand the plant-sediment interaction on an accreting delta. Vegetation generally will slow down the water flow; however, it is possible that a vegetated channel forms during colonization, maintaining or even enhancing flow within the non-vegetated center. The use of vegetation in the stabilization and accretion of a growing delta has shown to be successful in this deltaic system. In addition, the plant communities can reduce the amount of N+N input and other nutrients being transported to the Gulf, thus possibly reducing the area of the hypoxic zone during summer months, which is supported by several previous studies (Nichols, 1983; Day et al., 2004; Fisher and Acreman, 2004; Hunter et al., 2009; Twilley and Rivera-Monroy, 2009; Henry and Twilley, 2014; Twilley et al., 2016). Furthermore, these nutrients can be deposited via inorganic and organic material and eventually become part of the sediment, creating an area of storage for carbon, nitrogen and phosphorus. Although vegetation density can reduce current velocity and attenuate waves, tides can still penetrate upstream, even during peak biomass. Future models should consider the passage of cold fronts or other nonlinear, episodic and energetic events. In this study, the distance from the ADV sampling volume to the bed as well as the sediment trap of up to 10 cm of deposition all reveal the quick and dynamic nature of the hydrodynamics and biological controls that regulate sediment deposition and biogeochemical processes during these events. The Wax Lake Delta is a highly dynamic system subject to several drivers including wind, wave, tide, river, current, and vegetation. However, storms and cold fronts
are very important to consider as they have shown large responses within Mike Island during my study period.

4.6 Limitations and Future Work

There are several limitations in my study that must be recognized. Overall, the coupled physical and biotic processes driving sediment dynamics on Mike Island is complex and difficult to measure with only two locations with different driving forces (Paola et al., 2011; Hiatt et al., 2015). The analysis of the results and conclusions are likely to vary across the width of the island due to the significant elevation gradient (Kolker et al., 2014; Carle et al., 2015). Two locations, one upstream and one downstream, were chosen to study the hydrology, sediment and vegetation within the island center. Due to limitations in time, funds and resources, only these two stations were sampled over two seasons. In the future, additional locations within the island should be used to capture the elevation gradient across the width of the island since there is likely to be stronger differences between sediment transport and vegetation influence. An analysis of accumulation rate would have been a great addition to help understand the deposition during fair weather versus storm events and would help better capture the system dynamics.

Our observation of ADV Ocean was limited to one station because of limited instrumentation. However, in the future, two ADV Oceans can be deployed simultaneously in the study site, one located in a “control” site with no vegetation and another in a highly vegetated site. Through the comparison of two sites, the velocity reduction and wave dampening effect can be better quantified.
The sediment trap was a useful addition to help characterize the sediment suspended in the water column being transported along the sediment surface. However, triplicate traps during both seasons would have been better to improve a statistical comparison. In addition, if multiple trips during each deployment were feasible, the deposition in the traps could be monitored or collected quarterly to quantify the transport of sediment over that period. If a permanent water level recorder or a benchmark for water level were deployed and measured, respectively, both actions could enhance my ability to show differences in absolute elevations of water levels between upstream and downstream, and during reversed flow conditions. At this stage, the sediment elevations cannot be compared directly due to lack of benchmarks.

Due to sampling error, the collection of porewater and surface water across months is not balanced therefore, reducing available data for analysis across season. It would be interesting to see how the nutrient ratios vary with additional temporal variation. An additional limitation is the targeting of vegetated patches based on “visual observation” of aboveground biomass. In March, there is little to no aboveground vegetation on the island however, this does not mean that vegetation was not there the previous season or will not appear later in the season.

Overall, my study establishes robust patterns in sediment transport and deposition including plant-sediment relationships in context of complex interactions of hydrology, sediment and vegetation. My work provides several new ideas on how to enhance our understanding of how this dynamics system functions. Further, my study provided a first-look on how accreting Wax Lake Delta responds to several drivers and how these processes and
feedbacks registered in my study sites require an interdisciplinary approach to elucidate complex interactions at various spatial and temporal scales.
5. CONCLUSIONS

Below are major conclusions based on this interdisciplinary study:

1) Sand, silt and clay can be found in trapped, surficial, and down-core sediments in Mike Island. Overall surficial sediment collected at the survey grid of 30 stations in April 2015 was 10 µm coarser than that of August 2015. On average, mud is about 80% and sand is 20% in surficial sediments. Higher organic matter was trapped at Mike3 than Mike1, but soil cores, which include a large spatial scale (50 cm), show little difference between Mike1 and Mike3.

2) Water levels at Mike1 and Mike3 are generally in phase, with variable tidal ranges of 0.2 to 0.5 m. Wind and wave play a key role in transporting sediment during the passage of cold fronts. Vegetation can dampen waves effectively whereas tides can penetrate through the vegetation in all seasons, including the peak biomass period at the end of the growing season.

3) Vegetation on Mike Island follows an elevation gradient with higher species diversity in areas of higher elevation. *Nelumbo* and *Eichornia* were the only species found at Mike3 during the sampling period; these species were also found at Mike1. Nutrient content of the plant tissues suggest a eutrophic environment where phosphorus can become a limiting nutrient due to high nitrogen input.

4) During May 2015 when river discharge is high, the differences in concentration between PO₄³⁻ and TIN in the overlying water are similar at the upstream Mike1 and downstream Mike3 locations. However, in October, there is a strong divergence of overlying concentration values with higher nutrient concentrations found at Mike1 than Mike3;
this spatial pattern in inorganic concentration indicates a strong interaction of a number of processes including sediment deposition, water flow dynamics and nutrient transport.

5) TC and TN concentrations with soil depth are highly correlated whereas TC and TP are not. This suggests that the majority of the TC and TN being deposited in the sediment are more organic while the TP is from more inorganic sources (sediment transport). Bulk density generally increases with depth in both locations and show major differences in sediment deposition that reflects, indirectly, soil age; especially pulsing events that regulate mineral deposition upstream.
REFERENCES


Smith, B.C., 2014. The effects of vegetation on island geomorphology in the Wax Lake Delta, Louisiana, Geological Sciences. The University of Texas at Austin, p. 67.


Table A1. TSS (mg/L) values for the surface and middle water column from March, May, August and October at both Mike1 and Mike3

<table>
<thead>
<tr>
<th>Day</th>
<th>Month</th>
<th>Year</th>
<th>Location</th>
<th>Sampling Point</th>
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<tbody>
<tr>
<td>30</td>
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<td>2015</td>
<td>Mike1</td>
<td>surface</td>
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<td>2015</td>
<td>Mike1</td>
<td>middle</td>
<td>235.43</td>
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<tr>
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<td>3</td>
<td>2015</td>
<td>Mike3</td>
<td>surface</td>
<td>75.71</td>
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<td>2015</td>
<td>Mike3</td>
<td>middle</td>
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<td>2</td>
<td>5</td>
<td>2015</td>
<td>Mike1</td>
<td>surface</td>
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</tr>
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<td>5</td>
<td>2015</td>
<td>Mike1</td>
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<td>surface</td>
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<td>Mike1</td>
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<tr>
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Table A2. List of genera collected in each quadrat at Mike1 and Mike3 with associated structure and aboveground biomass

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<th>Location</th>
<th>Quadrat</th>
<th>Genus</th>
<th>Structure</th>
<th>Biomass (g/m²)</th>
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<td>leaf</td>
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Courtney Elliton was born and raised in a small town in southern Maryland. Growing up and living near the Chesapeake Bay, Courtney grew to love the water and knew at a young age, that she wanted to study marine science. Courtney attended Coastal Carolina University in Conway, South Carolina, where she graduated Suma Cum Laude with a Bachelor’s of Science in Marine Science and a minor in Biology and Psychology. She completed an undergraduate thesis project on the possibility of acoustic instruments to detect biological anomalies in Port Royal Sound. Following graduation in May 2013, she decided to join the Xu lab at Louisiana State University in January 2014 in the Department of Oceanography and Coastal Science. Courtney is interested in coastal restoration and is completing her thesis research on the interactions among hydrology, sediment and vegetation in accreting Wax Lake Delta. The project Courtney was assigned was through the Coastal Science Assistantship Program where she completed an internship at the Louisiana Coastal Protection and Restoration Authority. Courtney is currently a candidate for the degree of Master of Science in the Department of Oceanography and Coastal Science which will be awarded in August 2016.