Progress Report for Grant "Planting and Monitoring of the Caernarvon Delta in Big Mar": July through December, 2012

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Introduction
Since 2009 the Lake Pontchartrain Basin Foundation (LPBF) has been actively documenting the development of an emergent delta in the receiving basin of the Caernarvon Diversion outfall canal (Big Mar). Since October 2010, in partnership with the Coalition to Restore Coastal Louisiana (CRCL), LPBF has conducted bald cypress (Taxodium distichum) plantings within Big Mar as part of a grant funded reforestation effort. Also, LPBF has been monitoring and quantifying the expanding land area in Big Mar in an effort to understand the delta building process under the influence of a diversion. To read about the restoration efforts and monitoring conducted in Big Mar from October 2010 to July 2011 visit http://www.saveourlake.org/ and view the report entitled "Geomorphology and Bald Cypress Restoration of the Caernarvon Delta near the Caernarvon Diversion, Southeast Louisiana," as well as the update entitled “Progress Report for Grant Planting and Monitoring of the Caernarvon Delta in Big Mar: January through June, 2012.”

This report will serve as a supplement to the aforementioned reports. It summarizes work done in Big Mar from July 2012 through December 2012. This report discusses the impact of Hurricane Isaac on the restoration activities in Big Mar. Furthermore, this report highlights the planting of 318 trees on October 16, 2012, including the addition of water tupelo (Nyssa aquatica) and green ash (Fraxinus pennsylvanica) into the planting regime, as well as the implementation of an expanded monitoring protocol.

Consequences of Hurricane Isaac
Hurricane Isaac was a slow moving Category I hurricane that impacted the southeast Louisiana and Mississippi coastlines from August 28 to August 30, 2012 (Boyd, 2012). On August 28th the storm stalled just off the mouth of the Mississippi River for 15 hours. Easterly winds pushed water into the Barataria Basin, the Pontchartrain Basin, Breton Sound and Bay St. Louis areas, elevating tides prior to landfall. Maximum sustained winds reached approximately 80 mph before the center of the storm reached land in the early morning of August 29th. After landfall the storm moved slowly northward, with winds coming from a southeastern to southern direction. Sustained tropical storm force winds were experienced over southeast Louisiana for approximately 45 hours. For enclosed water bodies such as Big Mar, the slow
speed and storm track of Hurricane Isaac influenced the resulting storm surge (Figure 1). Surge elevations reached 12-14 feet in the Caernarvon area, near Braithwaite outside of the Inner Harbor Navigational Canal Barrier (USACOE, 2012).

Post-storm reconnaissance of Hurricane Isaac’s impacts coincided with the scouting of potential planting sites and later with the implementation of an expanded monitoring plan. Of particular interest was the impact of the storm on the most recent, 4th planting of bald cypress trees, carried out in May, 2012, on spoil banks in the southwestern corner of Big Mar (Figure 2). This planting consisted of six separate planting locations (4A-F) along a canal that forms the southern boundary of Big Mar (Figure 3).
Figure 2. An overview of the different plantings and locations of plantings in Big Mar. Yellow represents the 2\textsuperscript{nd} planting (March, 2011), blue represents the 3\textsuperscript{rd} planting (November, 2011), red represents the 4\textsuperscript{th} planting (May, 2012) and green represents the 5\textsuperscript{th} planting (October, 2012). No trees survived the first planting so it is not indicated.

Figure 3. The location and distribution of sites that make up the 4\textsuperscript{th} planting in Big Mar. The 4\textsuperscript{th} planting is located in the southwest corner of Big Mar. The white dots represent trees that were tagged for future monitoring (see below).
Pre-storm monitoring of these sites, about one month after their initial planting, indicated tree survival was 94%. Post-storm tree survival at these sites was reduced to 65% (Table 1). Of 251 trees planted in May, 2012, one hundred and sixty-one were located and alive after Hurricane Isaac. Most of the mortality was attributed to storm surge impacts at two (of six) specific locations; 4A and 4B. At these two locations survivorship was reduced to 25% and 20%, respectively. Site 4A and 4B are located at the intersection of three separate canals, one of which runs in a southeasterly direction and likely directed storm surge through these two sites and into Big Mar, (Figure 4). Severe wrack deposition was observed at these sites, often covering entire trees. Many trees snapped in half above the Nutria (*Myocaster coypus*) Exclusion Device (NED), others weren’t located and were possibly washed away during the storm surge.

Table 1. Survivorship for planted trees pre and post Hurricane Isaac. The most recently planted trees demonstrated the highest hurricane induced mortality rates.

<table>
<thead>
<tr>
<th>Tree Planting</th>
<th>Pre-storm</th>
<th>Post-storm</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2</td>
<td>22%</td>
<td>18%</td>
</tr>
<tr>
<td>#3</td>
<td>67%</td>
<td>67%</td>
</tr>
<tr>
<td>#4</td>
<td>94%</td>
<td>65%</td>
</tr>
</tbody>
</table>

Figure 4. Visible storm surge damage at site 4A. Survivorship was reduced to 20% at 4A. Many trees were covered with storm debris (A) and (B) and snapped just above the NEDs (C).
The other two previous plantings, March 2011 (2nd) and November 2011 (3rd) were only minimally impacted by Hurricane Isaac’s storm surge and post-storm tree survivorship did not differ drastically from pre-storm survivorship. Trees from these plantings have been in ground longer and their root systems were likely more established. Also, the specific locations of the sites from the 2nd and 3rd planting were not directly in line with canals funneling storm surge. Pre-storm tree survivorship for the 3rd planting was found to be 67% in June, 2012. Post-storm, tree survivorship for the 3rd planting was also 67%, with all sites (3A-3I) accessible. Furthermore, pre-storm survivorship of the 2nd planting was 22% while post-storm monitoring indicated that survivorship had been reduced to 18%.

Cypress/Tupelo/Green Ash Planting

A 5th Big Mar tree planting was scheduled for October 16, 2012. It was decided that water tupelo and green ash would be planted in addition to bald cypress. Water tupelo is commonly found alongside bald cypress in Southeast Louisiana swamps and can tolerate extensive flooding. Green ash is a wetland tree species that can tolerate short term flooding, but not elevated salinity and is expected to perform well under the freshwater influence of the Caernarvon Diversion, albeit better still on elevated ridges and spoil banks. In total, three hundred trees were ordered from Ecological Restoration Services (ERS) through CRCL, consisting of 150 bald cypress trees, 100 water tupelo trees and 50 green ash trees.

Three distinct planting sites were chosen based on specific geomorphologic characteristics (5A-5C) (Figure 5). Site 5A is an open spoil bank located in the southeast corner of Big Mar where two canals converge. The establishment of a healthy bald cypress-tupelo swamp, especially at this site, will act as a natural storm surge buffer. Site 5B is a small area of emergent land in the pro-delta, located in the southwest corner of Big Mar. This site will allow LPBF and CRCL to determine whether the pro-delta region of Big Mar has consolidated and stabilized enough to support further planting efforts. The third planting location, site 5C, is located on the main delta forming at the end of the Caernarvon Diversion Canal. This site furthers the goal of establishing a freshwater swamp on the emergent delta of the Caernarvon Diversion.
Staff from LPBF and CRCL received 318 trees from ERS on October 15, 2012 at the Delacroix Corporation boat launch. Trees randomly selected for the new monitoring protocol (described below) were marked with numbered aluminum tags. Tag number, tree species, site location and baseline heights were recorded on site. Baseline heights were measured in feet and inches, using a CST/Berger 16-ft. Locking Inches Telescoping Rod. Measurements were later converted to meters and centimeters. The trees were proportionally sorted into three groups, one for each site and moved to Big Mar using a boat provided by LPBF. One hundred twenty-nine trees were moved directly to the delta site (5C). One hundred eighty-nine trees (two groups of trees) were moved to the spoil bank site (5A). Site 5A was used as a staging site for the pro-delta site (5B) because the inaccessibility of 5B (extremely shallow water) precluded LPBF and CRCL staff from moving the trees there beforehand without the use of an airboat or mud boat.

All three hundred and eighteen trees were planted on October 16, 2012 by LPBF and CRCL staff, and approximately 40 volunteers. NEDs, zip ties, 5 ft. bamboo stakes, and shovels were provided by CRCL. CRCL also secured the use of four airboats and one mud boat. One boat was provided by LPBF. All personnel, volunteers and remaining materials were transported to site 5A via boat. From there, 49 trees (30 water tupelo, 14 bald cypress, and 5 green ash trees), 15 volunteers, NEDs, zip ties, stakes, shovels and one LPBF staff member were transported to site 5B via two airboats, for planting in the pro-delta. Thirty-five volunteers, 1 LPBF staff member and 1 CRCL staff member remained at site 5A and began planting the remaining group of 140 trees. This group of trees consisted of 64 bald cypress, 48 water tupelo and 28 green ash trees. Volunteers worked in groups of 2, spacing and then planting trees. Trees were spaced approximately 5 to 10 meters apart and were fitted with NEDs after planting. NEDs were
secured using zip ties and the planted trees were anchored in the ground by placing the bamboo stakes through the NED and pushing the stakes at least two feet into the ground. When planting at 5A and 5B was completed all volunteers, personnel and remaining materials were transported to site 5C to plant the final group of 129 trees (63 bald cypress, 43 water tupelo and 23 green ash) at the delta site.

**Monitoring**

Previous monitoring of bald cypress plantings in Big Mar focused primarily on tree mortality (Baker et al. 2011). The data collected and lessons learned from the earlier efforts influenced subsequent plantings in Big Mar (Baker et al. 2012). LPBF is expanding the monitoring program to include measurements of tree height (m) and diameter at breast height (dbh) (cm) of a subset of trees to monitor growth rates of planted trees. This data should provide insight about some of the effects of river diversions (nutrients and sediment) on tree growth in newly emergent wetlands. Further, this information can be used to continue to develop best practices for future coastal restoration projects, especially since the State Master Plan relies heavily on the construction of sediment diversions for coastal restoration.

LPBF has conducted nine monitoring trips to Big Mar since the October 16, 2012 planting. The GPS location of each live tree (that was able to be located) from all previous plantings (2-5) was recorded using a Trimble GeoExplorer 6000 Series GeoXR with an external GNSS. Also, 25% of planted trees from the 3rd, 4th, and 5th planting were marked with numbered aluminum tags and flagged with colored tape. All remaining 32 trees from the 2nd planting were also tagged and flagged, as only 18% of trees from that planting remain. Overall, 29% of found, live trees were flagged and tagged. Tree species, height, dbh, gps coordinates, planting number, site name and type of location were recorded along with other notable information, such as storm and/or nutria damage (Figure 6). DBH was measured in inches, using a caliper (“General” brand). Measurements were converted to cm at a later date. If tree height was insufficient to measure actual dbh, it was noted and girth was measured 6” from the top of the tree. Only data from trees with sufficient height to collect actual dbh data were used to calculate mean dbh for an entire planting. Height was measured for all tagged trees and incorporated to calculate mean height for an entire planting whether it was found whole or broken. However, it was noted when a tree was found broken in half, presumably from storm surge and wind and/or had visible nutria damage (Figure 7). When a tree was found in the field without an intact NED it was secured or replaced if one was available, if covered in storm debris it was cleared and if not upright it was straightened. All data were analyzed in SYSTAT 10.2
Figure 6. Cypress trees from the 2nd planting being tagged for monitoring (A) and being measured for height (B).

Figure 7. A nutria in Big Mar at twilight (A) Visible nutria damage on a planted cypress tree found without a NED (B).
Results and Discussion
To date, 1,615 trees have been planted as part of a broad reforestation effort in Big Mar. Of those, 967 are still alive and growing, which represents 60% of all trees planted (Table 2). High mortality in the 1st and 2nd planting, mostly from nutria herbivory and unconsolidated soil, indicated the importance of consistently utilizing NEDs when planting trees, securing the trees with 5' bamboo stakes and planting the trees in areas with sufficient emergent vegetation. Three hundred and thirty trees from the first two plantings that were not outfitted with NEDs or long stakes and that were planted on bare mudflats, did not survive. For the 1,291 trees planted with NEDs and longer stakes in areas with sufficient emergent vegetation, survivorship was 75%. Of those 1,291 trees a subset of 282 trees were marked with numbered tags for monitoring. This subset of 282 trees consisted of the remaining 32 trees (out of 175) from the second planting, one hundred thirty-nine trees (out of 678) from the third planting, fifty trees (out of 251) from the fourth planting and 61 trees (out of 318) from the most recent, fifth planting.

Table 2. Survivorship rates of trees planted in Big Mar. The use of NEDs greatly improved survivorship rates.

<table>
<thead>
<tr>
<th>Planting</th>
<th>Date Planted</th>
<th>Trees Planted (#)</th>
<th>NEDs Deployed (#)</th>
<th>Estimated Survival (#)</th>
<th>Survival Overall (%)</th>
<th>Survival w/NEDs (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10/15/2010</td>
<td>200</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3/11/2011</td>
<td>175</td>
<td>44</td>
<td>32</td>
<td>18%</td>
<td>73%</td>
</tr>
<tr>
<td>3</td>
<td>11/1-11/3/2012</td>
<td>678</td>
<td>678</td>
<td>455</td>
<td>67%</td>
<td>67%</td>
</tr>
<tr>
<td>4</td>
<td>5/1/2012</td>
<td>251</td>
<td>251</td>
<td>162</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>5</td>
<td>10/16/2012</td>
<td>318</td>
<td>318</td>
<td>317</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>Total</td>
<td>2010-2012</td>
<td>1,622</td>
<td>1,291</td>
<td>966</td>
<td>60%</td>
<td>75%</td>
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</table>

Baseline height data collected on tagged trees showed that the survivors from the 2nd planting have grown substantially more than all subsequent plantings to date (Figure 8). Average tree height regardless of type of location for the 2nd planting was 2.59 m. Average tree height for the 3rd and 4th planting was 1.31 m and 1.53 m, respectively. Maximum tree height for a single tree was 3.61 m. This bald cypress tree was from the second planting and is located on the edge of a large, centrally positioned island in the new delta. The second planting occurred in the spring of 2011, experiencing two full growing seasons. The third and fourth plantings have both been in place for one full growing season.
Pre-planting heights for trees planted in the 2\textsuperscript{nd}, 3\textsuperscript{rd} and 4\textsuperscript{th} planting are not available. Therefore, it isn’t possible to gauge at this point how much those trees have grown since they were planted. It was noted at the time that trees varied in initial height from .3 to 1.5 meters. Little measurable growth in height seems to occur during the first growing season, possibly because trees are disproportionately expending energy below ground. Also, it is important to note that a number of trees from the 3\textsuperscript{rd} and 4\textsuperscript{th} planting were observed to have suffered storm damage, often found alive, but snapped in half above the NED. Others were found under storm debris with the top of the crown damaged. These impacts are reflected in the mean height measurements for the 3\textsuperscript{rd} and 4\textsuperscript{th} planting and may explain, in part, why little growth in height is detectable after one growing season. Regardless of which planting, trees were still generally taller on spoil banks, presumably due to higher elevation, less flooding stress and greater soil stability (Figure 9).
Baseline data collected for dbh also showed that the 2nd planting exhibited the greatest measurements for tree girth (Figure 10). The mean dbh for trees of the 2nd planting was 2.7 cm. The largest dbh for a single tree was 4.8 cm, for a bald cypress tree from the 2nd planting. The mean dbh measurements for the 3rd and 4th planting were 0.7 and 0.82 cm, respectively. Mean dbh for trees newly planted in October, the 5th planting, was 0.59 cm. Here, we can detect a mean difference between newly planted trees, trees after one growing season and trees after two growing seasons. Although the difference is small, trees from the 3rd and 4th planting had greater dbh than trees from the most recent planting, which was not the case when looking at tree height across plantings. When examined by type of location, after one and two growing seasons, dbh was also greater for trees growing on spoil banks (Figure 11).
**Figure 10.** Diameter at breast height (DBH) of trees across planting. The 2\textsuperscript{nd} planting has been established for two growing seasons. The 3\textsuperscript{rd} and 4\textsuperscript{th} planting have been in place for one growing season.

**Figure 11.** Diameter at breast height (dbh) of trees across planting and type of location. The 2\textsuperscript{nd} planting has been established for two growing seasons. The 3\textsuperscript{rd} and 4\textsuperscript{th} planting have been in place for one growing season.
Geomorphology
LPBF has been studying the geomorphology of the emerging Caernarvon Delta in Big Mar since October 2010 and has done some analysis on land growth rates throughout the entire Caernarvon Delta Complex since 2004 (Henkel et al. 2011). In a continuing effort to monitor the delta, an overhead flight was conducted over Big Mar on June 23, 2012. At the time, the water level in Big Mar was high due to southeasterly winds. The delta appeared to be smaller than previously observed. Post Hurricane Isaac, another overhead flight was conducted on September 4, 2012. The water level in Big Mar was still high from Hurricane Isaac. Although the Braithwaite/Caernarvon area sustained 12-14’ storm surge, the delta in Big Mar did not appear to have shifted and the size of the delta appeared to have expanded since the previous overhead flight. More area of emergent vegetation was visible, especially in the northeast corner of the delta (Figure 12).

Figure 12. Aerial view of the Caernarvon Delta pre- and post-Hurricane Isaac. The delta seems to have expanded since the June overhead flight.

LPBF attempted to quantify delta expansion in Big Mar by collecting data sets of gps coordinates using a Trimble GeoExplorer 6000 Series GeoXR with external GNSS. Between November 2012 and January
2013, LPBF scientists used a canoe and an air boat to move around the delta and intermittently record GPS coordinates of the land/water interface enveloping the delta. This boundary was generally delineated by the presence of emergent wetland vegetation. As of January 2013, the delta has expanded to a size of 178 acres. This is an increase of 50 acres in one year and an increase of approximately 158 acres since 2005. The delta has expanded at an average rate of 22.5 acres per year, although the data suggests that the rate of growth was slower from 2005-2010 and has increased from 2010-2012 (Figure 13). This land change analysis does not include the pro-delta area within Big Mar.

![Figure 13](image)

**Figure 13.** As of January 2013, the Caernarvon Delta has expanded to a size of 178 acres, an increase of 50 acres from the previous year and an increase of 128 acres since 2005.

The Caernarvon Diversion was nonoperational from August 29, 2012 through November 29, 2012 due to Hurricane Isaac and extremely low river stage in the Mississippi River (Table 3). LPBF turbidity measurements indicate that not much sediment was introduced into the area from the diversion for a three month period. However, very large mudflats were observed during field reconnaissance on November 2,
2012. The majority of these mudflats were located around the northeast section and along the southern boundary of the delta. The water level in Big Mar was very low at this time. With some sediment input, these mudflats may soon be at an elevation that can support emergent vegetation, which will further increase the size of the delta.

**Table 3.** Activity log for work in Big Mar from July 2012 through December 2012. The Caernarvon Diversion was not in operation from August 29, 2012 through November 29, 2012.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date</th>
<th>Discharge (cfs)</th>
<th># Trees Planted</th>
<th>Bald Cypress</th>
<th>Water Tupelo</th>
<th>Green Ash</th>
</tr>
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<tbody>
<tr>
<td>Overhead Flight</td>
<td>9/4/2012</td>
<td>-</td>
<td>-</td>
<td></td>
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<tr>
<td>Reconnaissance</td>
<td>9/19/2012</td>
<td>-</td>
<td>-</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reconnaissance</td>
<td>10/5/2012</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Planting Prep</td>
<td>10/15/2012</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Planting</td>
<td>10/16/2012</td>
<td>-</td>
<td>318</td>
<td>141</td>
<td>121</td>
<td>56</td>
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<tr>
<td>Monitoring</td>
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<td>-</td>
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<tr>
<td>Monitoring (1/2 day)</td>
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<tr>
<td>Monitoring (1/2 day)</td>
<td>11/16/2012</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Monitoring (1/2 day)</td>
<td>11/19/2012</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Monitoring (1/2 day)</td>
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<td>694</td>
<td>-</td>
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<td>Monitoring</td>
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<td>-</td>
<td>748</td>
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<tr>
<td>Monitoring</td>
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<td>1,100</td>
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<tr>
<td>Monitoring</td>
<td>12/13/2012</td>
<td>876</td>
<td>-</td>
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<td></td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>318</td>
<td>141</td>
<td>121</td>
<td>56</td>
</tr>
</tbody>
</table>

**Future Work**

Big Mar offers LPBF the opportunity to observe both the effect of a river diversion on coastal restoration activities and to document emergent delta formation and expansion. LPBF wants to continue monitoring of the delta and restoration activities in Big Mar either on an annual or biannual basis. We plan to monitor growth rates of individual plantings and use that information to also inform future plantings. We are particularly interested to incorporate other wetland tree species, such as swamp red maple (*Acer rubrum*), to the planting regime and to expand the planting area. A large portion of the flow from the Caernarvon Diversion is thought to bypass Big Mar and flow towards Lake Lery by way of a side canal. LPBF plans to expand restoration activities along this route, as well as directly south of Big Mar, to determine
whether and how far the potential effects of the diversion can be felt (Figure 14). If soil conditions prove suitable, LPBF also wants to continue to utilize the pro-delta region of Big Mar for tree plantings. Further, it is important to establish a control/reference planting of trees outside of Big Mar, removed from the possible effects of the Caernarvon Diversion against which growth rates from diversion plantings can be compared.

**Figure 14.** A portion of flow from the Caernarvon Diversion bypasses Big Mar and flows to Lake Lery via a side canal. The above map outlines a broad area between Big Mar and Lake Lery where future plantings are possible, as well as the location for a control planting.

Along with future plantings, LPBF continues to be interested in delta expansion in Big Mar, especially as compared to the amount of sediment input from the Mississippi River. We are also actively collecting ground elevation data along transects throughout the delta, as well as bathymetry data. Bathymetry data will allow LPBF to track changes in water bottom elevation throughout Big Mar. Over all, the data we are collecting and hope to collect is very important because river diversions are an important component of the Louisiana State Master Plan and the work LPBF is conducting in Big Mar, documenting the effects of the Caernarvon Diversion, is an opportunity to preview the effects of many State Master Plan projects on Louisiana wetlands.
Lessons Learned

Lessons-Learned:
Newly Reported

Site Selection and Planting
1. Experimentally, more trees should be planted in the pro-delta region of Big Mar.
2. A control/reference planting of trees removed from the effects of the diversion is advisable in order to effectively compare growth rates.
3. Planting trees at the intersection of 2 or more canals poses risks to survivorship during storm events due to stress and burial.

Monitoring and Maintenance
1. Monitoring should commence immediately after plant installation and should include baseline tree heights and dbh measurements in order to effectively monitor growth rates.
2. Tree height and dbh should be monitored annually, after the growing season.
3. The data suggests it takes up to 2 growing seasons to see substantial increase in tree height.
4. NEDs provide structural support for young trees; however, these trees can snap just above the NED during storm events.

Geomorphology
1. Access to a large part of Big Mar is limited unless water level is extremely high.
2. The flatboat only maneuvers in the canals around Big Mar. The canoe can maneuver within Big Mar, however, due to shallow water, an airboat, mudboat or prorogues would be more efficient for field work.
3. Sediments become softer away from the diversion outfall.

Herbivory and Control
1. Nutria population in Big Mar is very high. Big Mar might be a good candidate for a nutria control program beyond the use of NEDs.
2. Improper installation of NEDs causes gaps that provide access for herbivores.
3. Three zip ties are preferable to properly secure NEDs.

References Cited


