Porewater salinity analysis to determine the Mississippi River Gulf Outlet (MRGO) influence area using the Coastwide Reference Monitoring System (CRMS)

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Introduction

The Mississippi River Gulf Outlet (MRGO) is a 76 -mile long artificial channel that was built to provide a navigation shortcut from the Gulf of Mexico to the heart of New Orleans. Authorized by Congress in 1956 and completed by the U.S. Army Corps of Engineers (USACE) in 1968, the MRGO originally was 500 foot wide bottom channel and at least 36 feet deep (USACE _______). Proposed as an economic development project, the MRGO was lightly used and expensive to maintain. In 2006, the MRGO cost taxpayers nearly $20,000 for each vessel traveling in the channel (Day et al. 2006). The MRGO also came at a steep environmental price. The dredged channel converted 20,000 acres (31.2 sq. mi.) of wetlands to open water, and allowed saltwater to flow inland from the Gulf, eventually damaging a much greater area of wetland and lagoon habitat (LPBF 2006). By 2005, erosion along the channel's banks expanded the MRGO to a width of 3,000 feet in some areas, bringing it in close proximity to the hurricane protection levee. In addition to the economic and environmental costs, there was also a human cost by acting as a conduit for storm surge during Hurricane Katrina, which caused destruction and death in many communities (van Heerden et al. 2009).

Advocacy efforts resulted in the passage of the Water Resources and Development Act (WRDA) in 2007, deauthorizing the MRGO and requiring that the channel be closed to navigation. This was accomplished in 2009 by construction of a 950-foot rock dam across the channel, along the Bayou La Loutre Ridge, a natural ridge (and coastal line of defense) in St. Bernard Parish that was breached for the construction of the channel. The Inner Harbor Navigation Canal Lake Borgne Surge Barrier serves as a second closure upstream of the rock dam and was also completed in 2009. The two closures have moderated surface water salinity, setting the stage for large-scale ecosystem restoration. Also mandated by WRDA, the Corps developed the MRGO Ecosystem Restoration Plan (USACE 2012).

Since the closure of the MRGO, the Lake Pontchartrain Basin Foundation (LPBF) has been investigating and documenting the changes across the basin, resulting from this large scale, hydrologic restoration project. Changes in salinity (both soil and surface), fishery migration patterns, and habitats have been observed. This presentation will focus on changes in porewater salinity, or soil salinity, observed across the basin. In general, it seems that the area of influence and impact of the MRGO, when it was open, was much larger than initially predicted.

Methods

Data Collection

Porewater salinity data was downloaded for the entire period of record from the Coastwide Reference Monitoring System (CRMS) for 21 CRMS stations (CPRA 2017a) (**Figure 1**). The data ranged from 2006 to 2017. However, some stations did not come online until 2007, 2008, or 2009. The 21 CRMS stations were chosen in order to represent areas across the basin from Lake Maurepas to the Biloxi Marshes as well as areas that were speculated to be out of the influence of the MRGO, in Breton Sound Marshes. CRMS data includes multiple porewater salinity readings each year (three to eleven throughout the year), and at multiple sub-plots at each station (Folse et al. 2012).

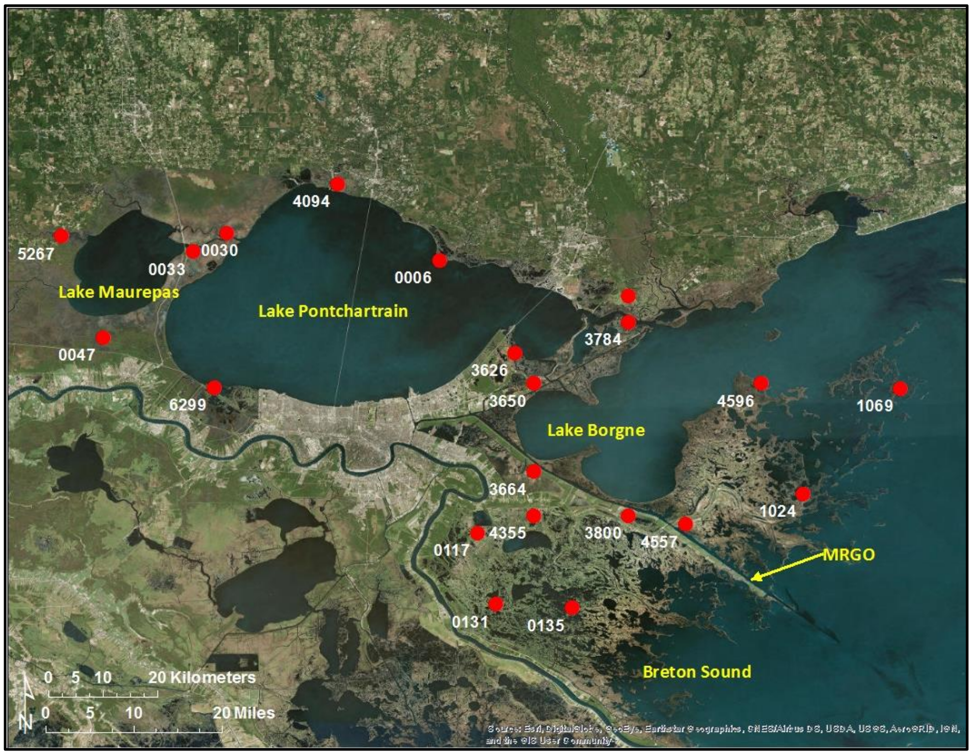

Figure 1: Locations of Coastwide Reference Monitoring System (CRMS) stations used to analyze porewater salinity across the basin.

Analysis

Porewater data (soil salinity) was analyzed in RStudio (R Studio Team 2016). Data was analyzed using a repeated measures Analysis of Variance (ANOVA) of soil salinity over time (year) by CRMS station. Additionally, soil salinity data was placed into the categories of 2006 through 2009 and 2010 through 2017, or before and after closure. An ANOVA was conducted by CRMS station to ascertain at which stations there was a significant difference in soil salinity before and after the closure of the MRGO. A Tukey's HSD was used to make pairwise comparisons within CRMS stations to ascertain which stations in the analysis were significantly different before and after the MRGO closure. Lastly, soil salinity was graphed over time by CRMS station in excel and the soil salinity data was spatially mapped in ArcMap (ESRI 2016) to predict the area of influence that the MRGO had, when it was open.

Results

Soil salinity was significantly different over time, by CRMS station, and the interaction of time and CRMS station ($p<0.0001$ for all three). It was expected that soil salinity would be significantly different by CRMS station, given the wide spread of stations chosen across the estuary for this analysis. Soil salinity was also significantly different before and after the closure ($p<0.0001$). Of the 21 stations that were analyzed, the soil salinity at 15 of them was significantly different before and after the closure (**Figure 2**). The mean difference across all stations before and after the closure was 1.9 ppt ± 1.5. When the stations were removed that were not significantly different before and after then the mean difference in soil salinity was 2.3 ppt ± 1.3. The maximum difference before and after the MRGO closure was at CRMS 3664 (in the Central Wetlands) at 5.35 ppt and the minimum difference was actually a slight increase of 0.03 ppt at CRMS 4110 (near the Pearl River). Additionally, when soil salinity was graphed over time, those stations that showed significant difference in before and after closure salinity, also showed that soil salinity began to decrease coincident with when the MRGO was closed (**Figure 3**).

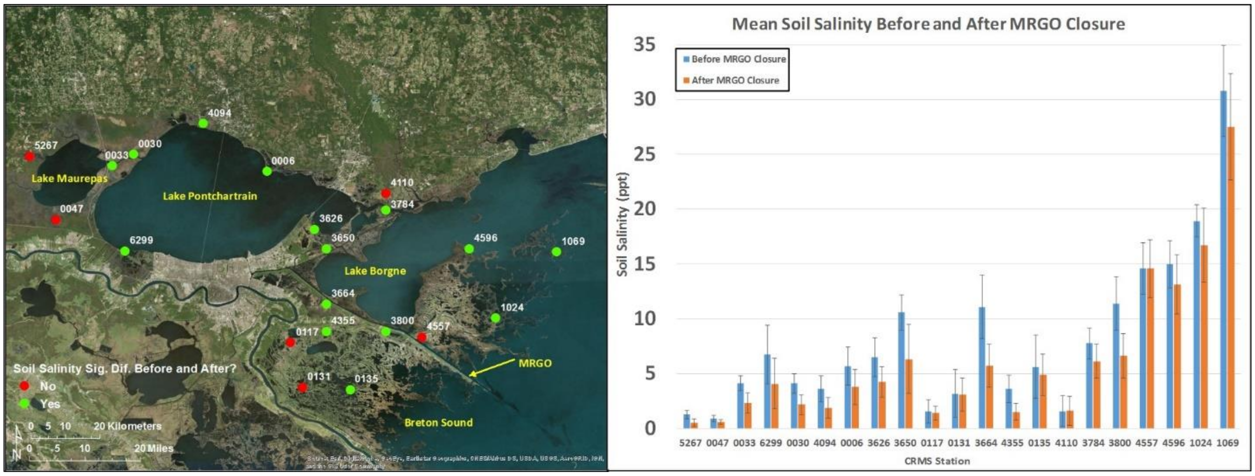

Figure 2: Coastwide Reference Monitoring System (CRMS) stations where mean soil salinity was significantly different before and after the Mississippi River Gulf Outlet (MRGO) closure (left; green dots) and bar chart showing the mean soil salinity before and after the closure of the MRGO at all CRMS stations included in this analysis (right).

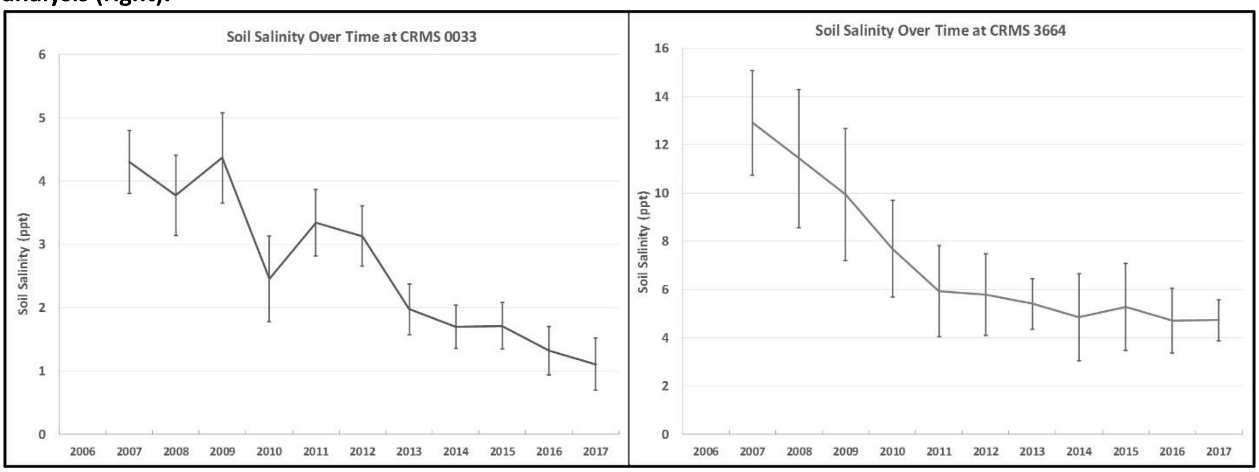

Figure 3: Soil salinity over time at two Coastwide Reference Monitoring System (CRMS) stations, one in Maurepas (left) and one in the Central Wetlands (right). The graphs show that, while there is year to year fluctuation, soil salinities at these two stations began to decrease after the Mississippi River Gulf Outlet (MRGO) was closed at the end of 2009.

Using the CRMS stations where there was a significant difference in soil salinity before and after the closure of the MRGO and stations where the soil salinity decrease began coincident with the closure, a predicted area of influence for the MRGO was drawn (**Figure 4**). The MRGO area of influence detected by using the CRMS stations was 525,207 hectares (2,025 square miles, 1,297,810 acres). This estimate could be conservative because the influence area may extend further west into the Maurepas swamp, but those CRMS stations were not investigated.

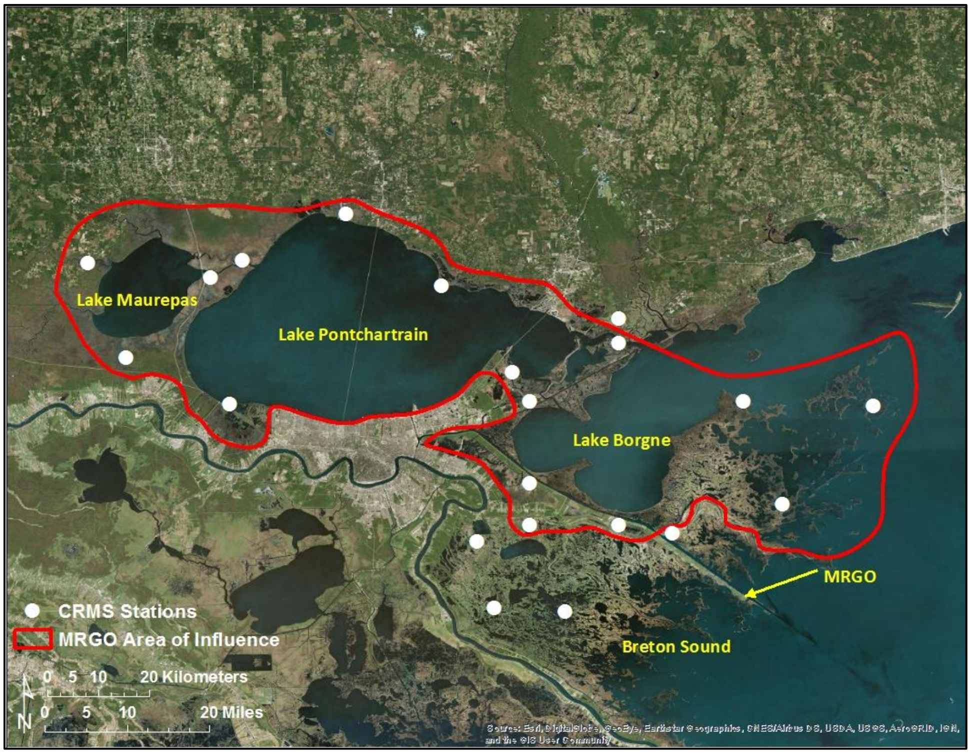

Figure 4: Estimated influence area of the Mississippi River Gulf Outlet (MRGO) in the Pontchartrain Basin. Using the soil salinity data at the Coastwide Reference Monitoring System (CRMS) stations, the area of influence was predicted to be 525,207 hectares (over 1.2 million acres).

Discussion

The influence area of the MRGO revealed by the CRMS soil salinity analysis was much larger than originally predicted (Lopez et al. 2010). Lopez et al. 2010 predicted that the MRGO, when it was open, impacted over 250,095 hectares (618,000 acres) of habitat including wetlands, bays, lakes, ponds, and benthic habitat. This prediction was based on the loss of 27,600 acres to dredging and spoil placement during the construction of the MRGO, 38,000 acres of conversion of fresher habitats to saltier habitats, 64,000 acres to the dead zone in Lake Pontchartrain (affecting benthic habitat) (Wagner and Hart 1986, Poirrier et al. 2009), and 488,400 acres that shifted from lacustrine to estuarine. This larger influence area may have had an especially negative impact on fresh forested wetlands. Surface water salinity is affected by episodic events such as rainfall and wind driven tides, making it difficult to ascertain the true impact area of the MRGO. The long-term record of soil salinity, which is less affected by these episodic events, elucidates patterns difficult to determine using surface salinity alone.

The swamps in the Pontchartrain Basin, especially in Maurepas, have been degrading for decades, after heavy logging at the turn of the 20th century. The CRMS stations in these locations may not have shown the largest difference in soil salinity before and after the closure of the MRGO, but the salinity reached a threshold that is ecologically important. Many of the CRMS stations in the Maurepas area had soil salinity above 2 ppt before the closure of the MRGO, which decreased to below 2 ppt after the closure. In general, elevated salinity impacts swamp species, causing reduced growth rates and mortality (Conner et al. 1997, Effler and Goyer 2006). This area, where soil salinity reached the 2 ppt threshold, is also where LPBF has observed natural regeneration and planted over 26,000 trees for swamp restoration (Henkel et al. 2017, Hillmann et al. 2017).

The discovery of a larger impact area makes restoration of the MRGO ecosystem more important than before. While the two closures go a long way to restoring the hydrology of the basin, returning the Rigolets and Chef Menteur Passes the dominant method of water exchange and fisheries migration, most of the restoration work has not begun. The USACE issued a plan for ecosystem restoration in the MRGO affected area, which currently doesn't have funding (USACE 2012). Some of the projects in USACE's plan are included in the 2017 Louisiana's state master plan for restoration (CPRA 2017b) and some projects have been executed under the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA). However, given the large impact area, there is still a lot of work to be done.

Conner, W. H., K. W. McLeod, and J. K. McCarron. 1997. Flooding and salinity effects on growth and survival of four common forested wetland species. Wetlands Ecology and Management **5**:99-109.

CPRA. 2017a. Coastwide Reference Monitoring System-Wetlands Monitoring Data. . Coastal Protection and Restoration Authority of Louisiana, New Orleans Louisiana. Retrieved from Coastal Information Management System (CIMS) database. http://cims.coastal.louisiana.gov.

CPRA. 2017b. Louisiana's Comprehensive Master Plan for a Sustainable Coast. Coastal Protection and Restoration Authority, Baton Rouge, New Orleans Louisiana, 184 p. http://coastal.la.gov/our-plan/2017-coastal-master-plan/.

Day, J., M. Ford, P. Kemp, and J. Lopez. 2006. A guide for the Army Corps; congressionally-directed closure of the Mississippi River Gulf Outlet. Baton Rouge, Louisiana.

Effler, R. S., and R. A. Goyer. 2006. Baldcypress and water tupelo sapling response to multiple stress agents and reforestation implications for Louisiana swamps. Forest Ecology and Management **226**(1-3):330-340.

ESRI. 2016. ArcGIS Desktop: Release 10.5. Redlands, CA: Environmental Systems Research Institute.

Folse, T. M., J. L. West, M. K. Hymel, J. P. Troutmann, L. Sharp, D. Weifenbach, T. McGinnis, and L. B. Rodrigue. 2012. A Standard Operating Procedures Manual For The Coast Wide Referencing System-Wetlands: Methods For Site Establishments, Data Collection, and Quality Assurance/Quality Control. The Louisiana Coastal Protection and Restoration Authority. Baton ROuge, LA. 207 pp.

Henkel, T. K., E. R. Hillmann, K. Butcher, D. B. Baker, and J. A. Lopez. 2017. Potential occurrence of natural swamp regeneration on the Maurepas Land Bridge, Southeast Louisiana. Lake Pontchartrain Basin Foundation 24pp. http://saveourlake.org/wp-content/uploads/2015/07/Potential-Occurrence-of-Natural-Swamp-Regeneration-on-the-Maurepas-Land-Bridge_FINAL_20170315.pdf.

Hillmann, E. R., T. K. Henkel, K. Butcher, D. B. Baker, P. Smith, and J. A. Lopez. 2017. Tree planting and monitoring on the Maurepas Land Bridge, Louisiana: February 2014 to May 2016. Lake Pontchartrain Basin Foundation. 31pp. http://saveourlake.org/download/maurepas-plantings-monitoring/?wpdmdl=12572.

Lopez, J., A. Moore, and J. Constible. 2010. Mister go isn't gone yet. Creating community and environmental resiliency in the wake of a man-made catastrophe. MRGO Must Go Coalition, New Orelans, LA. 26 pp. https://mrgomustgo.org/wp-content/uploads/2016/08/mrgo_april_2010_report_mrgomustgocoalition.pdf.

LPBF. 2006. Comprehensive habitat management plan for the Lake Ponchartrain Basin. Lake Pontchartrain Basin Foundation 142 pp. http://saveourlake.org/wp-content/uploads/PDF-Documents/our-coast/CHMP_final_%2022706.pdf.

Poirrier, M. A., E. A. Spalding, and C. D. Franze. 2009. Lessons Learned from a Decade of Assessment and Restoration Studies of Benthic Invertebrates and Submersed Aquatic Vegetation in Lake Pontchartrain. Journal of Coastal Research:88-100.

R Studio Team. 2016. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA http://www.rstudio.com/.

USACE. 2012. Mississippi River Gulf OUtlet (MRGO) ecosystem restoration plan: Final feasibility report. Supplemental report of the Chief of Engineers in response to the Water Resources Development Act of 2007. U.S. Army Corps of Engineers. 285 pp.

USACE. _______. History of MRGO. U. S. ARmy Corps of Engineers. http://www.mvn.usace.army.mil/Missions/Environmental/MRGO-Ecosystem-Restoration/History-of-MRGO/.

van Heerden, I. L., G. P. Kemp, R. Bea, G. Shaffer, J. Day, C. Morris, D. Fitzgerald, and A. Milanes. 2009. How a Navigation Channel Contributed to Most of the Flooding of New Orleans During Hurricane Katrina. Public Organization Review **9**(4):291.

Wagner, F., and D. Hart. 1986. Urban estuarine systems under stress: Environmental issues facing Louisiana's Lake Pontchartrain. Environmentalist **6**(1):25-33.