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SHORT COMMUNICATION

EFFECTS OF CLOSURE OF THE MISSISSIPPI RIVER GULF OUTLET ON SALTWATER INTRUSION AND BOTTOM WATER HYPOXIA IN LAKE PONTCHARTRAIN

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INTRODUCTION

Saltwater intrusion from the Mississippi River Gulf Outlet (MRGO) through the Inner Harbor Navigation Canal (IHNC) produced salinity stratification in Lake Pontchartrain which caused episodes of bottom water hypoxia and anoxia from 1968—2009 (Poirrier et al. 2009). This resulted in significant changes in benthic invertebrate community structure which were more distinct and persistent in a 250 km^2 (100 mi^2) area north of the IHNC (Abadie and Poirrier 2001a, 2001b) where more saline water entered.

The MRGO was a deep draft shipping channel which provided a more direct route from the Gulf of Mexico (GOM) to New Orleans. Construction began in 1958 and the MRGO was completed and fully operational in 1968. However, planned economic development along the outlet never materialized and maintenance costs greatly exceeded economic benefits. The MRGO also impacted adjacent wetlands and contributed to the storm surge from Hurricane Katrina that flooded New Orleans (Shaffer et al. 2009). The need to improve hurricane protection and prevent additional damage to coastal resources resulted in its de—authorization as a navigation channel in 2008. The MRGO was closed in July 2009 following the construction of a rock dam across the channel near Bayou La Loutre, about 38 km from the intersection with the Gulf Intracoastal Waterway (GIWW). Flow from the IHNC into Lake Pontchartrain was also blocked by a temporary rock cofferdam, which was completed on 31 October 2010. This was to allow construction of a larger cofferdam and a 30 x 5.5 m (95 x 18 ft) sector gate as well as two 15 x 5.5 m (50 x 18 ft) vertical lift gates for hurricane surge protection. The gates were opened to navigation in July 2012. Construction of the IHNC—Lake Borgne surge barrier, which included a sector gate on the GIWW, a vertical lift gate at Bayou Bievenue and a concrete barrier wall across the MRGO began in May 2009 and was completed in June 2011. It reduced tidal exchange through marshes between Lake Borgne and the MRGO. The floodgates at the mouth of the IHNC were opened on 3 August 2012. Details, including maps of the MRGO and other waterways and design and status of recent U.S. Army Corps of Engineers projects related to the IHNC and MRGO, are available at www.nolaenvironmental.gov as well as other internet sites.

The past occurrence of saltwater intrusion and associated detrimental low dissolved oxygen (DO) from the MRGO is well documented. Poirrier (1978) was first to report that salinity stratification and associated low bottom DO from MRGO saltwater intrusion occurred in Lake Pontchartrain and discussed possible effects on biota. In this paper, it was assumed that significant intrusion started when the MRGO was completed in 1968. Sikora and Sikora (1982) found through various measures of community structure that a stressed benthic community was present in southern Lake Pontchartrain. They attributed this stress mainly to chemical contamination. However, based on studies conducted in 1976—1978, Junot et al. (1983) found that the principal driver of community change was detrimental low DO associated with saltwater intrusion from the IHNC. Poirrier et al. (1984) collaborated with Schurtz and St. Pè (1984) in a more extensive study that included analysis of contaminants and distribution of anoxia and hypoxia which confirmed that low DO was the major source of stress. Further studies of stratified water circulation were conducted by Georgiou and McCorquodale (2000). Abadie and Poirrier (2000) found that the density of large (> 21 mm) *Rangia cuneata* increased after the cessation of shell dredging in 1990. However, they also documented that large clams were absent from about a 250 km^2 (100 mi^2) area north of the IHNC (Abadie and Poirrier 2001a, 2001b). The absence of clams was attributed to low DO. Additional information on the distribution of anoxia and hypoxia and effects on benthos is summarized by Poirrier et al. (2009) and Shaffer et al. (2009). The goal of this study was to determine if MRGO closure by hurricane flood protection projects stopped saltwater intrusion, salinity stratification, and associated low bottom water DO in Lake Pontchartrain.

MATERIALS AND METHODS

The area of study is in Lake Ponchartrain, LA north of

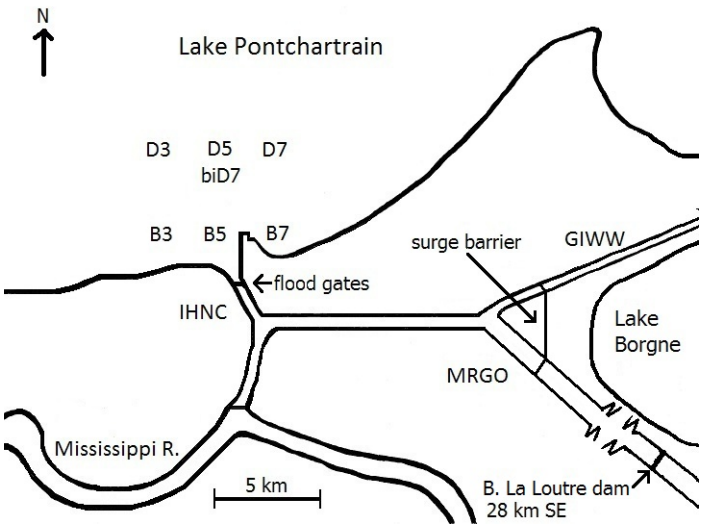

Figure 1. *Map of study area showing the 7 sampling sites in Lake Pontchartrain, and location of the Inner Harbor Navigation Canal (IHNC) and flood gates, the Mississippi River Gulf Outlet (MRGO), the Gulf Intracoastal Waterway (GIWW) and the IHNC–Lake Borgne surge barrier. The MRGO dam at Bayou La Loutre which was off the map scale was included and a gap in the MRGO was used to indicate its true position 28 km SE of the arrow.*

the outlet of the IHNC, an area impacted by changes in water movement through the GIWW, MRGO and IHNC due to flood control structures (Figure 1). Surface salinity and DO (30 cm below surface) and bottom salinity and DO (30 cm from bottom) were measured with either a YSI 85 meter or a YSI 600 sonde. Depth was measured with a calibrated, weighted chain. A benthic invertebrate sampling site biD7 (Poirrier et al. 2009) located 5 km north of the IHNC (30.07500N, 90.04916W) had representative stratification while the MRGO was open. With the exception of fall 2007, it was sampled every fall from 1997 through 2011. Data from this typical site were used to present representative changes that occurred in long–term differences between surface and bottom salinity and dissolved oxygen as flood protection projects that closed the MRGO were completed.

A sampling grid north of the IHNC established in past studies (Poirrier et al. 2009) was used to determine the distribution of stratified water after the 2009 MRGO closure. Surface and bottom temperature, salinity, DO and depth were measured in most months from July to November 2009, March to July 2010 and in August 2012 after the gates at the mouth of the IHNC were opened. Sites near the mouth of the IHNC were sampled first, and sites away from the canal were added until stratification was no longer detected. After closure of the MRGO, it was determined that only 6 sites within 8 km of the IHNC needed to be sampled to confirm the extent of stratification. Sites used with geographic positions and distances from the IHNC were as follows: B3 30.05000N, 90.08333W (4.98 km); B5 30.05000N, 90.05000W (2.44 km); B7 30.05000N, 90.01667W (2.77 km); D3 30.08333N, 90.08333W (7.33 km); D5 30.0833N, 90.05000W (5.90 km); D7 30.08333N, 90.01667W (6.05 km) (Figure 1). Not all sites were sampled on each trip due to bad weather and limited resources. Measurements were not taken during winter months and after storm events that are known to disrupt stratification (Poirrier 1978). Site B7 was not sampled in 2010, because no stratification was detected in 2009. Site D3 was sampled more often upon the elimination of site B7.

Results

A comparison of surface and bottom salinity and DO (Figure 2) from site biD7 indicated that following the closure of the MRGO at Bayou La Loutre in July 2009, salinity differences were less than 0.2 and DO differences were less than 10%, illustrating that the closure stopped significant levels of saltwater intrusion, stratification, bottom water anoxia and hypoxia. Seasonal data from 6 sites near the mouth of the IHNC following the closure of the MRGO supported these results; no differences in surface and bottom salinity values greater than one were present and there was no evidence of hypoxia (DO < 2 mg/l) (Table 1). Differences between surface and bottom salinity ranged from 0.2–0.9. Dissolved oxygen % saturation differences ranged from 0–38 %. Surface and bottom salinity differences greater than 0.1 (the accuracy and resolution of the instrument) occurred on five sampling events; site B5 in July 2009 (0.2), sites B5 and B7 in early August 2009 (0.4 & 0.6), site B5 in late August 2009 (0.9) and site B3 in October 2009. Surface and bottom dissolved

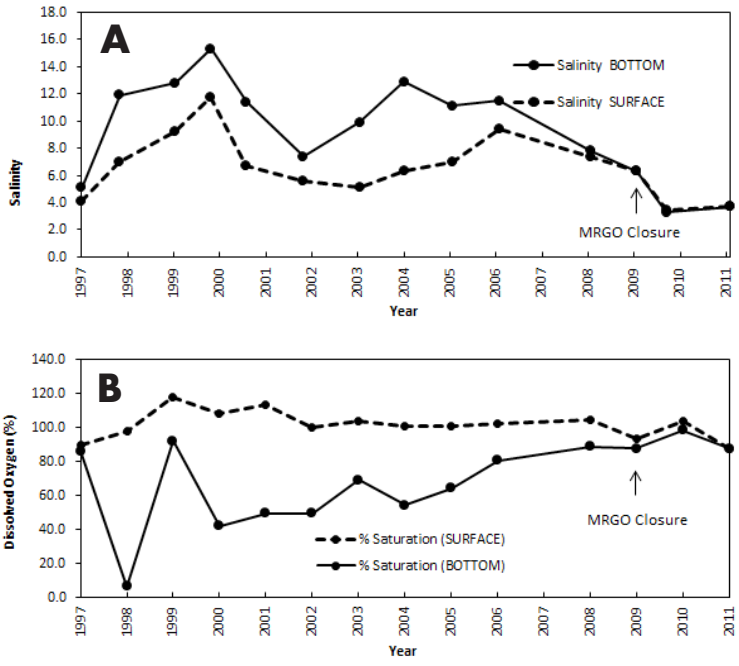

Figure 2. *Comparison of (**A**) surface and bottom salinity and (**B**) surface and bottom dissolved oxygen % saturation values at site biD7 located 5 km north of the IHNC before and after the 2009 closure of the MRGO.*

TABLE 1. *Surface and bottom salinity and dissolved oxygen measurements from 6 sites within 8 km of the Inner Harbor Navigation Canal (IHNC) after closure of the Mississippi River Gulf Outlet (MRGO). Numbers in bold represent differences > 0.1 salinity unit or > 10% DO between surface and bottom measurements.*

Date	Site	Surface Salinity	Bottom Salinity	Salinity Differance	Surface DO%	Bottom DO%	%DO Difference	Bottom DO mg/L
7/25/09	B3	5.1	5.2	0.1	99	93	6	7.0
	B5	5.1	5.3	**0.2**	93	89	4	6.4
	B7	5.1	5.1	0	99	95	5	7.0
	D5	4.9	4.9	0	91	91	0	6.7
	D7	4.9	4.9	0	95	89	6	6.6
8/11/09	B3	5.2	5.2	0	97	90	7	6.6
	B5	5.3	5.7	**0.4**	107	69	**38**	5.1
	B7	5.2	5.8	**0.6**	97	82	**15**	6.3
	D5	5.3	5.4	0.1	105	99	6	7.2
8/24/09	B5	6.1	7.0	**0.9**	89	67	**22**	5.0
10/28/09	B3	6.6	6.8	**0.2**	98	93	5	8.1
	B5	6.7	6.8	0.1	102	93	9	8.2
	D5	7.1	7.1	0	93	92	1	8.2
11/19/09	B3	5.9	5.9	0	96	90	6	8.4
	B5	6.2	6.2	0	90	88	2	8.0
	B7	6.4	6.4	0	98	95	3	8.7
3/31/10	B3	1.6	1.6	0	91	88	3	8.4
	B5	1.6	1.6	0	93	89	4	8.5
	D3	1.6	1.7	0.1	94	93	1	8.9
	D5	1.6	1.6	0	94	96	2	9.2
	D7	1.7	1.7	0	97	96	1	9.2
4/29/10	B3	1.9	1.9	0	92	89	3	7.7
	B5	1.9	1.9	0	85	84	1	7.2
	D5	2.0	2.0	0	92	90	2	7.8
5/25/10	B3	1.7	1.7	0	93	90	3	6.9
	B5	1.8	1.8	0	92	91	1	6.9
	D3	1.9	1.9	0	90	86	4	6.7
	D5	1.8	1.8	0	85	86	1	6.6
	D7	1.8	1.8	0	86	86	0	6.6
6/24/10	B3	2.3	2.3	0	95	86	9	6.6
	B5	2.3	2.3	0	84	84	0	6.2
	D3	2.1	2.1	0	94	87	7	6.4
	D5	2.3	2.3	0	92	89	3	6.6
	D7	2.3	2.3	0	93	91	2	6.8
7/10/10	B3	2.4	2.4	0	108	102	6	7.7
	B5	2.4	2.4	0	102	100	2	7.5
	D3	2.4	2.5	0.1	103	100	3	7.5
	D5	2.5	2.5	0	98	95	3	7.1
	D7	2.5	2.5	0	104	102	2	7.6
8/12/12	B3	2.5	2.5	0	101	82	**19**	6.3
	B5	2.6	2.7	0.1	102	92	10	7.0
	D3	2.7	2.7	0	103	91	**12**	6.9
	D5	3.0	3.0	0	105	87	**18**	6.4
	D7	2.6	2.6	0	101	70	**31**	5.3
8/23/12	B3	3.0	3.0	0	102	92	**11**	7.1
	B5	3.0	3.0	0	103	98	5	7.5
	D3	3.2	3.2	0	102	93	9	7.1
	D5	3.0	3.0	0	105	87	**18**	6.4
	D7	2.9	2.9	0	105	93	**12**	7.2

oxygen differences greater than 10% saturation were found on 3 sampling events: 11 August 2009 (B5 [38%; 5.1 mg/l] and B7 [15%; 6.3 mg/l]) and 24 August 2009 (B5 [22%; 5.0 mg/l]). Lower bottom DO, but not hypoxic DO, was associated with stratification. Mean depths for sites throughout the sampling period were: 4.5 ± 0.1 m (B3), 4.9 ± 0.1 m (B5), 3.9 ± 0.1 m (B7), 4.7 ± 0.1 m (D3), 4.7 ± 0.1 m (D5), and 4.8 m ± 0.1 (D7). Low DO values were found at 2 of the deeper sites north of the IHNC; the lowest values were at B5, closest to the IHNC. No evidence of salinity stratification or associated detrimental bottom DO was found in 2010. Data obtained in August 2012 after the IHNC gates at Lake Pontchartrain were opened indicated the continued absence of salinity stratification and hypoxia. However, surface and

bottom DO % saturation differences ranged from 5—31%.

Surface water temperatures ranged from 17.2—30.9°C. Bottom temperatures ranged from 17.2—30.0°C. Water temperature followed typical seasonal trends. Differences between surface and bottom temperatures ranged from 0.0—0.8°C. The temperature differences for the sites with relatively low DO were 0.1°C for B5, 0.2°C for D7 and 0.8°C for D5 on 11 August 2009. Temperature differences within this range were common at other sites that did not have relatively low bottom DO values.

Discussion

Data obtained in this study indicate that MRGO closure at Bayou La Loutre in July 2009 has stopped saltwater intrusion and associated low DO through the IHNC into Lake Pontchartrain. Episodes of extensive anoxia and hypoxia reported in previous studies (Schurtz and St. Pè 1984, Poirrier et al. 2009) were not found after the closure. A trend toward decreased mixing (Figure 2) appears to be present from 2006 to 2008, but this is due to lack of sampling in 2007 and a weather event in 2008. Points on the graph were connected with a line to compare surface and bottom values and do not imply any rate of change over time before the 2009 closure. Some evidence of residual stratification was detected during July, August, and October 2009 (Table 1). No stratification was detected in November 2009 or from March through July 2010. Construction of the temporary IHNC rock cofferdam began in February 2010 and was completed in October 2010. Sampling was discontinued after July 2010 because no stratification was detected and intrusion of higher salinity bottom water appeared to be blocked by the cofferdam which was in the final stages of construction. The IHNC—Lake Borgne surge barrier was under construction as well, and should have stopped any remaining exchange.

The residual stratification observed in 2009 was not surprising. Deep scour channels are present on both sides of the mouth of the INHC. Saline bottom water was probably present in the IHNC and MRGO after closure at Bayou La Loutre. Closure at Bayou La Loutre greatly reduced tidal exchange between the GOM and Lake Pontchartrain through the navigation canals. Any potential exchange was eliminated after placement of the temporary cofferdam for construction of flood protection gates. As in previous studies, temperature differences were not responsible for stratification.

Based on data obtained in August 2012, opening the gates at the IHNC did not produce saltwater intrusion. This is an expected result considering the MRGO was closed and the depth and cross—sectional area of the IHNC at Lake Pontchartrain was reduced by the flood gates. The higher surface to bottom DO differences in this data set may be due to measurements taken only during hot August weather, or to reduced water exchange due to control structures.

Closure of the MRGO has reversed north—to—south salinity gradients in eastern Lake Pontchartrain. Salinity measurement taken prior to closure of the MRGO were higher near the south shore due to saltwater intrusion and decreased with increasing distance from the mouth of the IHNC. Since the closure, salinity is generally higher near the north shore and decreases with decreasing distance to the IHNC.

After the MRGO closure, recovery of the benthic invertebrate community in the 250 km^2 area north of the IHNC has been slower than anticipated. In addition to the long—term effects of the MRGO, Hurricane Katrina in 2005 caused an acute disturbance that resulted in loss of *R. cuneata* and other community dominants from 815 km^2 (50% of the bottom) at depths > 3.7 m and limited recovery was observed in 2006 (Poirrier et al. 2008). Fall 2008 benthic invertebrate samples indicated an additional lake—wide disturbance, which further reduced the density of *R. cuneata* and other community—dominant species. This disturbance was more widespread than Katrina and extended to depths < 3.7 m. Ray (2009) studied effects of the 2008 Bonnet Carré Spillway opening on benthos and found similar results. He attributed the stressed community to hurricanes Ike and Gustav. Samples from fall 2009 and 2010 indicate some recovery toward pre—hurricane Katrina conditions, as evidenced by fewer annelids, and more mollusks and arthropods (M. Porrier, unpublished data). However, large *R. cuneata* clams were rare or absent in 2009 and 2010 samples. Recovery studies are still in progress and details will be submitted for publication after ongoing work is completed.

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