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MEMORANDUM

DATE: March 29, 2023

FROM: Robert Wiygul

SUBJECT: Information re Bonnet Carré Spillway, Essential Fish Habitat Impacts and Mitigation

Transmitted with this memorandum are an initial set of documents relevant to the impacts on Essential Fish Habitat of operations of the Bonnet Carré Spillway element of the Mississippi River and Tributaries Project.

In addition, I have included links to several documents relevant to the U.S. Army Corps of Engineers' (the Corps) discretion in operating the different elements of the Mississippi River and Tributaries Project. The fact that the Corps has broad discretion is relevant to the options available to mitigate impacts to Essential Fish Habitat (EFH).

A brief explanation of the contents of each set of documents is provided below.

I. IMPACTS OF BONNET CARRÉ SPILLWAY OPERATIONS ON ESSENTIAL FISH HABITAT

As the United States Court of Appeals for the Fifth Circuit recently recognized, "the Spillway's deployment takes a toll on a host of environmental and economic interests, causing everything from disruption to oysters, sea turtle and shrimp, to toxic algae blooms, seafood warnings and beach closures." *Harrison County, Mississippi et al v. U.S. Army Corps of Engineers*, No. 21-60897 (5th Cir. March 27, 2023).

The Northern Gulf Institute at Mississippi State University has compiled an initial bibliography and executive summary detailing the literature on impacts of spillway operations. The bibliography is annotated and includes links to the underlying literature. The literature demonstrates widespread impacts across Lake Pontchartrain, Lake Borgne and the Mississippi Sound. These impacts include some that were immediately apparent in the aftermath of earlier openings, such as near-total oyster mortality. Other impacts are not as well known, including negative impacts on larval fish survival. These impacts are linked to both the volume and the timing of the BCS discharges.

The Northern Gulf Institute is also in the initial phases of a modeling project that will provide more specific information on the characteristics of Bonnet Carré discharge regimes that would help mitigate impacts to natural resources, including EFH. This effort should provide more specific guidance for operations that would reduce impacts to EFH.

In addition to the documents compiled by the Northern Gulf Institute, included with this memo are a number of documents reflecting information about water quality and impacts during the 2019 openings of the spillway. These demonstrate the impacts of spillway operations on salinity, oyster mortality and shrimp spawning and recruitment.

II. THE CORPS HAS DISCRETION TO PROTECT ESSENTIAL FISH HABITAT

The system of spillways, levees and other structures comprising the Mississippi River and Tributaries Project was designed to allow no more than 1,250,000 cubic feet per second of water to reach the area of New Orleans. The Bonnet Carré Spillway design capacity is 250,000 cubic feet per second.

The Corps has on several occasions stated or implied that it cannot use other elements of the Mississippi River and Tributaries Project, such as the Morganza Spillway or the Old River Control Structure until Mississippi River flows exceed 1,500,000 cubic feet per second. This position effectively means that the Corps cannot discharge even modest amounts through these structures to reduce flows through the Bonnet Carré Spillway.

This is not a correct characterization of the 1928 Flood Control Act, which does not contain any such mandatory language. The "Jadwin Report" which was referenced by the 1928 Act does not include such a mandate. Any interpretation of the Flood Control Act or subsequent statutes requiring inflexible compliance with some specific order of use of elements of the Mississippi River and Tributaries Project, regardless of the consequences, would be both contrary to the intent of the statutes and the Corps' own practice.

As an example, the Corps has operated the Bonnet Carré Spillway above its design capacity. In 2011, the Corps operated the Bonnet Carré Spillway at 316,000 cubic feet per second, 66,000 cfs over its design capacity. *MR&T 2011 Post Flood Report,* p. IV-54, available at https://www.mvd.usace.army.mil/Portals/52/docs/regional_flood_risk_management/Docs/SectionIV-MRTOperation.pdf. At the same time the Corps was operating the Morganza Spillway at 186,000 cfs, less than a third of its design capacity of 600,000 cfs.

The Corps has full discretion to act to mitigate impacts to EFH, so long as public safety and other appropriate interests are protected. This could require the Corps to amend its operating protocols for the relevant elements of the Mississippi River and Tributaries Project, but that is entirely within the Corps control.

I should also note that the Corps has sometimes taken the position that operation of the Bonnet Carré Spillway simply mimics natural crevasses and the natural flooding cycle. This statement is not correct, and ignores the fact that the Mississippi River has been extensively leveed and modified over the past 150 years, and those modifications have changed the river's levels and behavior. For example, the Bonnet Carré Spillway now leaks into Lake Pontchartrain in many years when it is not even opened.

Index entry is linked to document

Index of Additional Documents re Bonnet Carre Spillway Impacts

1. 2019 Bonnet Carre Spillway Overview - August 30, 2019

2. 2019 Spillway 2nd Operations Effects

3. 2019 Water Quality Parameters

4. Shiller Isotopic Tracking

5. Dr. Robert Leaf Declaration

6. Oyster & Crab Surveys

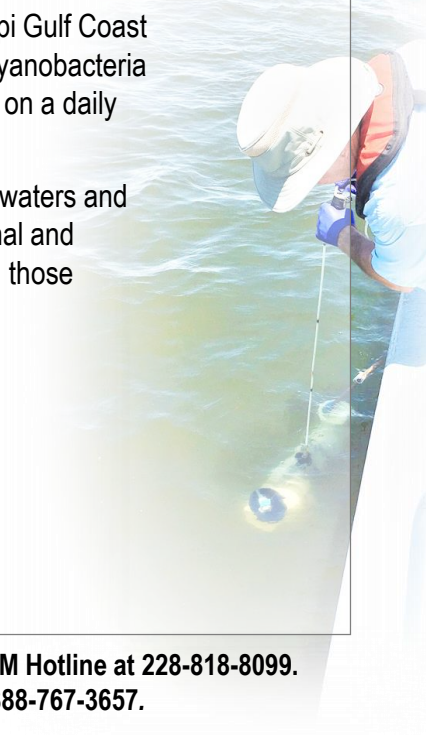
7. Temporal & Spatial Inflows

8. Presentation - Water Quality of Lake Pontchartrain associated with Bonnet Carre Spillway Openings 2008-2016

2019 Bonnet Carré Spillway Monitoring Update

August 30, 2019

- Full closure of the Bonnet Carré Spillway was achieved on July 27, 2019 (35 days ago).
- Salinity levels, as measured by USGS/MDMR gauges, continued to increase in the central Mississippi Sound since the closure of the spillway and have ranged between 15 and 20 ppt in the western Sound in recent days (Figure 1).
- Surface salinity modeling for August 28 again projects a continued but diminishing freshwater influence in the western Mississippi Sound (Figure 2); animated imagery available at: http://131.95.1.37/~BCS_share/CircModel/hourly/20190829/ngofs_saltUV_20190829.gif.
- Surface and bottom salinity levels measured during last week's field sampling (August 22; Figure 3) remained considerably higher than early August measurements and as observed during the spillway's extended period of opening. Dissolved oxygen levels also remained seasonally low in the south-central survey region on August 22 but had shown an increase in the north-central Sound (Figure 3).
- The distribution of river-borne sediments at the surface of coastal waters of the northern Gulf, as derived from satellite imagery, for August 22 illustrated a pronounced reduction in sediment input in the western Mississippi Sound (Figure 4).
- Field observations from expanded sampling conducted by USM on August 29:
  - Stations 1 - 7: no algal blooms noted; water more turbid than last week; salinities still fairly high (lower 20s)
  - Stations 8 - 16: no visible algal blooms observed; low bottom dissolved oxygen measured at offshore stations 8, 11, and 14; no low surface dissolved oxygen measurements
- For August 2019, five dead dolphins and four dead sea turtles have been reported. A total of 143 dead dolphins and 191 dead sea turtles have been reported during 2019, through August 30. *Source*: IMMS
- Water contact warnings remain in effect for coastal waters immediately adjacent to Mississippi Gulf Coast beaches (http://opcgis.deq.state.ms.us/beaches/) as a result of the presence of freshwater cyanobacteria capable of producing toxins. MDEQ and MDMR continue to sample waters from those areas on a daily basis to test for the presence of the freshwater cyanobacteria.
- The MDMR continues to test water and fish samples to ensure seafood safety in Mississippi waters and is advising fishermen to avoid catching seafood in waters where algae is present. Recreational and commercial fishing offshore in Mississippi waters remains unaffected by the algal bloom, and those catches are safe for consumption.



Report any unusual observations associated with the Bonnet Carré spillway opening to the USM Hotline at 228-818-8099. Dolphin and turtle strandings should be reported to the IMMS 24-hour hotline at 888-767-3657.

2019 Bonnet Carré Spillway Monitoring Update

August 30, 2019

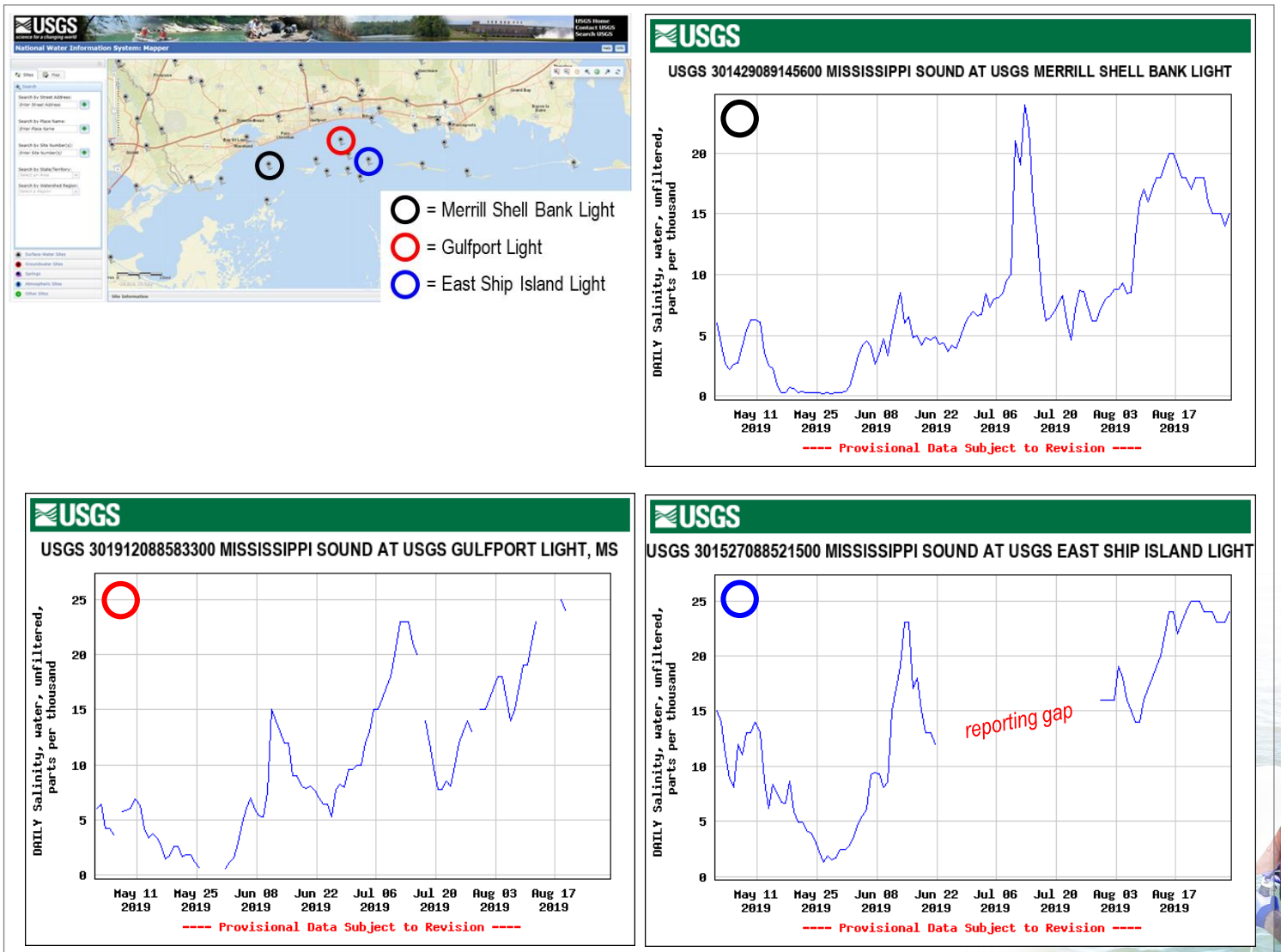


Figure 1. Daily salinity measurements from May 01 to August 29, 2019, at USGS/MDMR gauges in the Mississippi Sound. Increased salinity levels observed for July 10 to 14 were a result of the passage of Hurricane Barry. *Source*: USGS/MDMR

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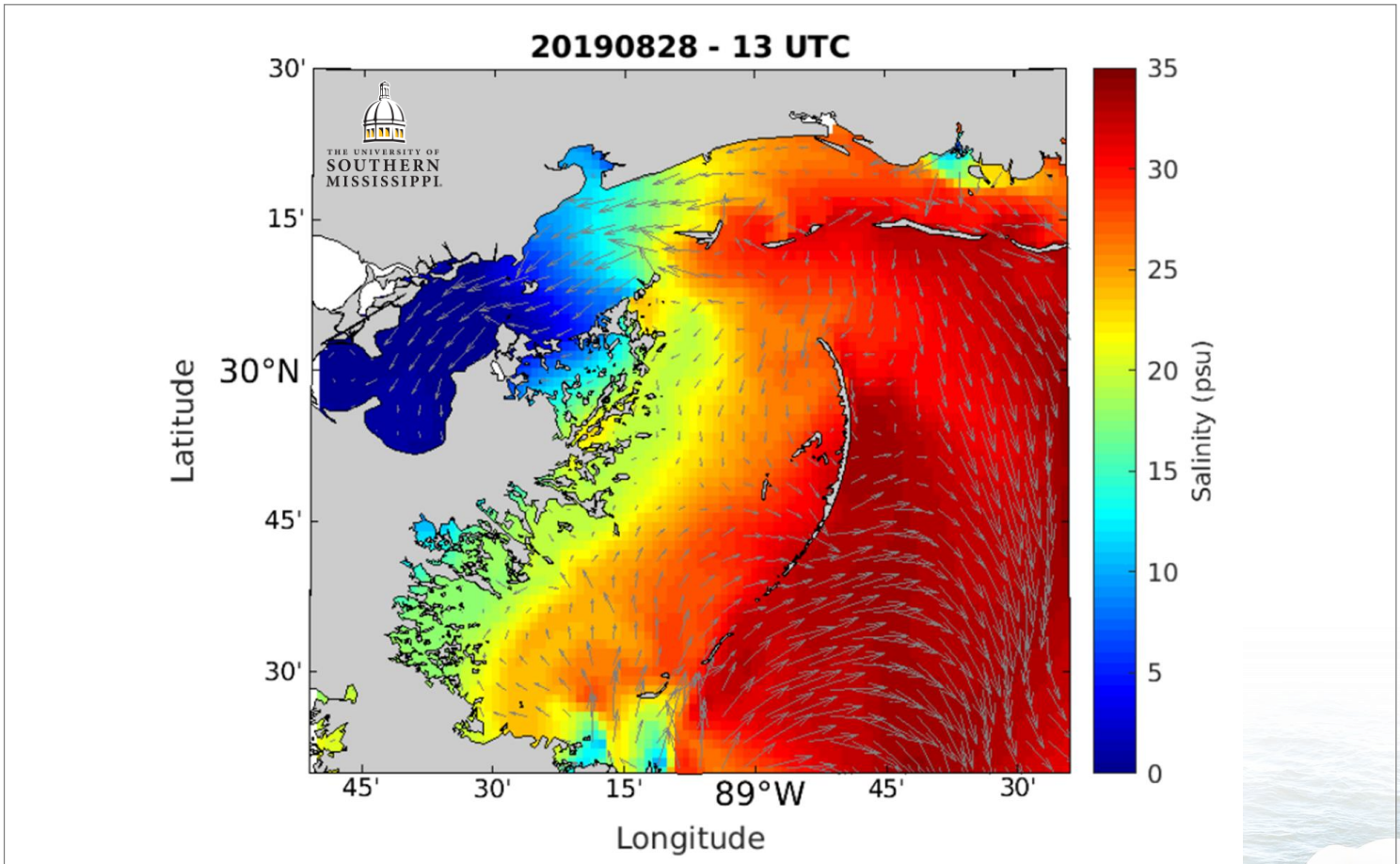

Figure 2. Screen shot of regional surface salinity model animation for August 28; animation of modeled salinity circulation is available at http://131.95.1.37/~BCS_share/CircModel/hourly/20190829/ngofs_saltUV_20190829.gif. Depiction illustrates the interaction of freshwater outflow, still influenced (but to a lesser degree) by remnants of the Bonnet Carré spillway discharge, and typical coastal circulation patterns influenced by wind, ocean currents and tides. *Source*: USM

Image Interpretation: Warmer colors (yellow to red) represent higher salinity waters typically observed in the region, while cooler colors (blue) are representative of lower salinity waters.

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2019 Bonnet Carré Spillway Monitoring Update

August 30, 2019

ENHANCE ★ PROTECT ★ CONSERVE

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

INSTITUTE FOR MARINE MAMMAL STUDIES

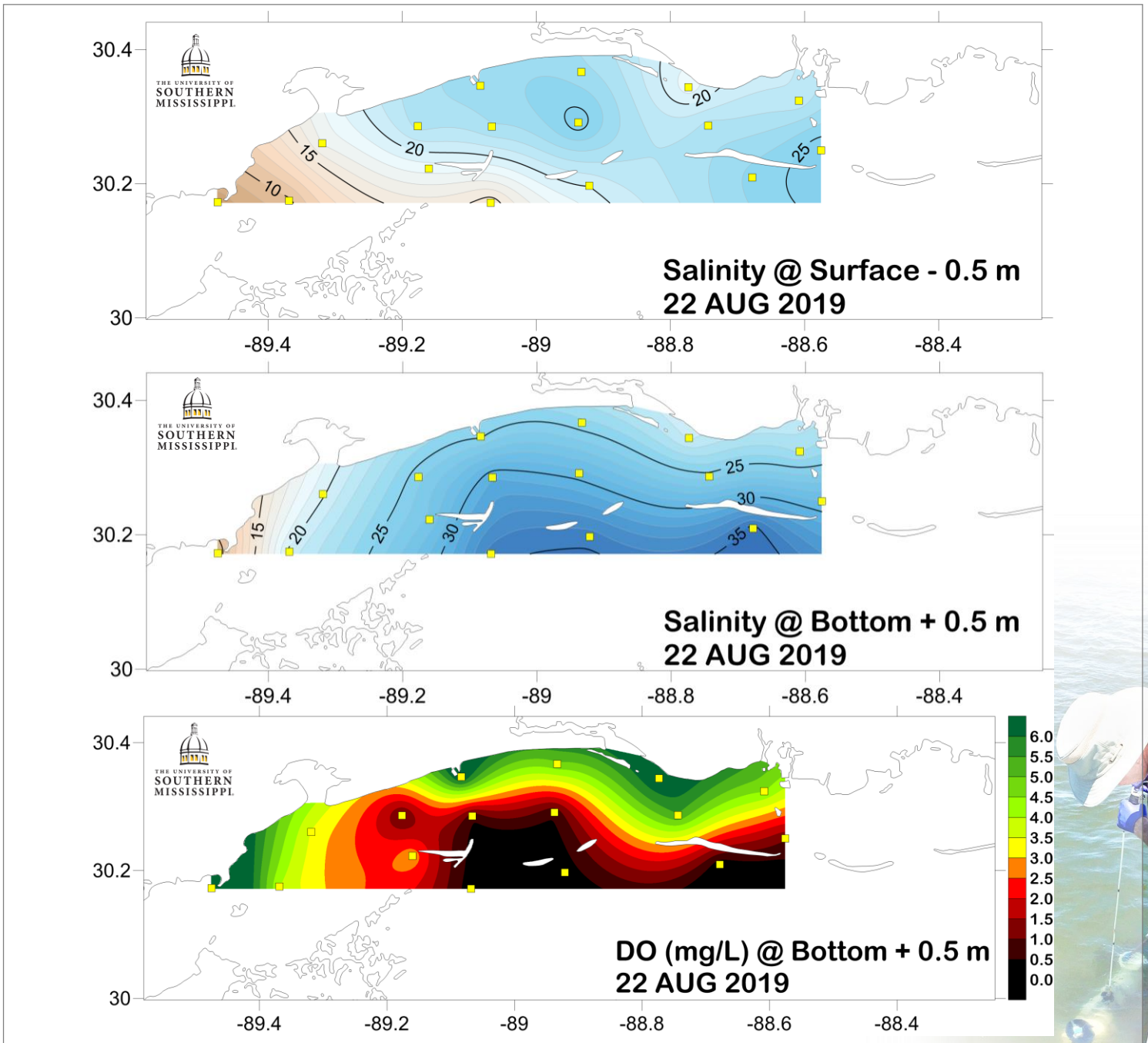

Figure 3. Depiction of surface salinity (top panel), bottom salinity (middle panel) and bottom dissolved oxygen (bottom panel) levels in the Mississippi Sound for August 22, as extrapolated from field data at expanded water quality stations (yellow squares). *Source*: USM

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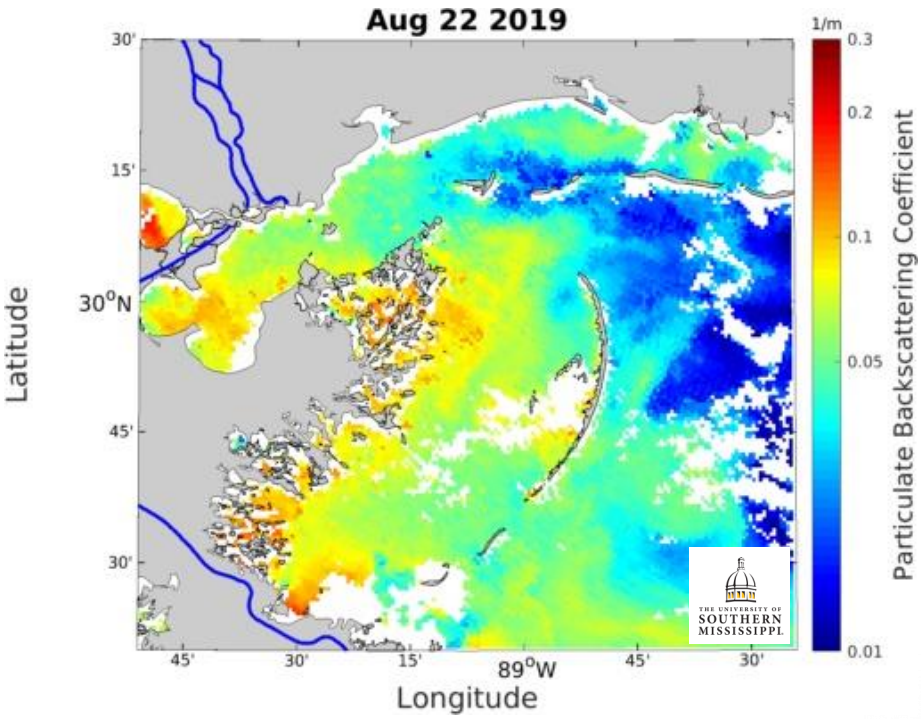

Figure 4. Satellite imagery of the distribution of river-borne sediments at the surface of coastal waters of the northern Gulf for August 22. *Source*: USM

Image Interpretation: Warmer colors (yellow to red) represent the extent of suspended sediments associated with freshwater influence from diverted river waters from the Bonnet Carré spillway discharge and the Pearl River in the western Mississippi Sound. Deep red colors are generally representative of salinities less than 5 ppt, and blue colors represent high salinity waters. White areas are gaps in satellite data.

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CEMVN-PDC-CC 7 May 2019
SUBJECT: 2019 Bonnet Carré Spillway 2nd Operations Effects

Algal Blooms
Current Conditions: No algal blooms have been reported to date.

Future Conditions: There is a potential for algal blooms to develop in the future as water temperature increases. If a bloom is reported, we have a plan in place to collect samples and have the species identified by Louisiana State University.

Endangered Species
Entrainment of sturgeon through the spillway (including the endangered Pallid sturgeon, and the threatened, Shovelnose sturgeon occurs. At the onset of each operation we initiate emergency Section 7 consultation under the Endangered Species Act with the USFWS. Through a close working relationship with the USFWS, we have established conservation measures to minimize impacts to sturgeon. As a result, CEMVN contracts ERDC to rescue (by netting) the entrained pallid sturgeon. Those fish are tagged and returned to the MS River. The introduction of invasive Asian carp into the Lake Pontchartrain tributaries is also a concern.

Current Conditions: The MS River stage and leakage through the bays has prevented the ERDC team from netting entrained sturgeon from the 1st 2019 opening.

Future Conditions: There is a potential for more sturgeon to be entrained. When the Spillway is closed the ERDC team will capture sturgeon, tag, and return to the River.

Asian Carp
The introduction of invasive Asian carp into the Lake Pontchartrain tributaries is also a concern.

Current Conditions: The MS River stage and leakage through the bays has prevented the ERDC team from netting and tagging Carp during the 1st 2019 opening.

Future Conditions: There is a potential for more Carp to be introduced to the Lake Pontchartrain watershed. When the Spillway is closed the ERDC team will capture and tag carp that are captured during the pallid sturgeon rescue.

Brown Shrimp
Current Conditions: The brown shrimp season opens in the Pontchartrain Basin during the month of May. Although Lake Pontchartrain normally produces fair volumes of brown shrimp, as of May 7, the LDWF sampled no brown shrimp in Lake Pontchartrain. Brown shrimp numbers and size are down 20% in Lake Borgne, MS Sound, and adjacent marsh. MS Department of Marine Resources are reporting similar low brown shrimp numbers. Some marketable size white shrimp are being sampled in Lake Borgne and MS Sound.

Future Conditions Low to no harvest is expected from Lake Pontchartrain. Brown shrimp in Lake Borgne and MS Sound will have reduced growth rates, and will be displaced Gulf-ward.

Oyster

The viable oyster reefs are located from the area where Lake Borgne meets MS Sound, eastward through MS Sound along the coast of MS to near Biloxi. The area also extends through the bays and lakes south from MS Sound to the MS River Gulf Outlet.

Current Conditions: 5% to 10% seed mortality is documented since last week's sampling effort. Adult (marketable sized) oysters are doing well with only 1% mortality in Louisiana waters. MS is seeing similar results but reefs closer to the Pearl River are showing increased mortality.

Future Conditions: It is likely that areas of oyster reefs, especially those in Lake Borgne and western MS Sound, will experience high mortality if salinity drops below 5ppt, and the water temperature increases. Other species will re-inhabit affected areas once salinity levels return to near normal, whereas oyster harvest will be adversely affected for the 2-3 years it takes for their growth to reach harvestable size.

Dolphin

NOAA hasn't fully processed the strandings data so these numbers are very preliminary (some deceased dolphin may have been counted more than once) and are for the entire state. NOAA typically sees some dolphins with signs of freshwater exposure in the northern Gulf at this time of year. Many of the strandings show signs of freshwater exposure, but they are highly decomposed. They will likely not be able to determine a cause of death for many of the individuals.

Current Conditions

The state of Louisiana has had approximately 69 dolphin strandings/deaths since 1 Jan 2019 to 5 May 2019. The average is 29.

The state of Mississippi had approximately 70 dolphin strandings/deaths since 1 Jan 2019. The average is 25.

It should be noted that many of these standings/deaths may be due to other environmental conditions, which includes fresh water from sources other than the Bonnet Carre'.

Future Conditions

There is a potential for more dolphin strandings/deaths to occur.

2019 Lake Pontachartrain/ Bonnet Carré Spillway Water-Quality Parmeters								X - samples collected for WQ/ALGAE compsition/toxin; NC = Not Collected; ND = Not Determined		
*****ALL DATA HAS NOT BEEN REVIEWED IS PROVISIONAL AND SUBJECTED TO CHANGE*****										
BONNET CARRÉ SPILLWAY -OPENING (Feb 27, 2019)										
Bonnet Carre Spillway at LA-Hwy 61										
2/27/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**BC Spillway Opened**								**NC**	LOW FLOW, LEAKAGE, OPENING
										USACE calc discharge at BC structure = 23,000 cfs (28 bays open)
3/6/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**8.68**	**273**	**0.13**	**6.79**	**10.78**	**92.5**	**0.4**	**X**	USGS discharge at Highway 61 = 133,000 cfs
										USACE calc discharge at BC structure = 148,000 cfs (148 bays open)
3/12/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**9.94**	**272**	**0.13**	**7.64**	**10.45**	**92.6**	**0.35**	**NC**	USGS discharge at Highway 61 = 180,000 cfs
										USACE calc discharge at BC structure = 196,000 cfs (206 bays open)
3/18/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**10.55**	**260**	**0.12**	**7.67**	**10.43**	**93.7**	**0.35**	**X + synop**	USGS discharge at Highway 61 = 174,000 cfs
										USACE calc discharge at BC structure = 207,000 cfs (196 bays open)
3/26/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**12.05**	**280**	**0.13**	**7.58**	**10.28**	**95.6**	**0.35**	**NC**	USGS discharge at Highway 61 = **167,000 cfs (3/24/19)**
										USACE calc discharge at BC Structure = 158,000 cfs (176 bays open)
4/9/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**14.75**	**308**	**0.15**	**7.58**	**8.59**	**84.8**	**0.3**	**NC**	USACE calc discharge at BC Structure = 38,000 cfs (55 bays open)
4/11/2019	**BC Spillway Closed**									LOW FLOW, LEAKAGE
										(0 bays open); leakage only
5/10/2019	**BC Spillway Re-opened**									
5/23/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**22.1**	**354**	**0.17**	**7.49**	**8.59**	**84.8**	**0.3**	**X**	USACE calc discharge at BC Structure = 158,000 cfs (168 bays open)
										USGS discharge at Highway 61 = 156,000 cfs (May24)
6/3/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**25.03**	**407**	**0.19**	**7.66**	**6.52**	**79**	**0.6**	**X**	USACE calc discharge at BC Structure = 140,000 cfs (168 bays open)
6/18/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**25.71**	**360**	**0.17**	**7.52**	**6.4**	**78.6**	**NC**	**NC**	USACE calc discharge at BC Structure = 142,000 cfs (168 bays open)
7/10/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
sample	**3**	**28.01**	**387**	**0.18**	**7.76**	**6.25**	**79.9**	**0.75**	**NC**	USACE calc discharge at BC Structure = 110,000 cfs (168 bays open)
										filamentous green algae observed in spillway

										isotope sample collected
7/19/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	
sample	**3**	**28.85**	**402**	**0.19**	**7.85**	**6.77**	**87.8**	**0.75**	**NC**	USACE calc discharge at BC Structure = 103,000 cfs (168 bays open)
										filamentous green algae observed in spillway
7/27/2019	**BC Spillway Closed**									
**********										
LAKE PONTCHARTRAIN										
Causeway Crossover #2 (lake, north)										
2/27/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.1	15.3	3,612	1.91	7.19	9.61	97			pre-spillway sample
mid	7.5	15.42	3,615	1.92	7.24	9.76	98.8			
top	1	17.8	3,568	1.89	7.22	10.18	108.4			
sample		**16.17**	**3,598**	**1.91**	**7.22**	**9.85**	**101.40**	**0.8**	**X**	blue-green tint, patches of duckweed in lake
3/12/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.9	15.32	3,259	1.72	8.14	9.19	92.70			2nd week first spillway open
mid	7.6	15.59	3,165	1.66	7.98	9.98	101.30			
top	1	15.68	3,163	1.66	7.96	10.25	104.20			
sample		**15.53**	**3,196**	**1.68**	**8.03**	**9.81**	**99.40**	**0.75**	**X**	flat, foggy, patches of duckweed, blue water
3/26/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	14.9	14.74	518	0.25	8.05	10.43	103.00			4th week first spillway open
mid	7.5	14.87	515	0.25	7.94	10.48	103.70			
top	1.1	14.89	515	0.25	7.92	10.48	103.80			
sample		**14.83**	**516**	**0.25**	**7.97**	**10.46**	**103.50**	**0.7**	**X**	moderate chop, windy, sediment rich water
4/9/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.8	17.94	290	0.14	7.82	9.36	98.80			Spillway closing this week
mid	7.7	18.13	290	0.14	7.90	9.46	100.30			
top	0.5	18.15	290	0.14	7.97	9.50	100.80			
sample		**18.07**	**290**	**0.14**	**7.90**	**9.44**	**99.97**	**0.6**	**X**	moderate to high chop, windy, sediment rich water
5/28/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	14.4	28.7	497	0.24	8.33	7.76	100.5			2nd spillway opening
mid	7.3	28.71	497	0.24	8.39	7.8	101.1			
top	0.8	28.76	495	0.24	8.4	7.92	102.7			
sample		**28.72**	**496**	**0.24**	**8.37**	**7.83**	**101.43**	**1.30**	**X**	clear, sunny, hot, moderate chop, water clear greenish color
6/11/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.277	28.56	300	0.14	7.86	7.25	93.6			2nd Spillway opening

mid	7.9	28.55	300	0.14	7.9	7.44	96.1			
top	1.4	28.54	300	0.14	7.89	7.42	95.8			
sample		**28.55**	**300**	**0.14**	**7.88**	**7.37**	**95.17**	**1.30**	**X**	Partly cloudy, sunny, hot, North Front moving in causing wave action towrds South shore
6/25/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	14.3	29.21	219	0.1	7.37	6.54	85.4			
mid	7.9	29.25	218	0.1	7.43	6.67	87.1			
top	1	29.41	220	0.1	7.49	6.9	90.1			
sample		**29.29**	**219**	**0.10**	**7.43**	**6.70**	**87.53**	**1.40**	**X**	Warm, cloudy, hazy
7/31/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	14	29	330	0.16	7.79	7.77	101			post Hurricane Barry
mid	8	29.15	330	0.16	7.8	7.82	101.7			
top	1.5	29.15	329	0.15	7.81	7.94	103.5			
sample		**29.10**	**330**	**0.16**	**7.80**	**7.84**	**102.07**	**2.50**	**X, iso**	hot, cloudy, clear water
10/18/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	16.8	22.71	3,131	1.64	7.04	7.44	87			
mid	8.5	22.67	3,134	1.64	7.2	7.43	86.9			
top	1.5	22.68	3,132	1.64	7.29	7.47	87.4			
sample		**22.69**	**3,132**	**1.64**	**7.18**	**7.45**	**87.10**	**0.70**	**X,iso**	rough seas, Tropical Storm approaching
**********										
Causeway Crossover #4 (mid-lake)										
2/27/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	16	15.4	3,575	1.89	7.33	9.67	97.8			
mid	8	15.39	3,561	1.88	7.33	9.69	98			
top	1	18.27	3,547	1.87	7.76	10.42	111.9			flat, slight brown tint , duckweed
sample		**16.35**	**3,561**	**1.88**	**7.47**	**9.93**	**102.57**	**0.7**	**NC**	gage ht = 0.4 ft
3/12/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	16.8	14.37	3,220	1.69	7.69	9.11	90.00			
mid	8.1	15.51	3,127	1.64	7.85	10.36	104.90			
top	1.2	15.54	3,126	1.64	7.91	10.46	106.00			flat, slight brown tint
sample		**15.14**	**3,158**	**1.66**	**7.82**	**9.98**	**100.30**	**0.8**	**NC**	gage ht = 0.62 ft
3/26/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	16.8	14.32	577	0.28	7.91	10.33	101.20			
mid	7.9	14.45	561	0.27	7.88	10.37	101.80			

top	1.1	14.58	561	0.27	7.87	10.38	102.20			moderate chop, windy, sediment rich water
sample		**14.45**	**566**	**0.27**	**7.89**	**10.36**	**101.73**	**0.65**	**NC**	gage ht = 0.45 ft
4/9/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.9	18.04	307	0.15	8.03	9.52	101.70			
mid	8	18.17	308	0.15	8.01	9.57	101.50			about 3.3 inches of rain at C4 from April 4 - 7, 2019
top	0.8	18.19	308	0.15	8.02	9.60	101.90			moderate to high chop, windy, sediment rich water
sample		**18.13**	**308**	**0.15**	**8.02**	**9.56**	**101.70**	**0.55**	**NC**	gage ht = 0.70 ft
5/28/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	14	28.66	423	0.2	8.38	7.67	99.2			2nd spillway opening
mid	7.1	28.71	417	0.2	8.52	7.91	102.5			
top	0.75	28.78	413	0.2	8.52	8.03	104.1			moderate chop, clear, sunny, hot, water clear greenish color
sample		**28.72**	**418**	**0.20**	**8.47**	**7.87**	**101.93**	**1.10**	**NC**	gage ht= 0.95 ft
6/11/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.9	28.2	370	0.18	8.37	7.16	91.9			
mid	8.1	28.21	370	0.18	8.44	7.53	96.6			
top	1.3	28.22	369	0.17	8.45	7.68	98.5			Choppy waters
sample		**28.21**	**370**	**0.18**	**8.42**	**7.46**	**95.67**	**1.10**	**NC**	Partly cloudy, sunny, hot, North Front moving in causing wave action towrds South shore
6/25/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	
btm	15.2	29.05	354	0.17	7.72	6.79	88.4			Warm, cloudy, hazy
mid	7.8	29.08	353	0.17	7.81	7.1	92.5			
top	1.4		354	0.17	7.88	7.39	96.4			
sample		**29.07**	**354**	**0.17**	**7.80**	**7.09**	**92.43**	**1.50**	**NC**	
7/31/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.5	28.96	349	0.16	7.89	8.48	110.3			post Hurricane Barry
mid	7.9	28.98	350	0.17	7.91	8.62	112.1			
top	1	29.01	350	0.17	7.94	8.75	113.9			
sample		**28.98**	**350**	**0.17**	**7.91**	**8.62**	**112.10**	**1.90**	**NC**	hot, cloudy, clear water
10/18/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	18.1	23.15	3,959	2.1	7.41	7.63	90.2			
mid	7.7	23.16	3,955	2.09	7.43	7.6	89.9			
top	1	23.16	3,942	2.09	7.45	7.62	90.1			
sample		**8.93**	**3,952**	**2.09**	**7.43**	**7.62**	**90.07**	**0.60**	**NC**	rough seas, Tropical Storm approaching
**********										
Causeway Crossover #7 (lake, south)										

2/27/2019	Depth (ft)	Wtemp (C)	SpCond (uS/cm)	Sal (ppt)	pH	ODO (mg/L)	ODO (% sat)	Secchi disk (m)	SampleCollect	NOTES
btm	15	16.1	2,558	1.33	7.69	9.66	98.8			pre-spillway sample
mid	7.4	16.15	2,534	1.32	7.67	9.62	98.5			
top	1	18.42	2,511	1.3	7.78	9.95	106.8			
sample		**16.89**	**2,534**	**1.32**	**7.71**	**9.74**	**101.37**	**0.55**	**X**	flat, brown tint, sediment runoff
3/12/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.2	11.28	270	0.13	7.98	10.83	98.80			2nd week spillway open
mid	7.4	11.57	270	0.13	7.87	10.86	99.80			
top	1.2	11.75	269	0.13	7.87	10.90	100.40			
sample		**11.53**	**270**	**0.13**	**7.91**	**10.86**	**99.67**	**0.7**	**X**	flat, brown-tinted water
3/26/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.7	14.60	276	0.13	7.93	10.44	102.70			4th week spillway open
mid	7.3	14.75	275	0.13	7.86	10.48	103.40			
top	1.2	14.78	275	0.13	7.82	10.50	103.70			
sample		**14.71**	**275**	**0.13**	**7.87**	**10.47**	**103.27**	**0.6**	**X**	moderate chop, windy
4/9/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.8	16.11	301	0.14	7.84	9.46	96.10			Spillway closing this week
mid	7.9	17.14	294	0.14	7.91	9.57	99.40			
top	0.5	17.45	294	0.14	7.93	9.64	100.70			highly turbid with some duckweed
sample		**16.90**	**296**	**0.14**	**7.89**	**9.56**	**98.73**	**0.3**	**X**	moderate to high chop, windy, sediment rich water
5/28/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	14.4	24.6	375	0.18	7.65	6.98	83.9			2nd spillway opening
mid	7.7	25.25	375	0.18	8.04	8.66	105.4			
top	0.5	25.81	374	0.18	8.35	10.13	124.6			
sample		**25.22**	**375**	**0.18**	**8.01**	**8.59**	**104.63**	**0.85**	**X**	clear, sunny, hot, moderate chop, slightly turbid water
6/11/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	14.5	27.87	406	0.19	8.66	8.72	111.7			
mid	7.3	27.89	405	0.19	8.68	8.91	113.8			
top	1.2	27.99	405	0.19	8.71	9.29	118.8			
sample		**27.92**	**405**	**0.19**	**8.68**	**8.97**	**114.77**	**0.60**	**X**	Partly cloudy, sunny, hot, North Front moving in causing wave action towrds South shore
6/25/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	14.1	27.69	359	0.17	7.86	7.43	94.5			warm, cloudy, hazy
mid	7.4	27.72	359	0.17	7.89	7.54	95.9			
top	1.4	27.76	359	0.17	7.9	7.58	96.5			
sample		**27.72**	**359**	**0.17**	**7.88**	**7.52**	**95.63**	**1.00**	**X**	
7/31/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**

btm	14.7	28.68	358	0.17	7.9	7.4	95.8			post Hurricane Barry
mid	7.8	28.7	359	0.17	7.86	7.5	97			
top	1.5	28.8	359	0.17	7.93	7.76	100.6			
sample		**28.73**	**359**	**0.17**	**7.90**	**7.55**	**97.80**	**1.90**	**X, iso**	hot, cloudy, clear water
10/18/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	16.8	23.39	1,775	0.90	7.29	7.76	91.70			
mid	8.5	23.38	1,774	0.90	7.25	7.80	92.00			
top	1.5	23.37	1,775	0.90	7.23	7.82	92.10			65
sample		**23.38**	**1,775**	**0.90**	**7.26**	**7.79**	**91.93**	**0.65**	**X, iso**	rough seas, Tropical Storm approaching
**********										
Hwy 11 (lake, outlet)										
2/28/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	11.8	16.92	2,832	1.48	7.42	10	104.3			pre-spillway sample
mid	5	16.93	2,832	1.48	7.48	10.04	104.7			
top	0.8	17	2,832	1.48	7.53	10.1	105.4			foggy, misty, flat water
sample		**16.95**	**2,832**	**1.48**	**7.48**	**10.05**	**104.80**	**0.7**	**X**	brown tint, sediment runoff
3/12/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	12.5	13.89	919	0.46	7.73	10.50	101.90			MS River water present
mid	6.8	13.93	917	0.45	7.89	10.54	102.30			
top	0.9	13.97	915	0.45	7.91	10.55	102.50			Windy, overcast, cool
sample		**13.93**	**917**	**0.45**	**7.84**	**10.53**	**102.23**	**0.45**	**X**	slack tide, moderate-heavy wave action
3/26/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	12.3	13.89	918	0.45	7.77	10.50	101.90			
mid	6.8	13.91	917	0.45	7.89	10.54	102.30			
top	0.9	13.96	916	0.45	7.91	10.57	102.70			slack tide
sample		**13.92**	**917**	**0.45**	**7.86**	**10.54**	**102.30**	**0.6**	**X**	moderate chop, windy
4/10/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	10.3	18.12	304	0.15	7.90	10.50	101.90			Spillway closing this week
mid	4.6	18.14	304	0.15	7.89	9.51	100.80			
top	0.5	20.64	304	0.15	7.99	9.70	107.90			outgoing tide
sample		**18.97**	**304**	**0.15**	**7.93**	**9.90**	**103.53**	**0.5**	**X**	flat, calm, sediment rich water with much duckweed
5/29/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	9.5	27.69	356	0.17	8.33	9.78	124.4			2nd spillway opening
mid	5.3	27.73	357	0.17	8.33	9.89	125.8			

top	0.5	27.86	356	0.17	8.45	10.14	129.3			incoming tide
sample		**27.76**	**356**	**0.17**	**8.37**	**9.94**	**126.50**	**0.90**	**X**	clear, sunny, moderate chop, clear water
6/11/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	10.2	28.03	389	0.18	8.18	7.21	92.3			Cloudy, south wind, cool with minimal sunlight -
mid	5	28.07	389	0.18	8.32	7.32	93.7			boat launch site distinct algae, less so at sampling site
top	0.8	28.12	389	0.18	8.38	7.53	96.6			
sample		**28.07**	**389**	**0.18**	**8.29**	**7.35**	**94.20**	**1.10**	**X**	
6/26/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	10.6	28.82	370	0.17	7.4	5.96	77.3			Cloudy, hazy, north wind
mid	6.3	28.82	370	0.17	7.43	6.01	78			
top	1.3	28.87	370	0.17	7.47	6.04	78.5			
sample		**28.84**	**370**	**0.17**	**7.43**	**6.00**	**77.93**	**1.30**	**X**	
7/2/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	11.5	29.47	357	0.17	7.61	8.32	109.2			sunny, partly cloudy, flat (low chop)
mid	8	29.46	357	0.17	7.7	8.36	109.5			
top	1	29.46	357	0.17	7.75	8.4	110.2			
sample		**29.46**	**357**	**0.17**	**7.69**	**8.36**	**109.63**	**1.20**	**X + isotope**	
8/2/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	11.7	29.77	400	0.19	7.19	7.16	94.4			Water clear blue
mid	5.6	29.79	400	0.19	7.21	7.21	95.2			thunderstorms, lite rain, moderate chop
top	0.3	29.81	400	0.19	7.24	7.27	95.9			
sample		**29.79**	**400**	**0.19**	**7.21**	**7.21**	**95.17**	**1.55**	**X + isotope**	
10/22/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	12.2	22.69	4,610	2.46	7.41	7.47	87.9			
mid	6.2	22.82	3,934	2.08	7.51	8.06	94.6			
top	0.7	22.94	3,904	2.07	7.52	8.16	96.2			moderate chop, sunny, cool
sample		**22.82**	**4,149**	**2.20**	**7.48**	**7.90**	**92.90**	**1.10**	**X**	ENV @ 1130, REP @ 1140
**********										
<u>Mississippi Sound at Grand Pass, LA (receiving basin for Pearl/MS River influence)</u>										
3/20/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	9.5	14.14	4,344	2.33	7.46	10.35	102.2			Time = 1030
mid	4.7	14.74	3,229	1.7	7.67	10.4	103.6			
top	1.2	15.14	3,064	1.61	7.82	10.52	105.6			gage ht = 2.1ft
sample		**14.67**	**3,546**	**1.88**	**7.65**	**10.42**	**103.80**	**0.45**	**X + DNA**	lite chop wind 15 mph NE , sunny, low tide

5/13/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	9.5	24.98	4,620	2.46	8.01	8.01	98.3			Time = 1030
mid	4.8	25.01	4,461	2.37	8.01	8.03	98.5			
top	0.5	24.94	4,460	2.37	8.02	8.07	99			gage ht = 2.1 ft
sample		**24.98**	**4,514**	**2.40**	**8.01**	**8.04**	**98.60**	**0.55**	**X**	moderate wind 15-20 mph, modeare to heavy chop, clear sunny, slack tide, turbid water
7/1/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	10	29.56	16,320	9.5	8.23	5.46	75.5			sunny, clear , flat (low chop)
mid	5.5	29.4	12,350	7.03	8.25	5.66	77			porpoise sighting
top	0.3	30.62	11,230	6.33	8.43	7.8	107.9			gage ht = 2.45 ft
sample		**29.86**	**13,300**	**7.62**	**8.30**	**6.31**	**86.80**	**0.60**	**X + isotopes**	
8/6/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	9.5	29.05	7,232	3.95	8.09	6.4	85.1			sunny, slightly cloudy
mid	4.3	29.26	4,775	2.54	8.33	7.94	105.1			low chop
top	0.5	29.67	4,574	2.42	8.42	8.5	113.3			gage ht = 1.5 ft
sample		**29.33**	**5,527**	**2.97**	**8.28**	**7.61**	**101.17**	**0.80**	**X + isotopes**	
**********										
Mississippi Sound at Merrill Shell Bank Light, MS (receiving basin Pearl/MS river water influence)										
3/20/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.5	14.25	1,262	0.63	7.86	10.16	99.5			Time = 11:30
mid	7.7	14.28	1,259	0.63	7.86	10.17	99.7			
top	1.3	16.53	1,183	0.59	7.88	10.27	105.6			
sample		**15.02**	**1,235**	**0.62**	**7.87**	**10.20**	**101.60**	**0.6**	**X + DNA**	lite chop, sunny, sediment rich water, low tide
5/13/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.4	24.94	6,950	3.81	7.82	6.44	79.5			Time = 11:30
mid	6.9	24.8	3,689	1.94	7.95	7.25	88.3			
top	0.5	24.94	3,389	1.77	7.84	7.8	95.3			gage ht = 1.95ft
sample		**24.89**	**4,676**	**2.51**	**7.87**	**7.16**	**87.70**	**0.45**	**X**	moderate chop, clear and sunny, slack tide, turbid water
7/1/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	13.1	29.35	16,240	9.42	8.13	5.59	77			sunny, clear, flat (low chop), slight turbid
mid	7.3	29.38	16,280	9.48	8.13	5.54	76.4			gage ht = 2.3 ft
top	0.7	30.65	11,400	6.45	8.42	8.83	123			
sample		**29.79**	**14,640**	**8.45**	**8.23**	**6.65**	**92.13**	**0.9**	**X + isotopes**	
8/6/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	12.8	29.49	25,750	15.62	7.73	1.8	25.7			little chop, sunny

mid	6.2	29.15	10,940	6.17	8.28	7.04	95			gage ht = 0.9 ft
top	0.3	30.57	10,130	5.66	8.51	10.01	137.7			
sample		**29.74**	**15,607**	**9.15**	**8.17**	**6.28**	**86.13**	**1**	**X+isotopes**	
**********										
Mississippi Sound at St. Joseph Island Light, MS (receiving basin with Pearl/MS river water influence)										
7/2/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	9.2	29.53	1,718	0.86	7.4	6.05	79.8			sunny to partly cloudy, warm, flat (low chop), slightly turbid
mid	5.4	29.54	1,557	0.78	7.77	6.1	80.4			visual green algae bloom patches just north of station (shore side)
top	0.5	29.85	522	0.25	7.93	6.68	88.2			stratified
sample		**29.64**	**1,266**	**0.63**	**7.70**	**6.28**	**82.80**	**0.45**	**X + isotopes**	gage ht = 3.5ft
8/5/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	8.6	29.38	4,843	2.57	7.81	5.32	70.5			heavy wave action, thunderstorms in vicinity
mid	3.3	29.68	3,362	1.75	8	6.38	84.8			low tide
top	0.4	29.75	3,293	1.71	8.03	6.57	87.3			stratified
sample		**29.60**	**3,833**	**2.01**	**7.95**	**6.09**	**80.87**	**0.65**	**X + isotopes**	gage ht = 2.6 ft
**********										
Synoptic Only Stations:										
Pearl River at Pearl River, LA (MS Sound input)										
3/19/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	27.6	14.6	56	0.03	6.93	9.08	89.3			Time = 1000
mid	14.9	14.6	56	0.03	6.88	9.13	89.8			
top	1.5	14.61	56	0.03	6.87	9.13	89.8			
sample		**14.60**	**56**	**0.03**	**6.89**	**9.11**	**89.63**	**0.35**	**DNA**	sunny, sediment rich water, overbank flow (flood stage)
7/2/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	15.4	29.22	84	0.04	7.38	7.07	92.3			Time = 1000
mid	7.9	29.22	84	0.04	7.42	7.09	92.5			
top	0.5	29.23	84	0.04	7.41	7.1	92.8			
sample		**29.22**	**84**	**0.04**	**7.40**	**7.09**	**92.53**	**0.4**	**isotopes**	sunny, partly cloudy
8/6/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
top	3.6	29.73	83	0.04	7.36	6.83	90			turbid water, moderate flow, lots of people in water
sample		**29.73**	**83**	**0.04**	**7.36**	**6.83**	**90.00**	**0.45**	**isotopes**	

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South Cat Island Beach, MS (receiving basin w/o MS river water influence)

3/20/2019	Depth (ft)	Wtemp (C)	SpCond (uS/cm)	Sal (ppt)	pH	ODO (mg/L)	ODO (% sat)	Secchi disk (m)	SampleCollect	NOTES
btm	10.4	15.64	23,450	14.24	8.08	9.09	99.8			Time = 11:00
mid	5.6	14.79	12,870	7.43	8.15	10.36	106.5			
top	1.4	15.82	10,380	5.9	8.19	10.56	110.4			
sample		**15.42**	**15,567**	**9.19**	**8.14**	**10.00**	**105.57**	**1.1**	**synoptic only**	lite chop, sunny, clear water, low tide

Lake Pont at Yacht Club near Mandeville (Site12A2)

3/20/2019	Depth (ft)	Wtemp (C)	SpCond (uS/cm)	Sal (ppt)	pH	ODO (mg/L)	ODO (% sat)	Secchi disk (m)	SampleCollect	
btm	9.2	16.18	2,255	1.16	7.49	9.77	100.1			
mid	4.9	16.18	2,253	1.16	7.49	9.79	100.3			
top	0.8	16.16	2,253	1.16	7.49	9.8	100.3			
sample		**16.17**	**2,254**	**1.16**	**7.49**	**9.79**	**100.23**	**1.1**	**synoptic only**	clear, sunny , clear water

Bay St. Louis at Highway 90, MS (MS Sound input)

3/19/2019	Depth (ft)	Wtemp (C)	SpCond (uS/cm)	Sal (ppt)	pH	ODO (mg/L)	ODO (% sat)	Secchi disk (m)	SampleCollect	NOTES
btm	10.1	14.34	990	0.49	7.34	9.92	97.3			Time = 1400
mid	5.5	14.51	925	0.46	7.39	9.85	97			
top	0.6	15.04	943	0.47	7.47	10.03	99.9			
sample		**14.63**	**953**	**0.47**	**7.40**	**9.93**	**98.07**	**0.45**	**synoptic only**	sunny, slight chop

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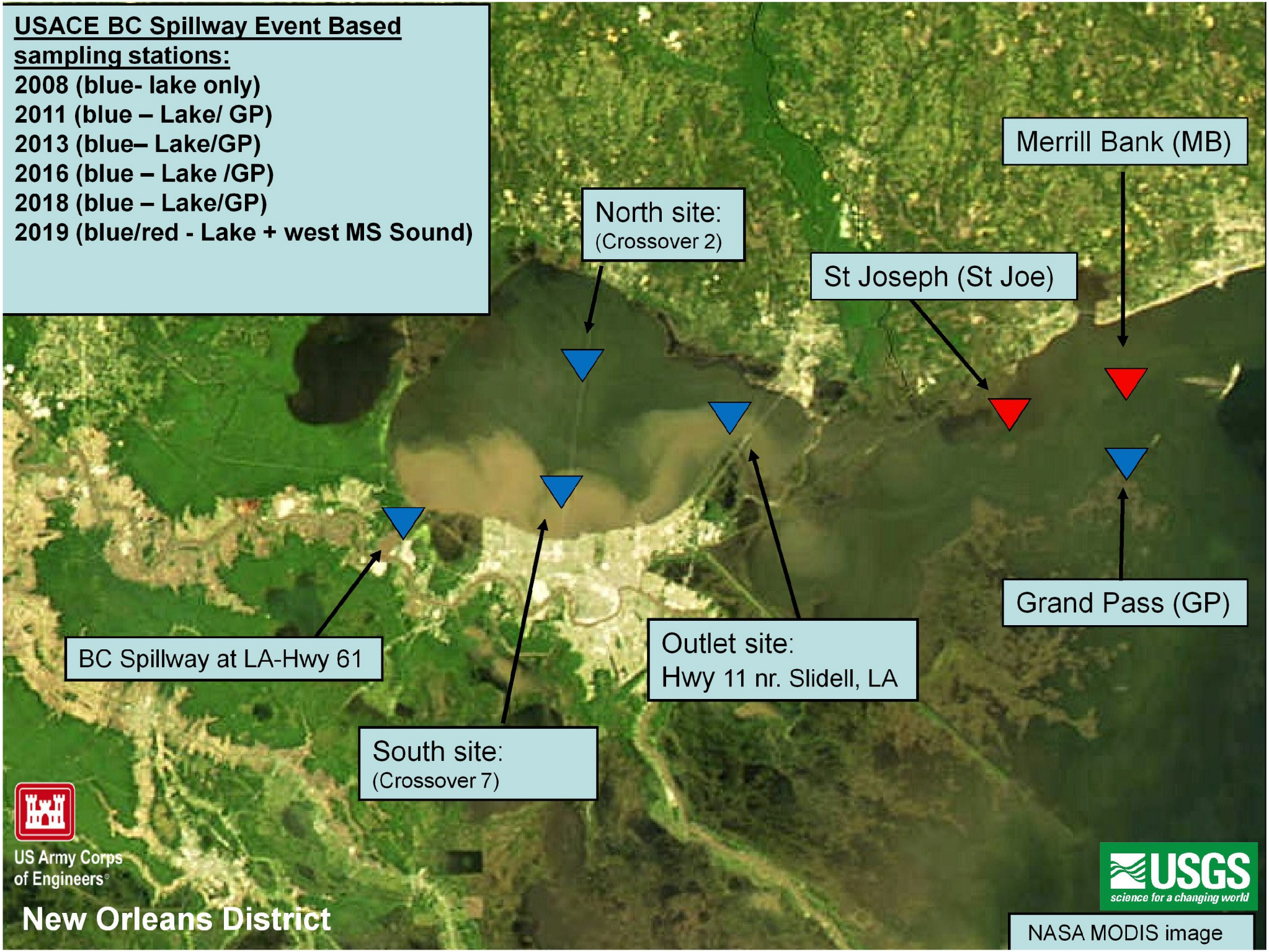
3 mile N of Grand Pass (GP-1)

7/1/2019	Depth (ft)	Wtemp (C)	SpCond (uS/cm)	Sal (ppt)	pH	ODO (mg/L)	ODO (% sat)	Secchi disk (m)	SampleCollect	NOTES
btm	11	29.1	24,360	14.71	7.88	5.66	79.9			Isotope synoptic sample only
mid	6.1	29.28	19,790	11.72	7.96	6.09	84.9			stratified
top	0.5	30.75	17,660	10.33	8.17	8.09	114.7			
sample		**29.71**	**20,603**	**12.25**	**8.00**	**6.61**	**93.17**	**1.10**	**isotope**	

8/6/2019	Depth (ft)	Wtemp (C)	SpCond (uS/cm)	Sal (ppt)	pH	ODO (mg/L)	ODO (% sat)	Secchi disk (m)	SampleCollect	NOTES
btm	11.8	28.77	39,380	25	7.54	0.44	6.5			Isotope synoptic sample only
mid	5.1	29.14	1,039	5.83	8.31	7.58	102			stratified
top	0.4	30.02	8,703	4.81	8.48	9.18	124.6			
sample		**29.31**	**16,374**	**11.88**	**8.11**	**5.73**	**77.70**	**0.85**	**isotope**	

6 mile N of Grand Pass (GP-2)										
7/1/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	9	29.27	17,800	10.45	8.08	5.75	79.5			Isotope synoptic sample only
mid	4.6	29.32	16,750	9.77	8.14	6.49	89.5			stratified
top	0.5	31.15	9,954	5.54	8.51	9.06	126			
sample		**29.91**	**14,835**	**8.59**	**8.24**	**7.10**	**98.33**	**1.00**	**isotope**	
8/6/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	7.9	29.05	18,970	11.19	8.06	4.17	57.8			Isotope synoptic sample only
mid	3.8	29.41	8,863	4.91	8.47	9.04	121.6			stratified
top	0.5	30.57	8,465	4.67	8.51	9.66	132.1			
sample		**29.68**	**12,099**	**6.92**	**8.35**	**7.62**	**103.83**	**0.85**	**isotope**	
2.5 mile N of Merrill Bank (MB-1)										
7/1/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	9.2	29.13	14,560	8.4	7.83	3.5	47.8			Isotope synoptic sample only
mid	4.5	29.42	10,880	6.13	8.31	7.95	107.7			stratified
top	0.6	30.65	8,624	4.76	8.46	9.71	133.4			
sample		**29.73**	**11,355**	**6.43**	**8.20**	**7.05**	**96.30**	**1.00**	**isotope**	
8/6/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	11.7	29.3	23,110	13.88	7.51	0.42	5.9			Isotope synoptic sample only
mid	6.2	29.15	16,410	9.56	7.8	3.44	47.3			stratified
top	0.3	30.58	11,350	6.4	8.47	9.26	128.1			
sample		**29.68**	**16,957**	**9.95**	**7.93**	**4.37**	**60.43**	**0.80**	**isotope**	
1 mile S of Pass Christian shore (launch) (MB-2)										
7/1/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	8.2	28.95	16,070	9.35	7.69	2.63	36			Isotope synoptic sample only
mid	4.1	29.25	12,160	6.91	8.06	5.32	72.5			stratified
top	0.6	30.37	9,819	5.48	8.48	9.76	133.9			
sample		**29.52**	**12,683**	**7.25**	**8.08**	**5.90**	**80.80**	**0.70**	**isotope**	
8/6/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	7.3	29.31	22,570	13.53	7.51	0.56	7.9			Isotope synoptic sample only
mid	3.5	29.45	13,860	7.96	8.14	6.31	86.4			stratified
top	0.4	30.55	12,610	7.18	8.31	8.25	114.5			
sample		**29.77**	**16,347**	**9.56**	**7.99**	**5.04**	**69.60**	**0.75**	**isotope**	

Lake Borgne near GIWW outlet										
8/2/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	8.3	30.05	736	0.35	7.88	7.39	98			Isotope synoptic sample only
mid	4.4	30.1	735	0.36	7.97	7.59	100.8			
top	0.7	32.43	717	0.34	8.58	10.28	141.5			green water (visible algae)
sample		**30.86**	**729**	**0.35**	**8.14**	**8.42**	**113.43**	**0.60**	**isotope**	
Rigolets at US 90, LA										
8/2/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	35.3	29.58	698	0.34	7.41	6.38	84			Isotope synoptic sample only
mid	24.5	29.58	698	0.34	7.44	6.51	85.6			
mid	14.5	29.58	698	0.34	7.45	6.43	84.6			
mid	4.5	29.64	700	0.34	7.48	6.61	87			
top	0.5	29.63	699	0.34	7.48	6.61	87			
sample		**29.60**	**699**	**0.34**	**7.45**	**6.51**	**85.64**	**0.80**	**isotope**	
btm is deeper than 35 feet but ran out of sonde cable										
Bayou Lacombe near mouth										
8/2/2019	**Depth (ft)**	**Wtemp (C)**	**SpCond (uS/cm)**	**Sal (ppt)**	**pH**	**ODO (mg/L)**	**ODO (% sat)**	**Secchi disk (m)**	**SampleCollect**	**NOTES**
btm	4.5	26.95	905	0.44	6.61	1.91	24.1			Isotope synoptic sample only
mid	2	27.47	671	0.32	6.58	2.28	28.9			groundwater input?
top	0.5	28.44	539	0.26	6.56	2.91	37.6			
sample		**27.62**	**705**	**0.34**	**6.58**	**2.37**	**30.20**	**1.20**	**isotope**	



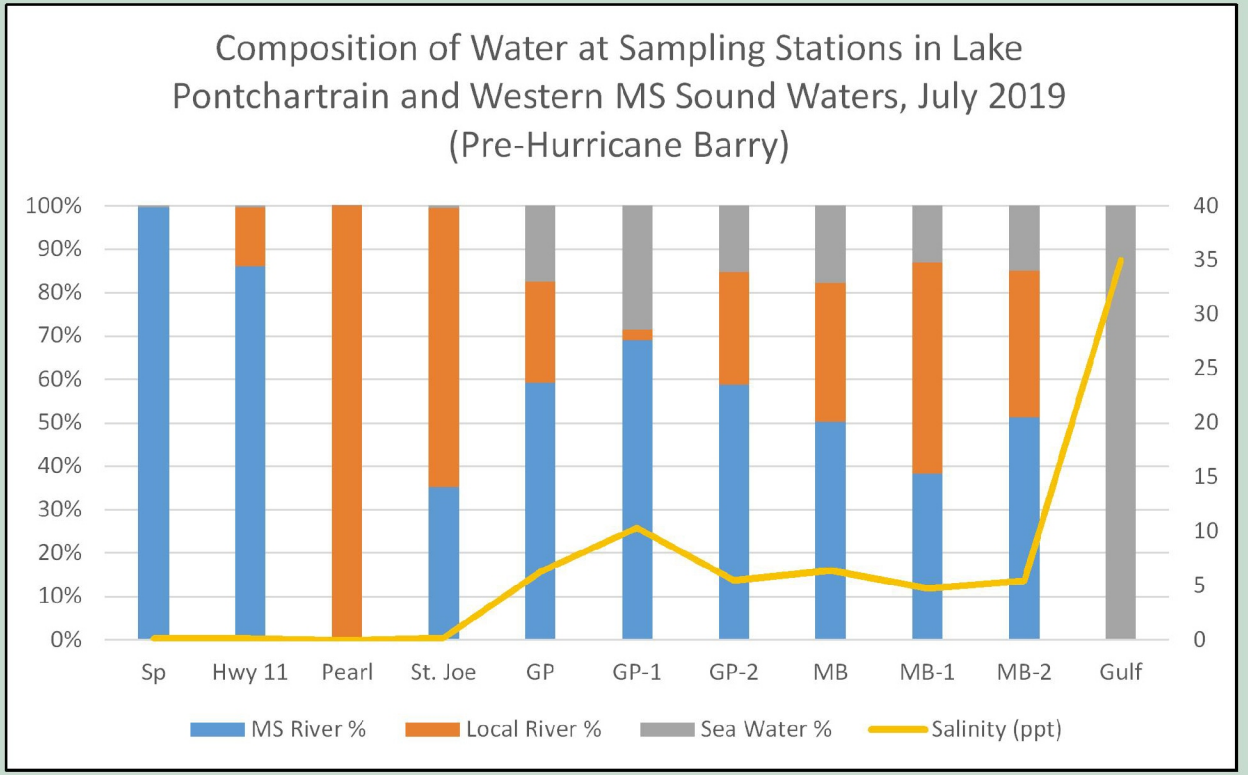
BCS_00007612

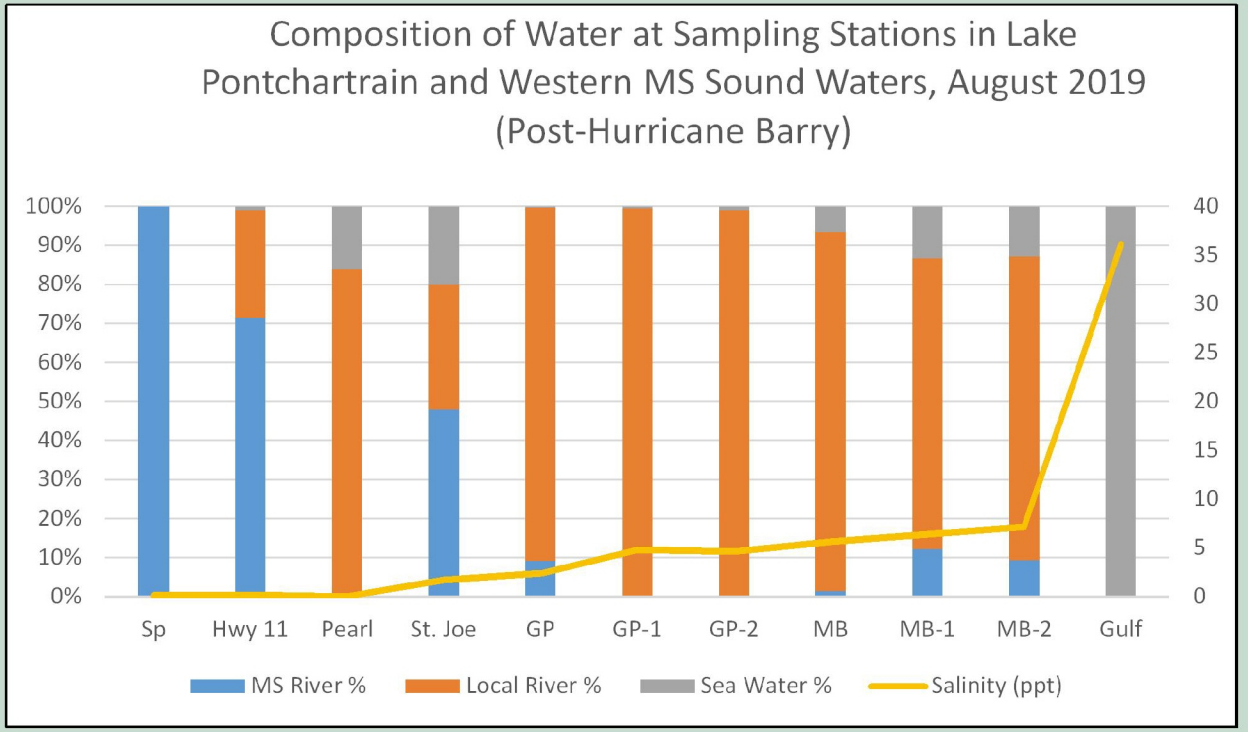
$\delta^{18}O$ isotopic tracking
A. Shiller, USM

Hurricane Barry
July 11 – 19, 2019

US Army Corps of Engineers
New Orleans District

USGS science for a changing world





BCS_00007613

UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF MISSISSIPPI

HARRISON COUNTY MISSISSIPPI, ET AL.	)	
	)	
Plaintiffs,	)	
	)	
v.	)	Case No.: **19-cv-00986-LG-RPM**
	)	
U.S. ARMY CORPS OF ENGINEERS	)	
	)	
Defendant.	)	
_____	)	

DECLARATION OF DR. ROBERT LEAF

1. I am Dr. Robert Leaf, and I am an Associate Professor and serve as the Interim Associate Director (Division of Coastal Sciences) of the School of Ocean Science and Engineering at the University of Southern Mississippi. My research interests lie in fishery science and developing approaches for the management and conservation of living marine resources. The goals of my research are to understand the biological and ecosystem processes that determine population dynamics and to incorporate this understanding for effective conservation and management. I received a Ph.D. in Fishery and Wildlife Sciences from the Virginia Polytechnic Institute and State University in 2010. My current work involves the assessment of fisheries and populations, primarily in the Gulf of Mexico but also in the northeastern and mid-Atlantic regions of the United States. A full copy of my curriculum vitae is attached.

2. The nearshore ecosystems in the Gulf of Mexico are recognized for their productivity, especially nearshore estuarine habitats. Estuaries are among the world's (and Gulf of Mexico's) most productive natural systems. Estuaries are characterized as transitional zones between freshwater and marine environments; the mixing of these waters lowers the salinity of the

seawater, creating a unique environment that provides valuable habitat for a wide variety of living marine resources (Gunter 1967). Living marine resources include fishes (e.g., Red Drum) and invertebrates (shrimp, oysters, crabs) that are targeted by commercial and recreational fishers in the region. The commercial revenue for the Gulf of Mexico in 2016 totaled more than $900 million, which accounted for 17% of all commercial landings in the United States that year. Similarly, recreational fishing expenditures in the Gulf of Mexico totaled more than $11 billion (36% of the nation's expenditures), with recreational fishermen completing more than 19 million fishing trips (33% of the nation's fishing trips, https://www.fisheries.noaa.gov). Living marine resources in our region provide other 'ecosystem services' that promote tourism and are an integral part of the cultural heritage of the Mississippi Gulf Coast.

3. Living marine species in the coastal zone (nearshore and estuarine habitats) of Mississippi such as Red Drum, Brown and White Shrimp, and Oysters are a part of widely distributed stocks in the northern Gulf of Mexico. Red Drum occurs in the Gulf of Mexico from the extreme southwest of Florida into Mexico (NOAA, 1986). Brown Shrimp is distributed along the Gulf Coast to northwestern Yucatan in Mexico (www.fisheries.noaa.gov/species/brown-shrimp). White Shrimp are found from the Ochlochonee River, Florida, to Campeche, Mexico (https://www.fisheries.noaa.gov/species/white-shrimp). Oysters occur in the coastal waters of the Gulf of Mexico to Mexico. Genetic studies of populations have been undertaken to determine and improve the efficacy of management and conservation. For widely distributed stocks impairment in the stock at the local level will have implications on population health throughout the stock's range. Gold et al (2021) reported that Red Drum exhibits genetic connectivity between neighboring estuaries and there is evidence that Red Drum exhibits long-range dispersal. White Shrimp in the Gulf of Mexico exhibit large-scale genetic homogeneity –

indicating that complete mixing of the stock is evident (Ball and Chapman, 2003). Buroker (1983), in an analysis of the genetics of oysters, reported that the genetic similarities between all contiguous populations from Cape Cod, Massachusetts to Corpus Christi, Texas were estimated as 99%.

4. Individual organisms move as larvae, juveniles, and/or adults and this is how connectivity is maintained. The studies cited above provide evidence that there is a considerable amount of genetic mixing for living marine resources. Each study highlights aspects of the biology of the stock as the reason for this. Kim et al. (2010) report that larval dispersal of oysters could be as much as 18 days. Red Drum exhibits substantial offshore movement from the estuary to offshore habitats during their life. Larvae and juveniles inhabit estuarine areas and subadults inhabit deeper channels of estuarine habitats. Upon reaching the subadult stage, shrimp will move offshore for reproduction. Similarly, In the Gulf of Mexico Red Drum occur in a variety of habitats, ranging from depths of about 40 m offshore to shallow estuarine waters. Both White and Brown Shrimp have a larval stage of development that occurs offshore. Spawning adults are found primarily in the fall and the spring on the shelf between 64 to 110 m in depth. Brown Shrimp migrate into estuaries from February to April and to a smaller extent, in the fall. White Shrimp migrate into estuaries from May to November.

5. For sedentary stocks (those that do not move at the adult stage), larval movement is responsible for the widespread connectivity patterns. The connectivity of stocks, through the movement of individuals and the dispersal of eggs and larvae, has implications for the abundance of stocks locally and the abundance of stocks at larger spatial scales. The local impacts on a stock, though indirect deleterious environmental impacts (oil spill or freshwater discharge) or direct removal (from fishing for example) impact the broader stock's abundance and

sustainability. NOAA defines an adverse impact as any direct or indirect effect that reduces the quality and/or quantity of the habitat and ranges from large-scale to small-scale. Impacts on water quality from the release of freshwater to the habitats of Lake Pontchartrain, Lake Borgne, and the western Mississippi Sound has impacts on stocks at larger geographic scales.

6. Hutchinson (1957) provided a fundamental and widely used description of an 'ecological niche'. The ecological niche is a concept that describes the abiotic and biotic factors that influence a species' geographic distribution. In the case of stocks in the coastal zone of Mississippi, the niche can be described as the conditions of the water and characteristics of habitat that allow the species to persist. These include salinity, temperature, and the oxygen concentration of the water. One of the primary determinants of the distribution and abundance of living marine resources is their tolerance and preference for a range of salinities. In addition to salinity, water temperature is a major determinant of the distribution and abundance of living marine organisms. Temperature regulates many physiological processes.

7. The tolerances and requirements of species' life stages are well characterized in the Essential Fish Habitat Amendment in the Fishery Management Plans of Red Drum and the Fishery Management Plans of Shrimp (Brown and White) (Gulf of Mexico Fishery Management Council, 1998). Below I describe the habitat requirements necessary for different life stages for these stocks. The EFH amendment describes the water quality and habitat characteristics necessary to fish for spawning, breeding, feeding, or growth to maturity – the multivariate niche of the species that allows for survival and individual and population growth. My discussion of the habitat characteristics is focused on the physical, chemical, and biological properties of the habitat that are used by the organisms under consideration. This includes types of habitats and associated biological communities (such as oyster reefs) that allow organisms to survive. The

summaries I present are developed from the EFH document and outline the necessary conditions that support the species in a healthy ecosystem. A common theme in each is the strong habitat associations of each species to nearshore vegetated areas including barrier islands, bays, and bayous, and generally an affiliation to soft sediment habitats, marsh habitats, and those with submerged aquatic vegetation and organic matter. Each of these species has a life stage that develops in the nearshore habitats in the northern Gulf of Mexico.

8. Brown Shrimp spend a significant part of their life cycle in estuarine areas affected by openings of the Bonnet Carre Spillway. Larvae and pre-settlement post larvae are present in estuaries (shoreline to 82 m) and occur in the spring. These stages tolerate salinities of 24 to 36 ppt. Late post larvae and juveniles are present in the spring through the fall and survival is good between 7 to 35° C, however, the temperature tolerance decreases at low salinities. Growth is optimum at 2 to 40 ppt. Low oxygen conditions of less than 1 ppm can lead to mortality. Subadults are present in the spring through the fall and are most abundant in the spring to early summer. They are found in the open water of bays and nearshore, concentrated in Texas, Louisiana, and Mississippi's coastal waters. This life stage is tolerant of salinities from 0.9 to 30.6 ppt. Persistent low oxygen conditions of less than 2 ppm result in mortality events.

9. The habitat requirements of White Shrimp also vary depending on their life stage, but all life stages use estuarine areas affected by the Bonnet Carre Spillway. Non-spawning adults are abundant in late summer and fall in nearshore waters, inhabiting depths of less than 27 m depth. Survival is good between 2 to 35 ppt. Low oxygen conditions of less than 2 ppm can cause stress. Spawning White Shrimp of found offshore in water depths of 9 to 34 m, however, they may occur within estuaries and bays. They are found in these habitats in June and July. Salinities of 27 ppt are optimal for spawning. Fertilized eggs are found in the spring to fall in offshore

habitats and occur within nearshore estuaries. Larvae and pre-settlement adults are found offshore from the spring to fall, and recruitment of estuaries occurs in the summer (June) and early fall (September). Post larvae migrate through passes at the top of the water column between May to November with peaks in June and September. Post larvae are present from late spring to the fall in estuaries in Louisiana, Texas, and Mississippi. Post larvae settle between 0.4 to 37 ppt and juveniles prefer salinities of less than 10 ppt. Sub-adults are present in the summer through the fall and are abundant in August and September in the open water of bays and nearshore habitats. This life stage is concentrated in Texas, Louisiana, and Mississippi. This life stage is abundant from 1 to 21 ppt and is tolerant to a wide range of salinities, however, juveniles avoid low oxygen conditions.

10. Red Drum habitat and environmental niche vary with life stage. Eggs are found from late summer through early fall and are found outside estuaries (advected into estuaries on tides and currents). The salinity tolerance is between 25 to 34 ppt. Salinity impacts the buoyancy of eggs where salinities above 25 ppt allow Red Drum eggs to float while lower salinities cause eggs to sink (Holt et al. 1981). Larvae are present from mid-August to late November and are found in open bays, estuaries, and tidal flats in vegetated and non-vegetated bottoms. Salinity tolerances are generally wide, ranging from 16 to 36 ppt but 30 ppt is optimal during the early stage of development. Overstreet (1983) notes the importance of a high salinity concentration for both hatching and survival during the first 24 hours. Post larvae are found from August to October in shallow water mud flats and seagrass beds. Optimal salinities are 23.4 to 36.6 ppt and Ross and Stevens (1992) reported that high salinity, coastal estuarine areas provide optimal conditions for egg and larval development. Growth increases with increases in salinity, up to 30 ppt. Salinity tolerance is 10 to 34 ppt. This life stage cannot survive in waters with less than 0.6 to 1.6 ppm of

dissolved oxygen. For late juveniles the salinity tolerance is 25 to 34 ppt. Adult Red Drum are found throughout the coastal zone in depths of 3 to 50 m. Powers et al. (2012) found that the greatest catch per unit effort occurred around the barrier islands of Mississippi Sound including Petit Bois Island in Mississippi. Using a complimentary aerial survey, the authors reported that schools of adult Red Drum were observed near the barrier islands of the Mississippi Sound and the Chandeleur Islands in Louisiana. The salinity tolerance for adults is 25 to 34 ppt.

11. Oysters, because of their economic, cultural, and ecological importance, have been well studied on the east coast and in the Gulf of Mexico. Although no Essential Fish Habitat has been designated for oysters, oyster reefs have been shown to provide critical habitat, primarily provisioning feeding opportunities and refuge sites for resident and transient estuarine finfishes and invertebrates (Coen et al. 1999). A primary focus of research is to understand the salinity and temperature tolerances of this organism (Marshal et al. 2021). Because they are not able to move, once established, altered salinity regimes from riverine and coastal management have been found to impact oysters by exposing them to water conditions that exceed their physiological tolerances (Rybovich et al. 2016). Using long-term monitoring data from Louisiana's public oyster reefs, Lowe et al. (2017) described patterns of temperature and salinity on mortality (sack oysters only) and growth for spat (<25 mm), seed (25–75 mm), and sack (>75 mm) oyster size classes. They reported that for spat oysters, growth, however, was maximized at high temperature (>27.0°C) and high salinity (>22 ppt). Growth declined above 30°C and was reduced when the water temperature was below 20°C, and salinity was less than 15 ppt. Seed oyster growth rates increased at temperatures between 22 and 30°C and growth was maximized at 27.8°C and a salinity of 26.8 ppt. Monthly growth rates, however, were reduced at temperatures above 30°C and at combinations of low water temperature (<15°C) and low salinity (<15). Growth

significantly decreased the longer sack oysters were exposed to salinities below 5 ppt and increased when exposed to salinities exceeding 15 ppt for a longer duration. Work by Gledhill et al (2020) who evaluated oyster mortality in Bay St. Louis reported that deployed oysters (deployed in baskets on April 23, 2019) suffered 100% mortality at all sites. This was 25 days following the first closing of the BCS. On September 27, 2019, 62 days following the BCS closing, dredge sampling revealed no live native adult oysters or spat, even at sites where living oysters were collected earlier in the summer.

12. Extensive monitoring work in the region has focused on understanding the impacts of freshwater discharge to estuaries in Louisiana and Mississippi, primarily the Mississippi Sound, as a result of the operation of the Bonnet Carré Spillway. Historically, the periodic openings of the BCS introduce significant amounts of freshwater, inorganic nutrients, and organic matter that alter the physical, biological, and chemical properties of local coastal waters within Lake Pontchartrain Estuary and the Mississippi Sound. The release of the freshwater into the coastal zone resulted in the alteration of the salinity of the waters of Louisiana and Mississippi: the salinity of Lake Pontchartrain decreased dramatically and was diluted to almost a freshwater level. Only after the spillway was closed did the lake's salinity recover, gradually, by the tide waters from the higher salinity Gulf of Mexico. Surface salinities in the Mississippi Sound were reduced in mid-July 2019 in the western portion to less than 5 ppt (Figure 1, from USM sampling).

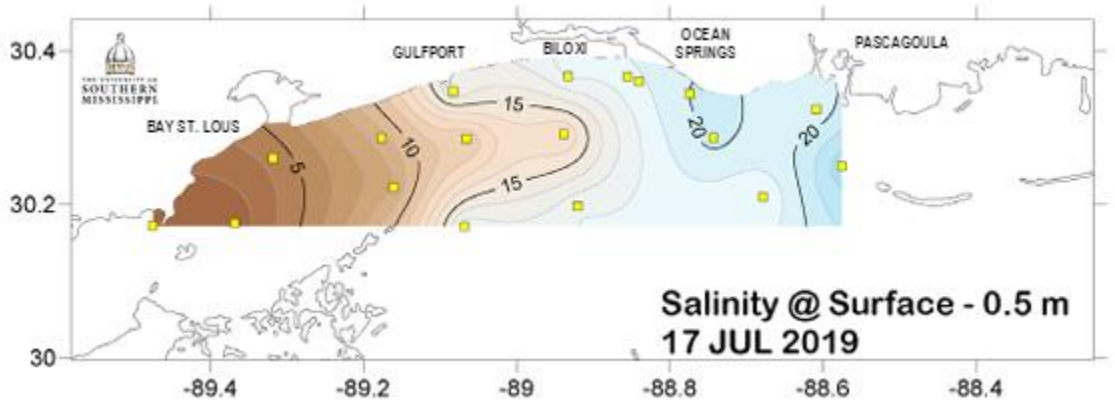


Figure 1. Depiction of surface salinity levels in the Mississippi Sound for July 17 was extrapolated from field data at expanded water quality stations (yellow squares).

The source water responsible for this reduction in salinity was determined through the tracking of chemical tracers. The analysis of source water tracking indicates that water from the Mississippi River was found in relatively high proportions in the center of the sound (Figure 2, from USM sampling).

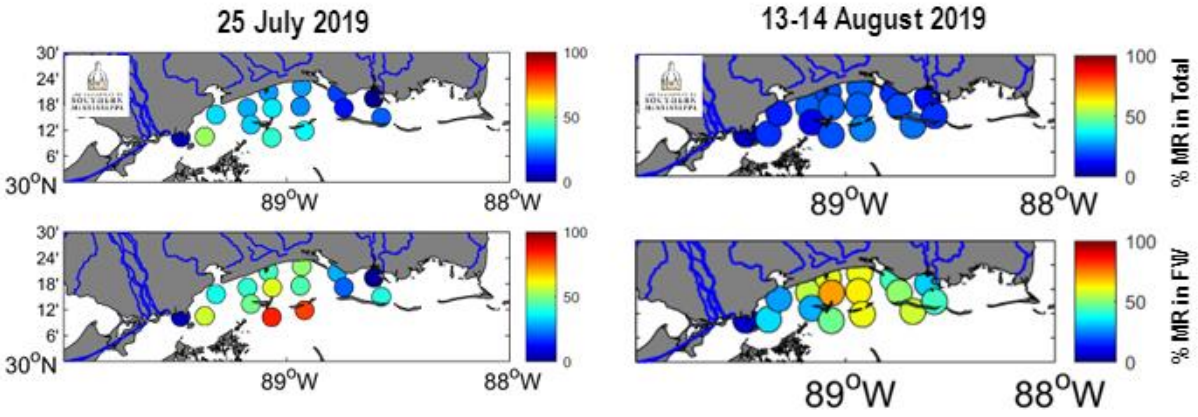


Figure 2. Preliminary results from July 25 (left) and August 13-14 (right) sampling to determine sources of freshwater in the Mississippi Sound, based on isotopic signatures. The top panels depict the percentage of all water in the sample assigned to the Mississippi River and the bottom panels depict the percentage of freshwater in the sample assigned to the Mississippi River.

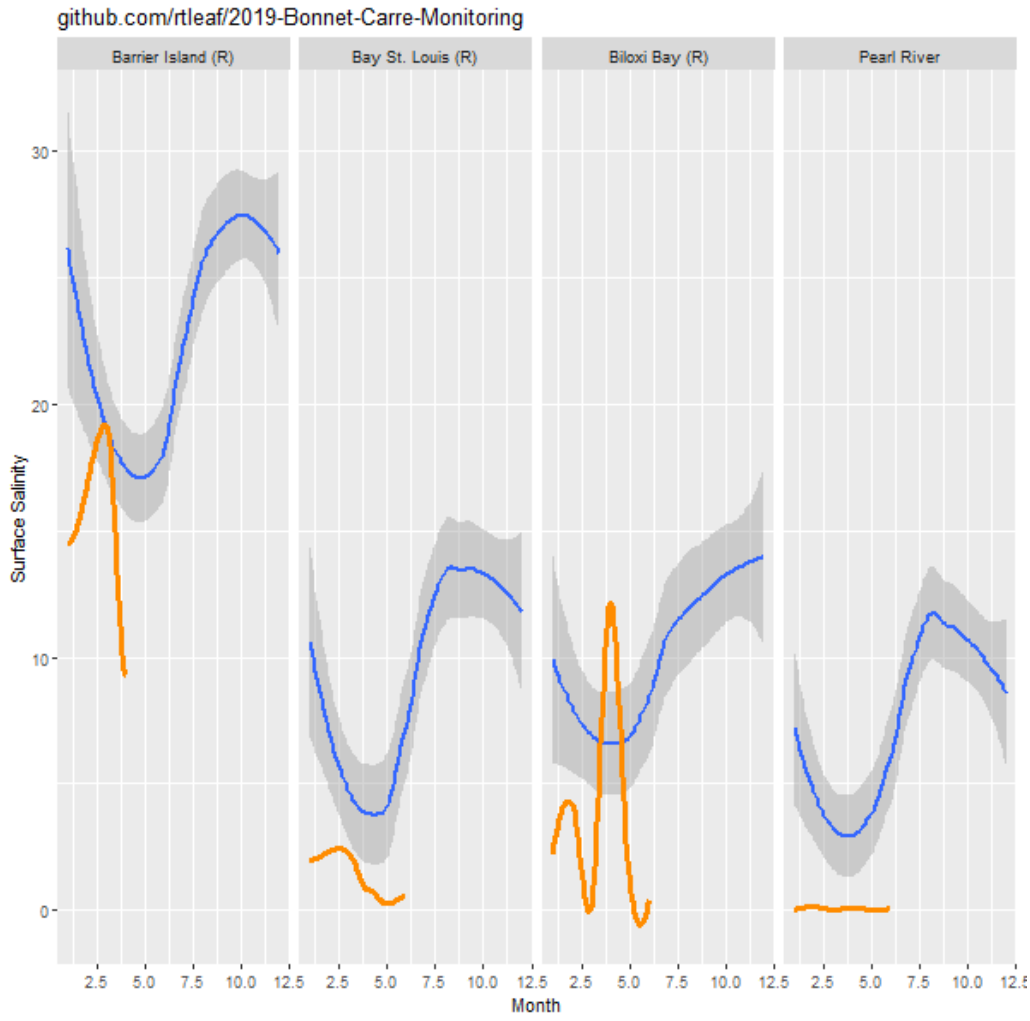


Figure 3. Surface salinity of long-term (blue) and 2019 (orange) at sites in the Mississippi Sound (including the barrier islands) from scientific sampling conducted by the Gulf Coast Research Laboratory.

Working with Mississippi's Department of Marine Resources, I evaluated the long-term (the average of ~10 y of data) of salinity. (Figure 3). At the stations in the Pearl River, Bay St. Louis, Biloxi Back Bay, and Barrier Islands we observed reductions in surface salinity. The result is an alteration of the fish community observed at these sites. I classified, using an online database (Fishbase.org) those fish in the survey with an estuary affinity. We found a reduction in the proportion of fish with an estuarine affinity (Figure 4). There is a more pronounced change

(reduction) in the proportion of fish with estuarine affinity on the west side of Mississippi Sound and reduced impacts on the two sites on the east side of the sound.

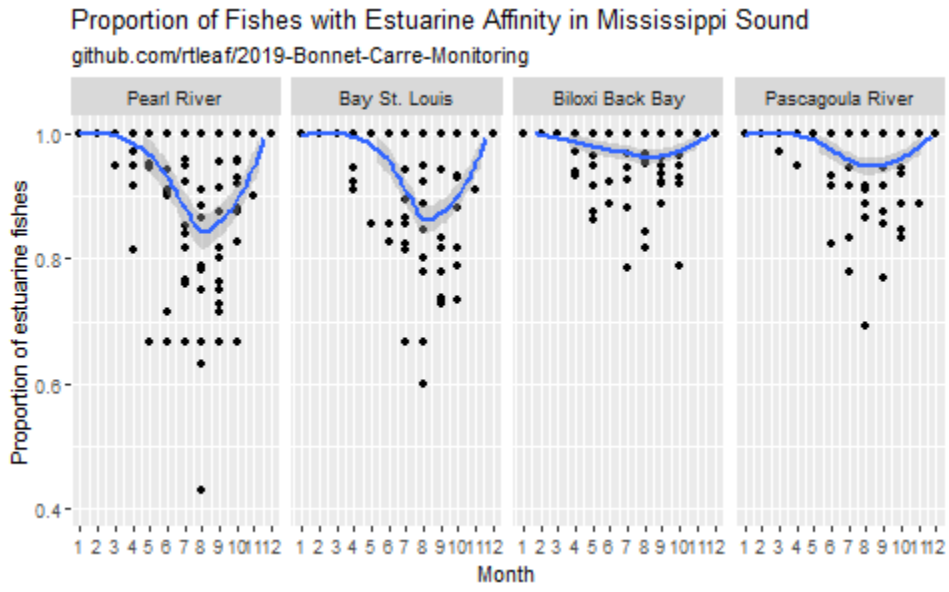


Figure 4. Change in proportion of fishes designated with estuarine affinity, in 2019, of the month-specific fish community surveyed by the Mississippi Department of Marine Resources.

The change observed in the fish community is a direct result of the tolerance of the individual species to temperature, salinity, and other environmental characteristics. As I mentioned above, species like oyster, Red Drum, and white and Brown Shrimp have water and habitat requirements that promote growth and survivorship. These change during their life history. However, it is the case (and documented above) that low salinity and low dissolved oxygen water conditions are deleterious to growth and survival. These are features of water of Mississippi River origin released during Bonnet Carré Spillway release events. These conditions reduce the quality and/or quantity of habitat for brown shrimp, white shrimp and Red Drum in the areas affected by the releases.

I declare under penalty of perjury that the above information is true and correct.

s/ Robert Leaf
Robert Leaf, Ph.D.

Robert Thomas Leaf

Associate Professor, School of Ocean Science and Engineering, University of Southern Mississippi
Gulf Coast Research Laboratory, 703 East Beach Drive, Ocean Springs, MS 39564
robert.t.leaf@gmail.com (228) 872-4296 rtleaf rtleaf.github.io | *Updated:* Mar. 28, 2022

Education

1997 **Bachelor of Arts, Biology** . University of California at Santa Cruz.

2005 **Master of Science, Marine Sciences** . San Jose State University - Moss Landing Marine Laboratories.

2010 **PhD, Fisheries and Wildlife Science** . Virginia Polytechnic Institute and State University.

Positions Held

2005 to 2005 **Environmental Consultant** - Garcia and Associates, CA.

2010 to 2010 **Research Assistant** - Natural Resources Group, City of New York Department of Parks Recreation, NY.

2011 to 2012 **Post-doctoral Researcher** - NOAA-Northeast Fishery Science Center, RI.

2012 to 2019 **Assistant Professor** - University Southern Mississippi, School of Ocean Sciences and Engineering, MS.

2019 to Present **Associate Professor** - University Southern Mississippi, School of Ocean Sciences and Engineering, MS.

Five representative recent publications

Midway, S.R., A.M. Schueller, R.T. Leaf, G.M. Nesslage, and R.M. Mroch. 2020. Macroscale drivers of Atlantic and Gulf Menhaden growth. Fisheries Oceanography. 29.3: 252-264.

Bennetts, C., R.T. Leaf, and N.J. Brown-Peterson. 2019. Sex-Specific Growth and Reproductive Dynamics of Red Drum in the Northern Gulf of Mexico. Marine and Coastal Fisheries. 11(2): 213-230.

Daley, T.T. and R.T. Leaf. 2019. Age and growth of Atlantic chub mackerel (Scomber colias) in the Northwest Atlantic. Journal of Northwest Atlantic Fishery Science. 50: 1-12.

Kuykendall, K., E.N. Powell, J.M. Klinck, P.T. Moreno, and R.T. Leaf. 2019. The effect of abundance changes on a management strategy evaluation for the Atlantic surfclam (Spisula solidissima) using a spatially explicit, vessel-based fisheries model. Ocean and Coastal Management. 169: 68-85.

Navia, A.F, S.R. Maciel-Zapata, A.F. González-Acosta, R.T. Leaf, V.H. Cruz-Escalona. 2019. Importance of weak trophic interactions in the structure of the food web in La Paz Bay, southern Gulf of California: a topological approach. Bulletin of Marine Science. 95(2): 199-215.

Five representative impactful publications

Rogers-Bennett, L. and R.T. Leaf. 2006. Elasticity Analyses Of Size-Based Red And White Abalone Matrix Models: Management And Conservation. Ecological Applications. 16(1): 213-224.

Leaf, R.T.. 2017. Environmental determinants of Gulf menhaden (Brevoortia patronus) oil content in the northern Gulf of Mexico. Ecological Indicators. 82: 551-557.

Adams, G.D., R.T. Leaf, J.C. Ballenger, S.A. Arnott, and C.J. McDonough. 2018. Spatial variability in the growth of Sheepshead (Archosargus probatocephalus) in the Southeast US: Implications for assessment and management. Fisheries Research. 206: 35-43.

Leaf, R.T. and M.C. Oshima. 2018. An evaluation of the impacts of alternative food web structure in the northern Gulf of Mexico ecosystem. Ecological Informatics. 50: Online.

Leaf, R.T., J. Trushenski, M.J. Andres, and N.J. Brown-Peterson. 2018. Temporal dynamics of lipid and fatty acid characteristics of Gulf Menhaden, Brevoortia patronus, in the northern Gulf of Mexico. Journal of Regional Marine Science. 24: 1 to 9.

Grant Funding Recieved

Mississippi Department of Environmental Quality. Number of funded projects: 1, 2013 to 2015. $ 689,642.

Mississippi Department of Marine Resources Tidelands Fund. Number of funded projects: 9, 2014 to 2021. $ 1,192,954.

NOAA Cooperative Research Program. Number of funded projects: 1, 2014 to 2015. $ 101,285.

NSF Research Experience for Undergraduates through NSF IUCRC. Number of funded projects: 5, 2014 to 2022. $ 40,000.

NSF Science Center for Marine Fisheries. Number of funded projects: 6, 2014 to 2019. $ 133,291.

Mississippi Alabama Sea Grant. Number of funded projects: 3, 2016 to 2019. $ 431,852.

USM Center for Undergraduate Research - Eagle SPUR award. Number of funded projects: 1, 2016 to 2017. $ 1,000.

NSF Research Experience for Veterans through NSF IUCRC. Number of funded projects: 1, 2020 to 2021. $ 10,000.

Service

Assessment Lead, number of Peer-Reviewed Stock Assessments: 12, from 2015 to 2022.

Assessment Team Member, number of Peer-Reviewed Stock Assessments: 4, from 2012 to 2018.

Courses Taught - Classroom

Biometry for the Coastal Sciences, taught 9 time(s), from 2013 to 2021.

Professional Skills, taught 3 time(s), from 2014 to 2016.

Quantitative Fisheries Management, taught 4 time(s), from 2014 to 2017.

Special Problems in Data Analysis Using R, taught 2 time(s), from 2020 to 2022.

Special Problems in Management Strategy Evaluation, taught 1 time(s), from 2018 to 2018.

Special Topics in Individual Based Simulation Modeling, taught 1 time(s), from 2014 to 2014.

From: Carl Britt <cbritt@wlf.la.gov>
To: Ladner, Howard W CIV CEMVN CEMVD (US); Brown, Michael T CIV USARMY CEMVN (US)
Sent: 4/15/2019 2:34:18 PM
Subject: [Non-DoD Source] RE: Spillway operations - 04/12/19

Howard,

Thanks for sending the update, and notice of the closure. That is really good news.

We are still compiling results from our oyster and crab surveys last week. I'm not expecting to see much different from the report I sent you guys on the 4th. I don't believe there have been any catches of real significance. We are still seeing mortality of spat- and seed-size oysters in Mississippi Sound. Our crab surveys show dislocation of blue crabs to the eastern end of the Lake (middle ground). Brown shrimp catches in our trawl samples have been very low. We are definitely observing low recruitment of juvenile brown shrimp into Mississippi Sound, Lake Borgne and the adjacent Biloxi Marsh. We've also observed over-wintering white shrimp being pushed out of the Lakes and into the outer Sounds.

Carl

Carl Britt, Biologist Manager
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P. O. Box 1190, Lacombe, LA 70445
(o) 985-882-0027 Ext. 2305
(f) 985-882-0029

-----Original Message-----
From: Ladner, Howard W CIV CEMVN CEMVD (US) <Howard.W.Ladner@usace.army.mil>
Sent: Friday, April 12, 2019 3:38 PM
To: Carl Britt <cbritt@wlf.la.gov>; Brown, Michael T CIV USARMY CEMVN (US) <Michael.T.Brown@usace.army.mil>
Subject: RE: Spillway operations - 04/12/19

Carl,
I just sent out an update to everyone on environmental contact list indicated that the Spillway is closed. It was actually closed by late Wednesday. There is still some seepage between the needles.

Could you give me a quick update on what impacts you have found with your sampling?

Thanks
Howard

-----Original Message-----
From: Carl Britt [mailto:cbritt@wlf.la.gov]
Sent: Friday, April 12, 2019 12:18 PM
To: Brown, Michael T CIV USARMY CEMVN (US) <Michael.T.Brown@usace.army.mil>
Cc: Ladner, Howard W CIV CEMVN CEMVD (US) <Howard.W.Ladner@usace.army.mil>
Subject: [Non-DoD Source] Spillway operations - 04/12/19

Miike,

Noticed this morning that the website was updated with the bays closed on Monday and Tuesday of this week. That was great to see. I was wondering what is the current status. I'd like to update our folks before the weekend, if possible.

Thanks,

Carl

Carl Britt, Biologist Manager

LA Department of Wildlife and Fisheries

cbritt@wlf.la.gov <mailto:cbritt@wlf.la.gov>

BlockedBlockedwww.wlf.louisiana.gov <BlockedBlockedhttp://www.wlf.louisiana.gov/>

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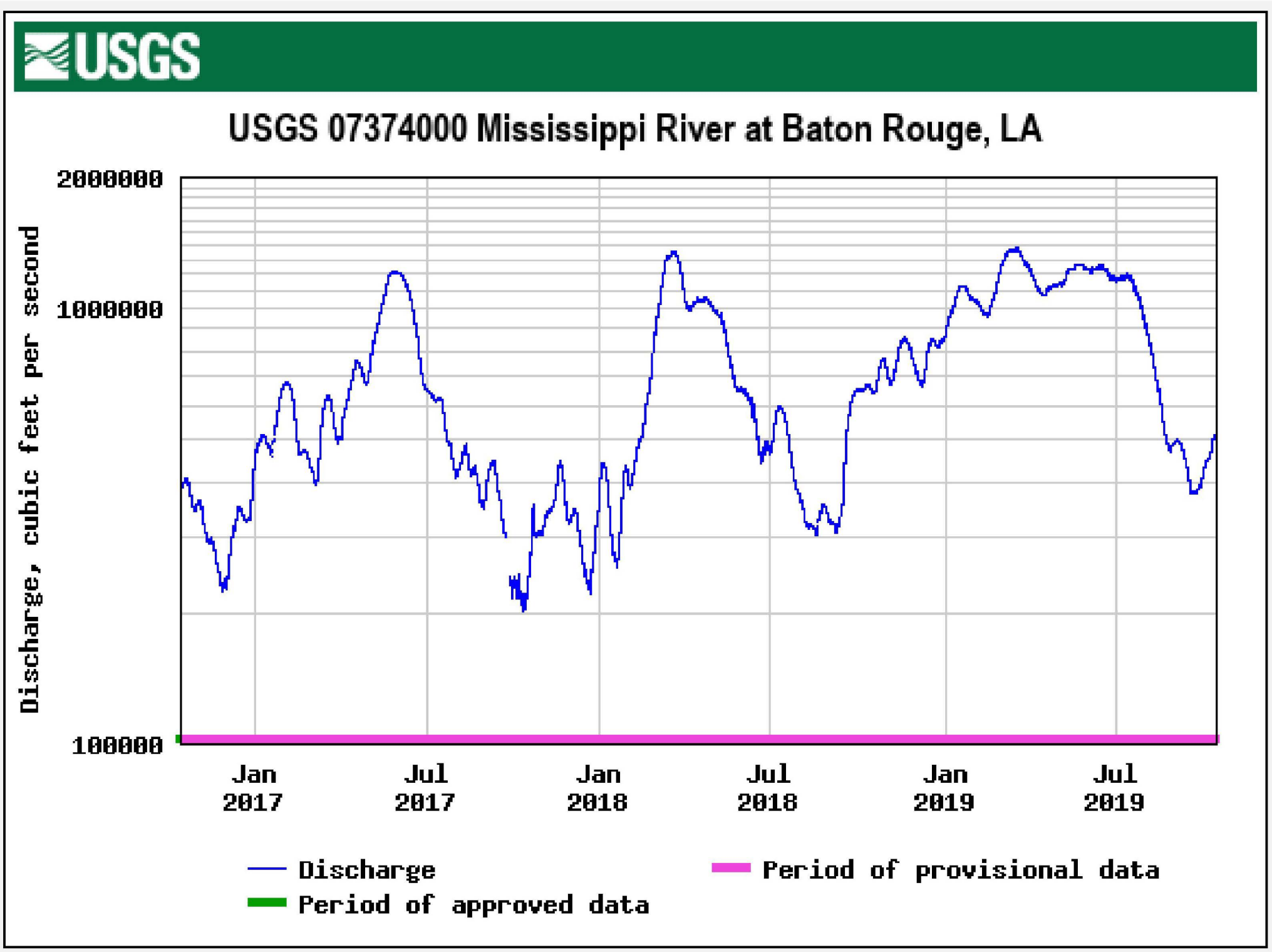
Temporal and Spatial Progression of the Freshwater inflows to Lake Pontchartrain & Mississippi Sound

Scott V. Mize & Chris Swarzenski (USGS) and Eric Glisch (USACE)

Presentation to Gulf States Marine Fisheries Commission

October 16, 2019

U.S. Department of the Interior
U.S. Geological Survey


USGS
USGS 07374000 Mississippi River at Baton Rouge, LA
Discharge, cubic feet per second
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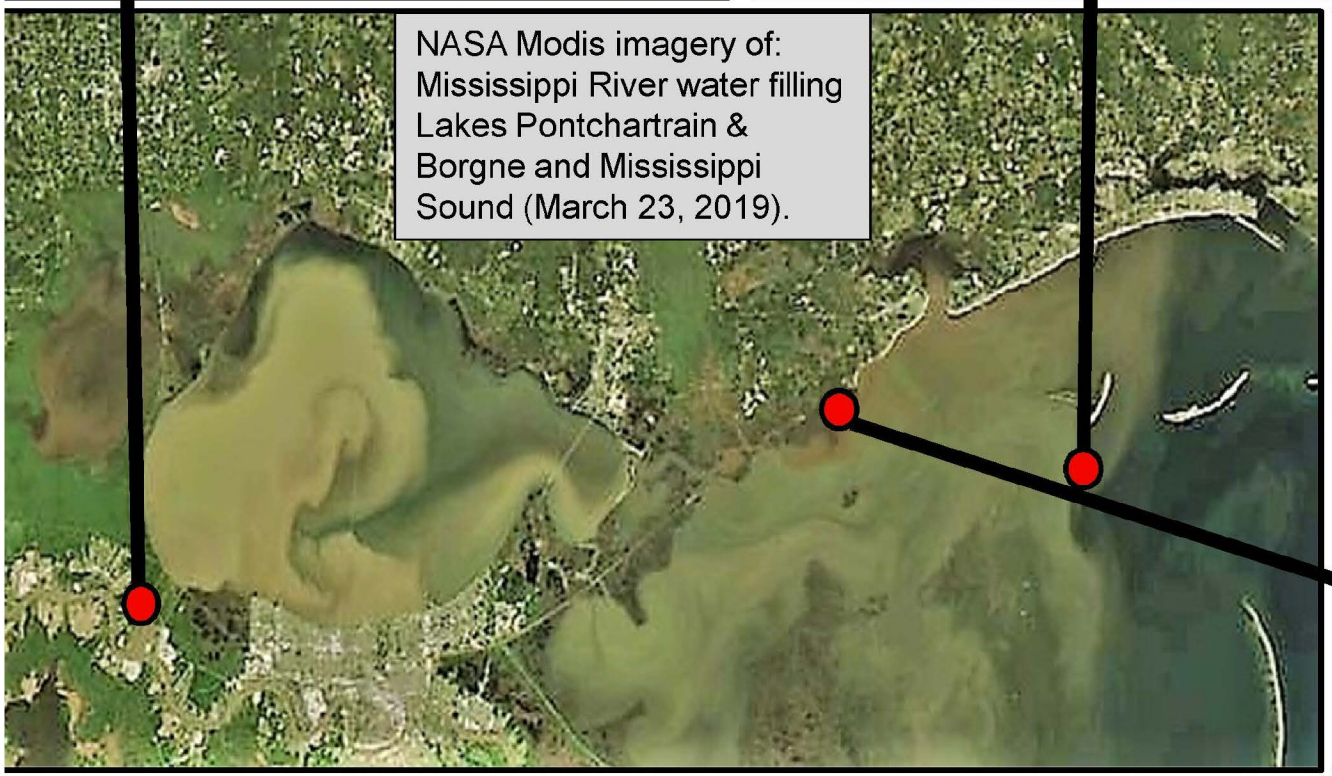
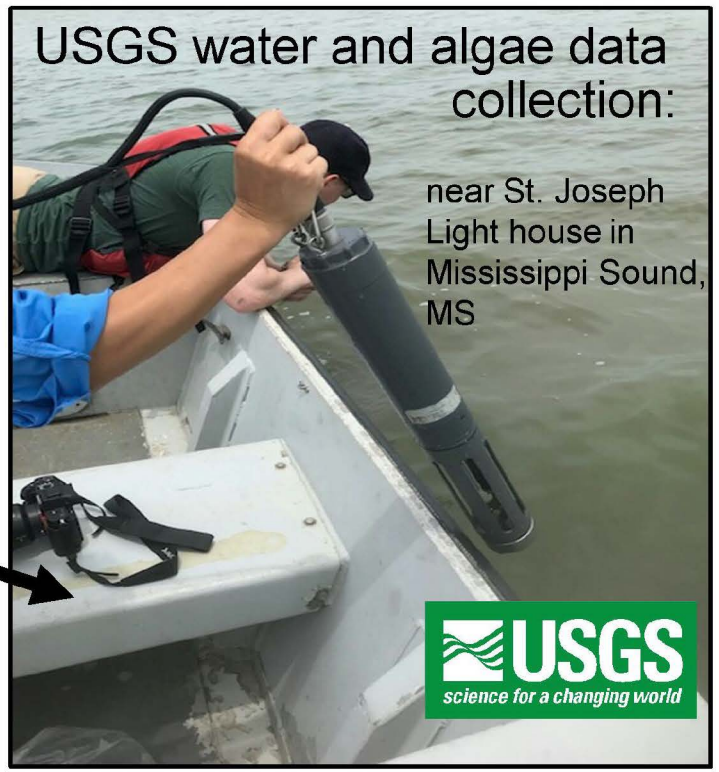
1000000
100000
Jan 2017
Jul 2017
Jan 2018
Jul 2018
Jan 2019
Jul 2019
Discharge
Period of approved data
Period of provisional data





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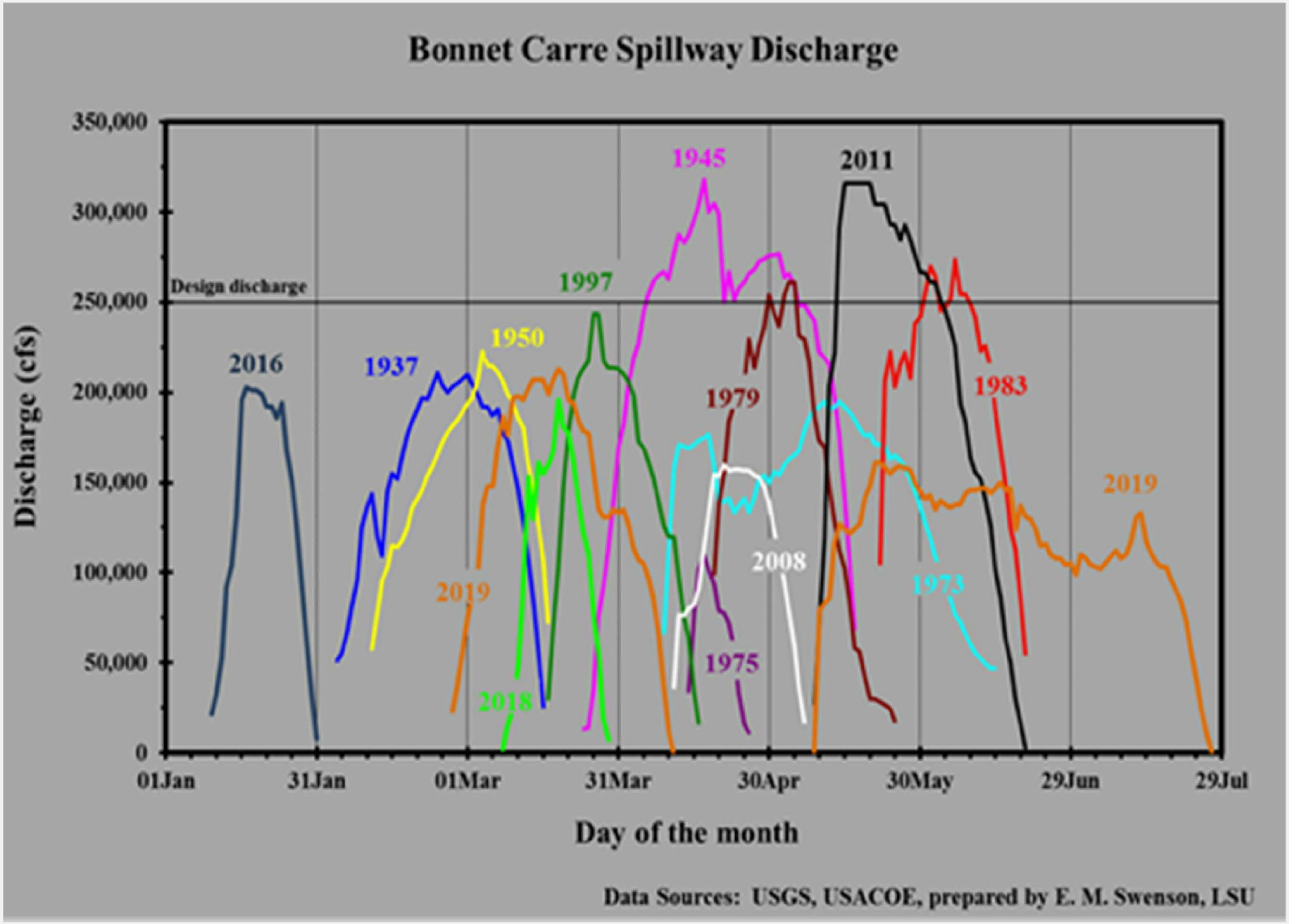
Spillway openings 1937-2019



Erick Swenson, Louisiana State University

Ranking of spillway openings 1937-2019

Event	Year	Date opened	Date closed	Total days open	Event total discharge (cubic feet)	Event percent of total lake volume
5	1975	04/14/1975	04/26/1975	13	7.46E+10	32
12	2018	03/08/2018	03/29/2018	22	2.04E+11	87
11	2016	01/10/2016	02/01/2016	23	2.45E+11	104
9	2008	04/11/2008	05/09/2008	29	2.64E+11	113
8	1997	03/17/1997	04/18/1997	33	4.12E+11	176
3	1950	02/10/1950	03/19/1950	38	4.72E+11	201
6	1979	04/17/1979	05/31/1979	45	4.92E+11	210
13	2019a	02/27/2019	04/11/2019	44	5.32E+11	227
1	1937	01/28/1937	03/16/1937	48	5.37E+11	229
7	1983	05/20/1983	06/23/1983	35	5.37E+11	229
10	2011	05/09/2011	06/17/2011	40	7.73E+11	330
14	2019b	05/10/2019	07/27/2019	79	8.13E+11	347
4	1973	04/08/1973	06/21/1973	75	8.30E+11	354
2	1945	03/23/1945	05/18/1945	57	1.06E+12	454
13+14	2019	02/27/2019	07/27/2019	151	1.34E+12	574

Erick Swenson, Louisiana State University

Fresh surface water sources: Pontchartrain & Mississippi Sound

Comparison of Bonnet Carré spillway opening discharge (annualized) to annual inflows from Lake Pontchartrain and coastal Mississippi drainages for indicated time periods.

	2019*	2005-17	2011	2012	2016
	Average annual flow, in cubic feet per second				
Lake Pontchartrain inflows (from local drainages)	4,200	3,800	2,300	3,800	8,600
Pearl / Pascagoula inflows	33,800	20,100	14,000	19,100	23,600
Bonne Carre Spillway discharge (annualized)	57,600		24,500	no opening	7,760

* Averaged January 2019-September 2019

Preliminary data
Subject to revision

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BCS_00059293


JAN 2019

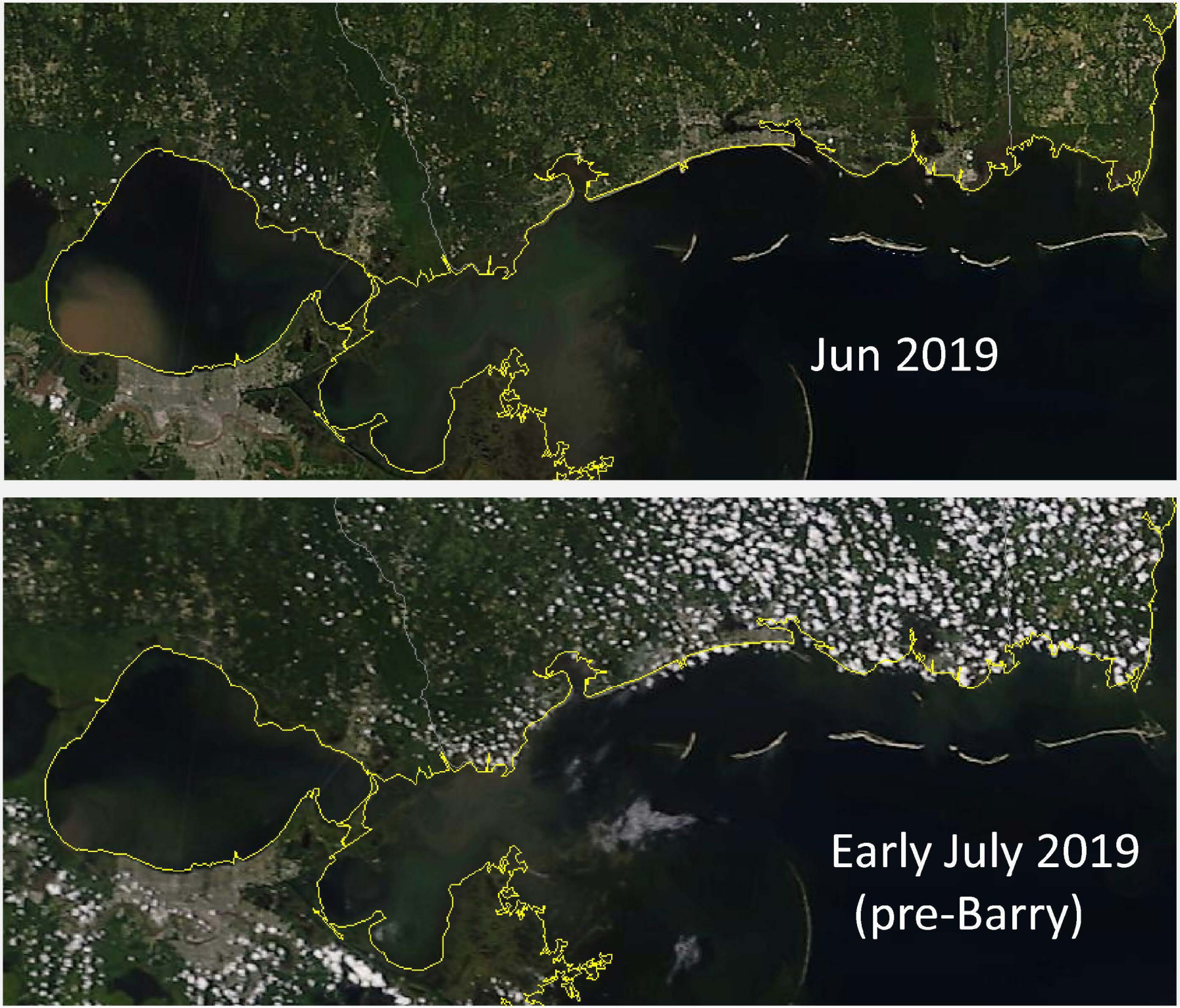

FEB 2019


MAR 2019

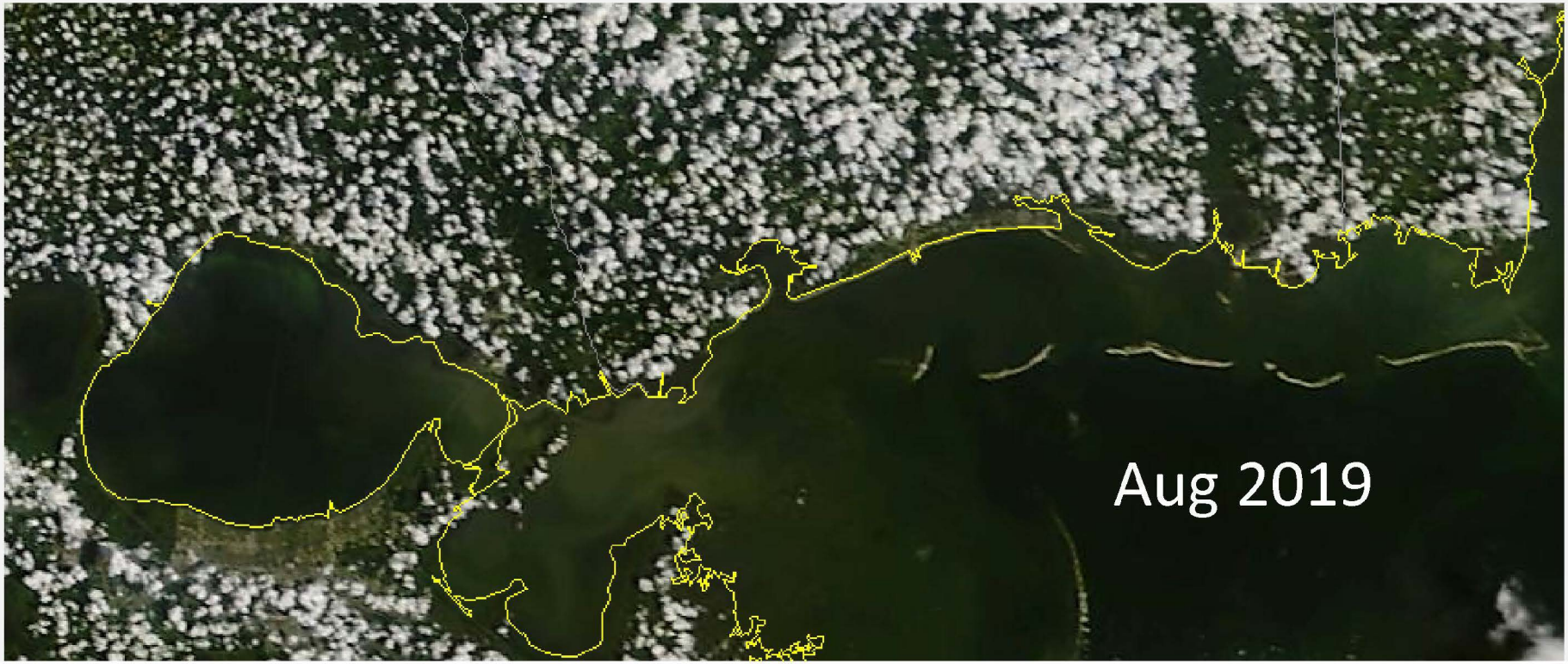

APR 2019


Early May 2019


Late May 2019

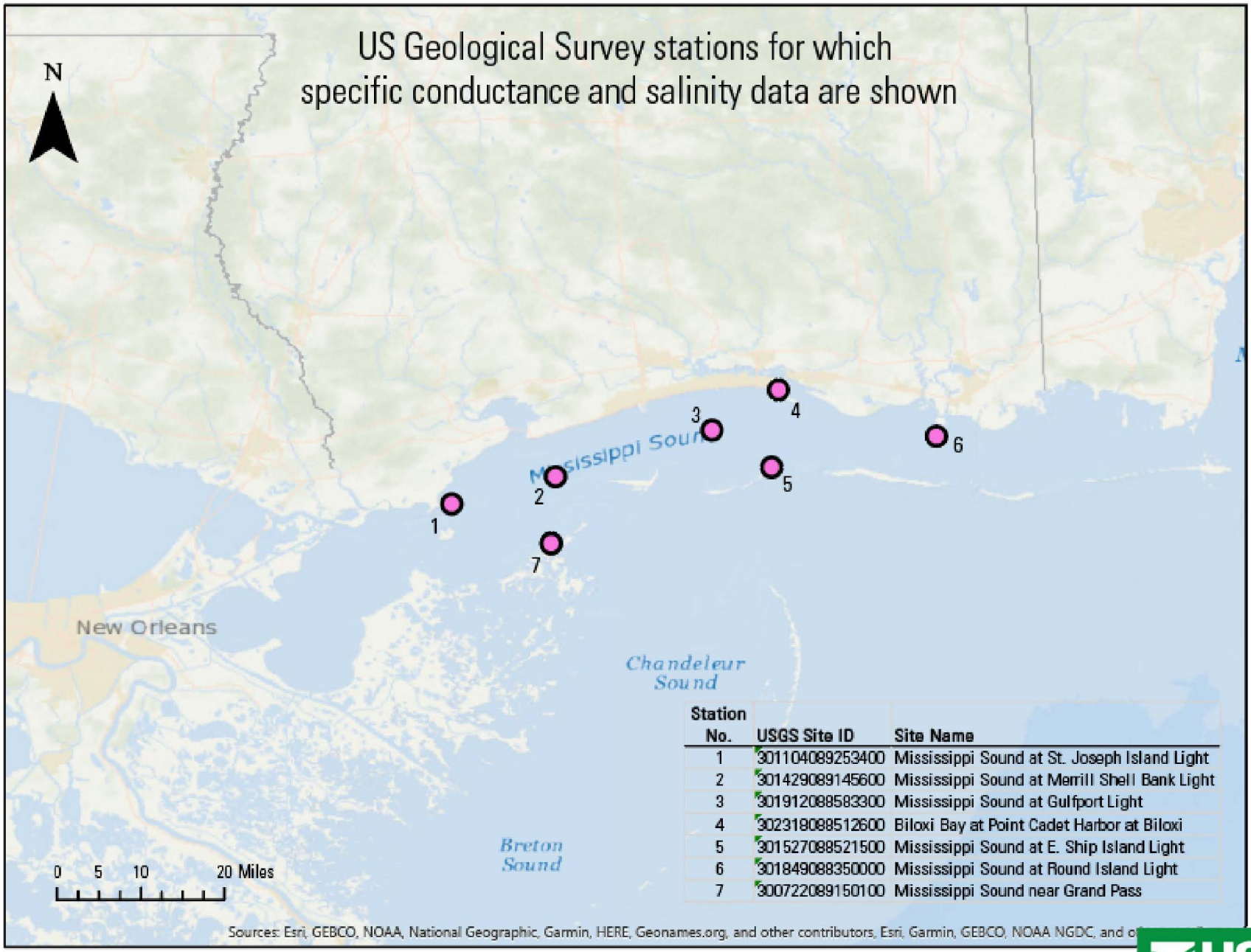

Jun 2019
Early July 2019
(pre-Barry)


Late July 2019
(post-Barry)


Aug 2019


Sept 2019


Oct 2019



Station No.	USGS Site ID	Site Name
1	301104089253400	Mississippi Sound at St. Joseph Island Light
2	301429089145600	Mississippi Sound at Merrill Shell Bank Light
3	301912088583300	Mississippi Sound at Gulfport Light
4	302318088512600	Biloxi Bay at Point Cadet Harbor at Biloxi
5	301527088521500	Mississippi Sound at E. Ship Island Light
6	301849088350000	Mississippi Sound at Round Island Light
7	300722089150100	Mississippi Sound near Grand Pass

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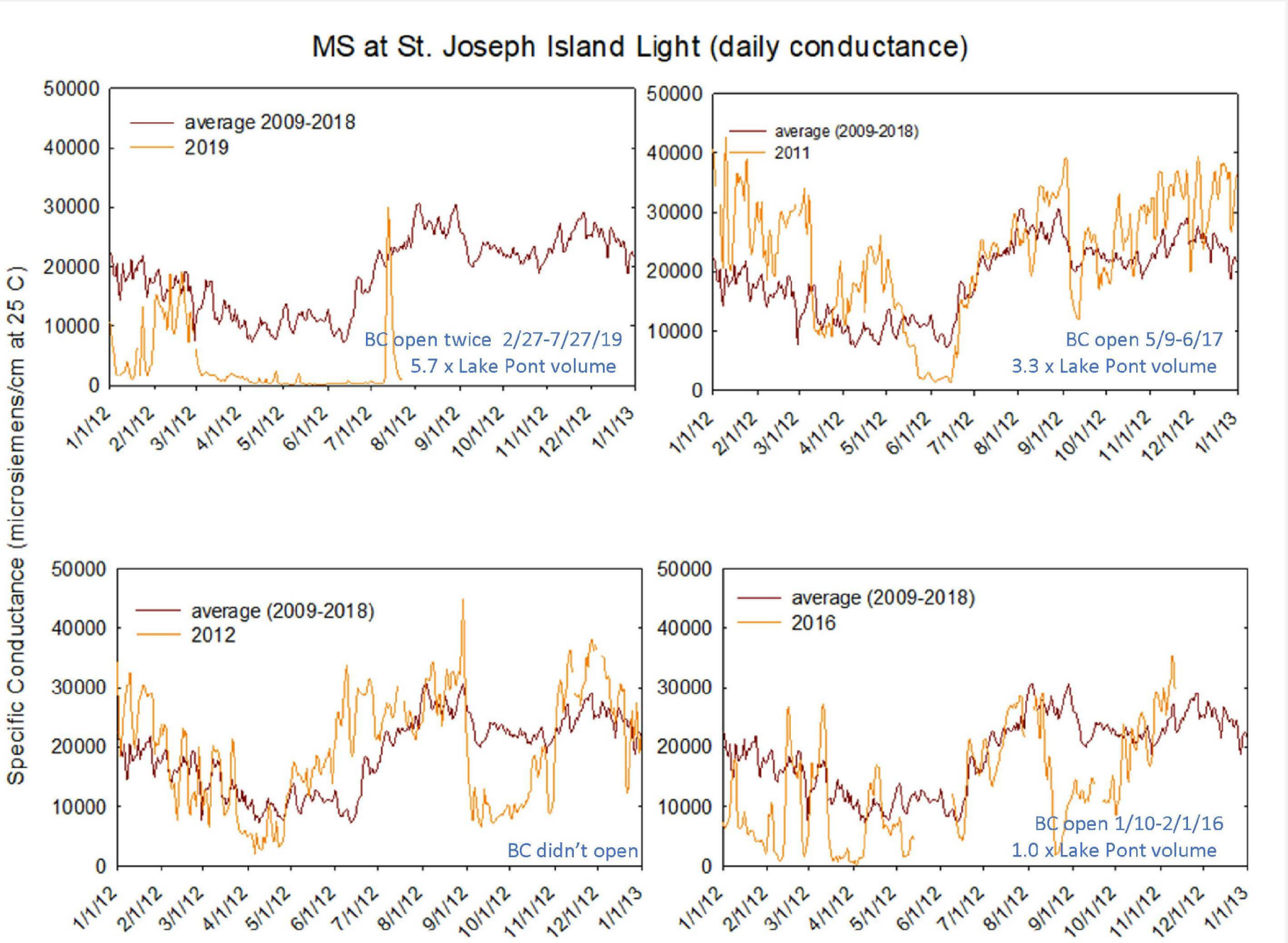

Preliminary data
Subject to revision

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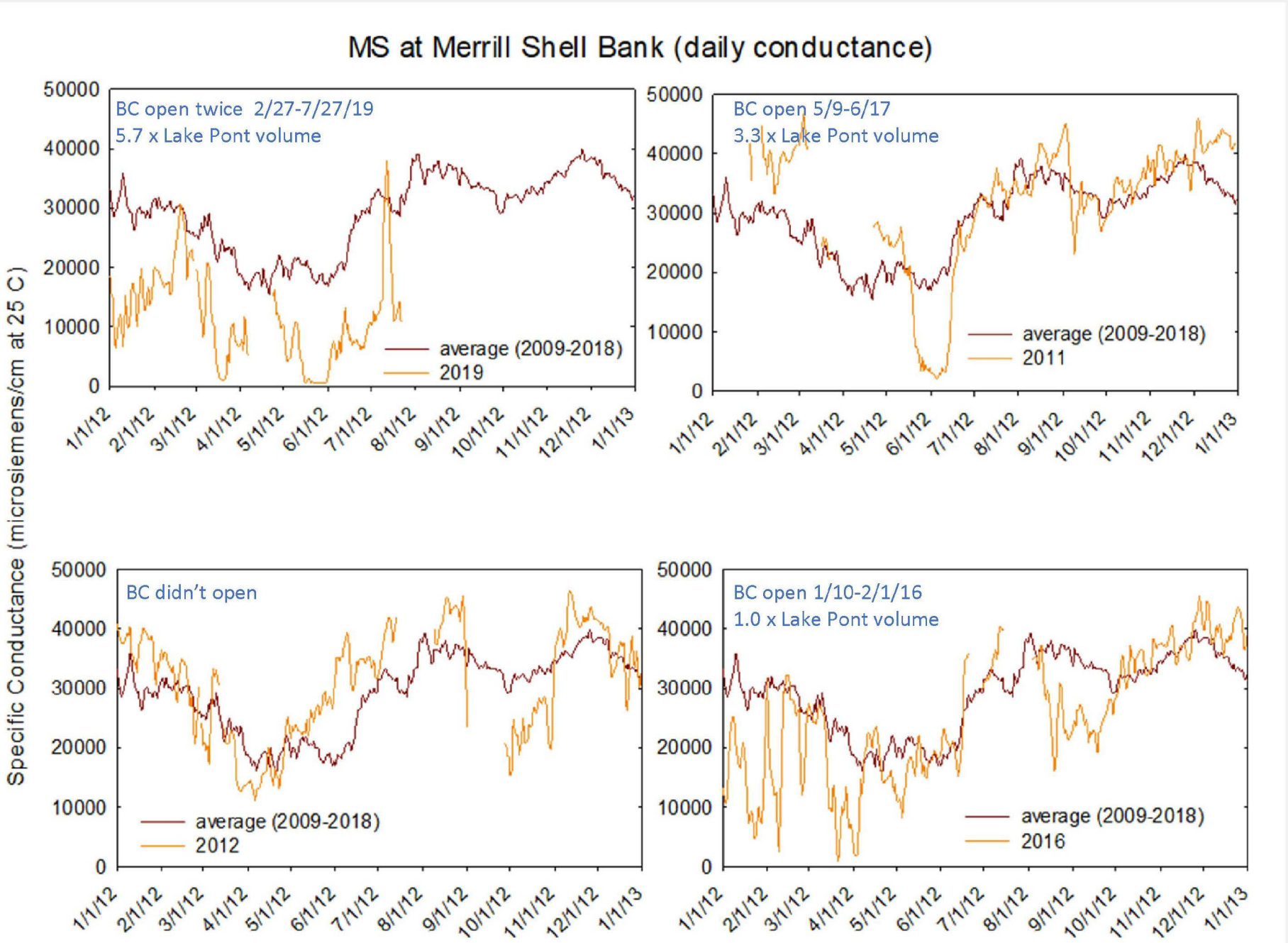

Preliminary data
Subject to revision

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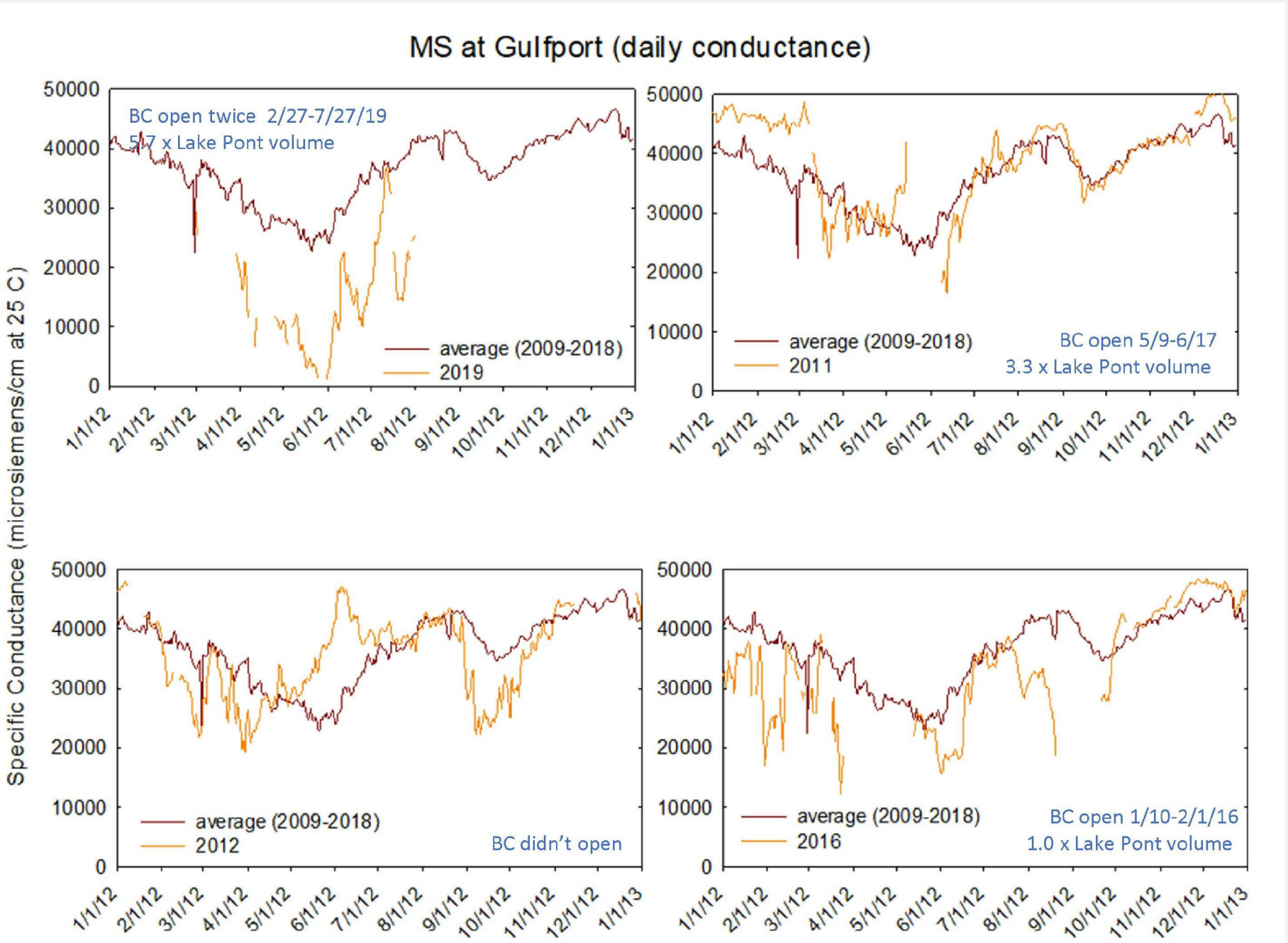
BCS_00059302



Preliminary data
Subject to revision

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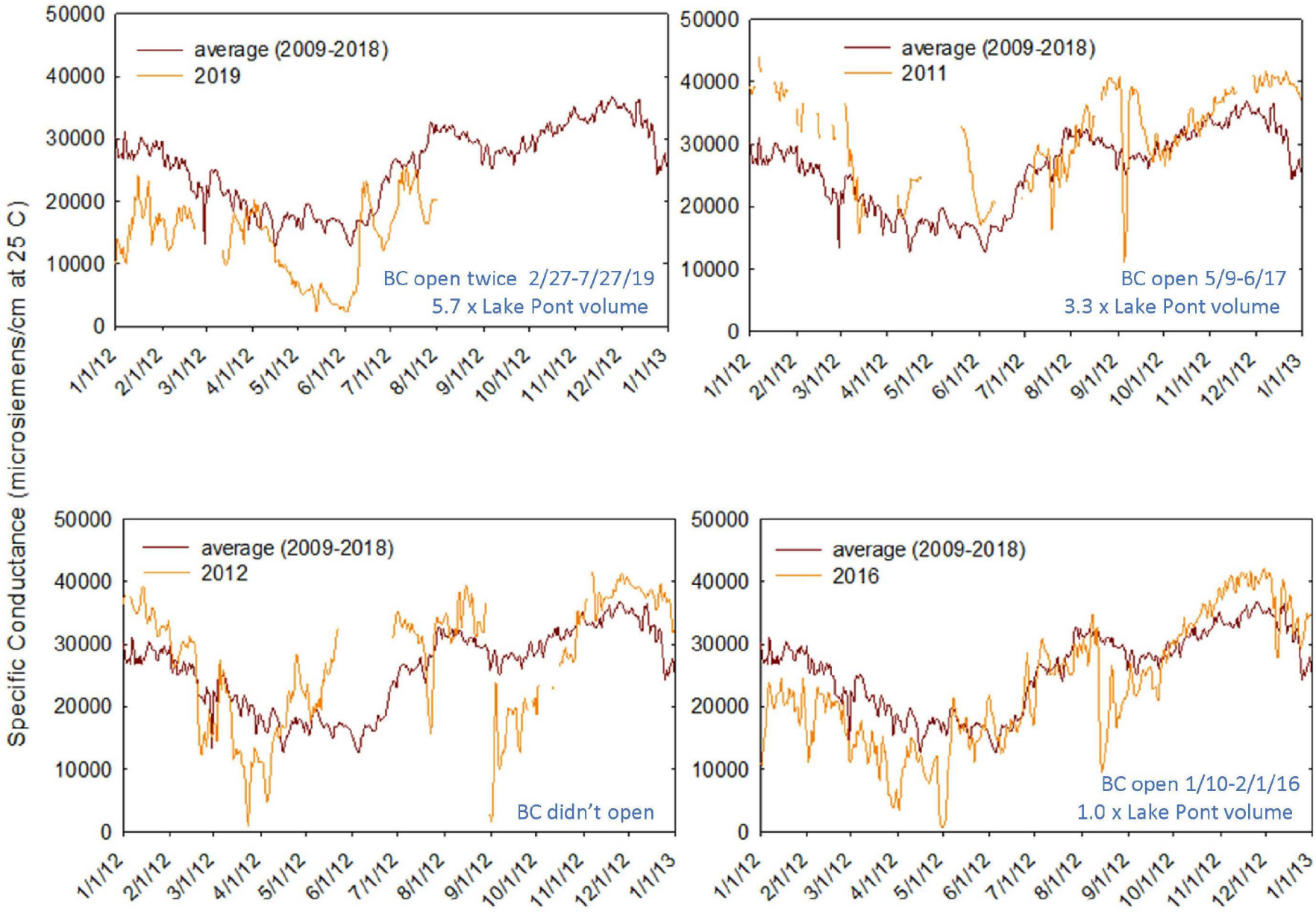
Biloxi Bay at Point Cadet Harbor at Biloxi



Preliminary data
Subject to revision

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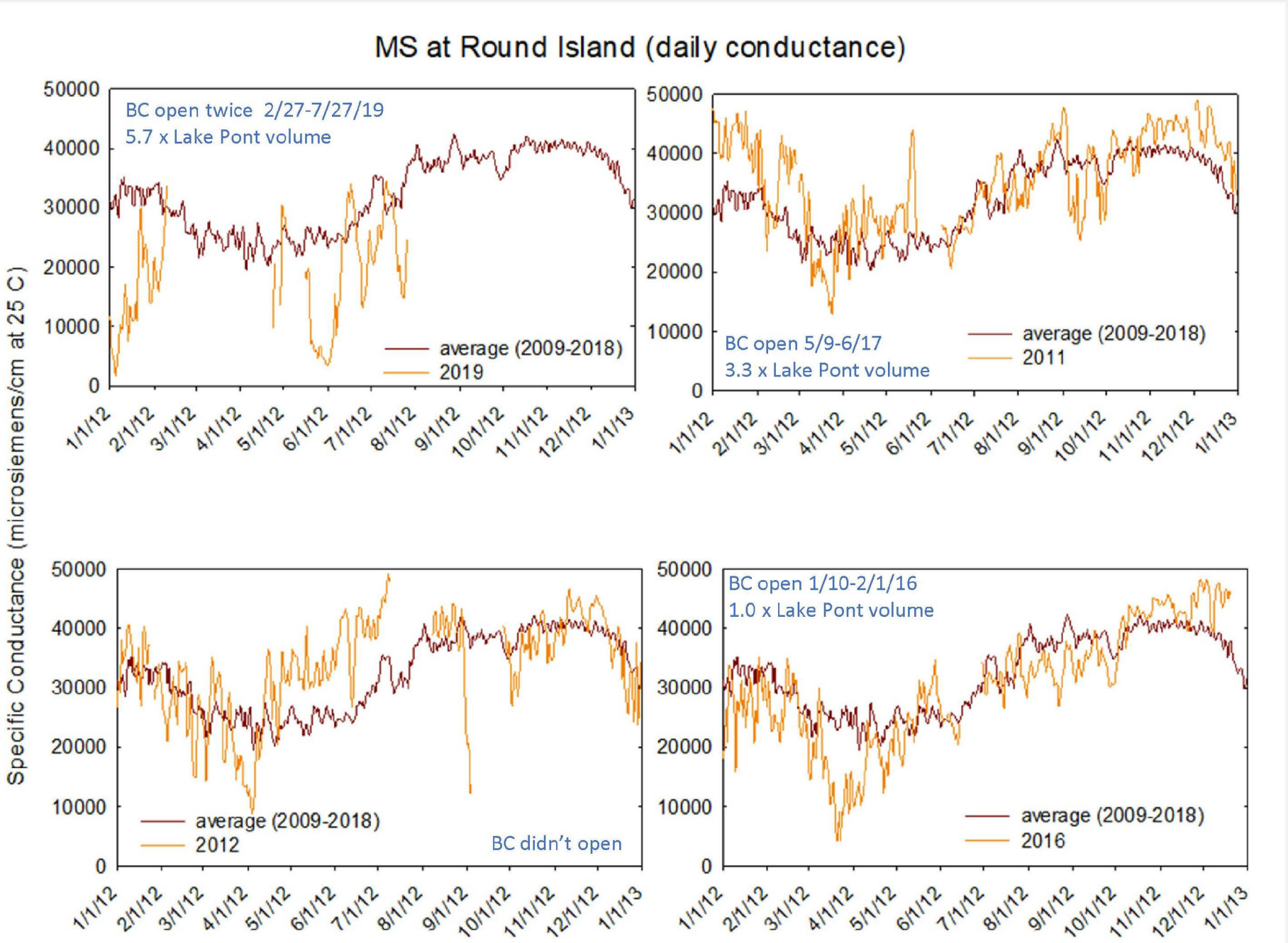
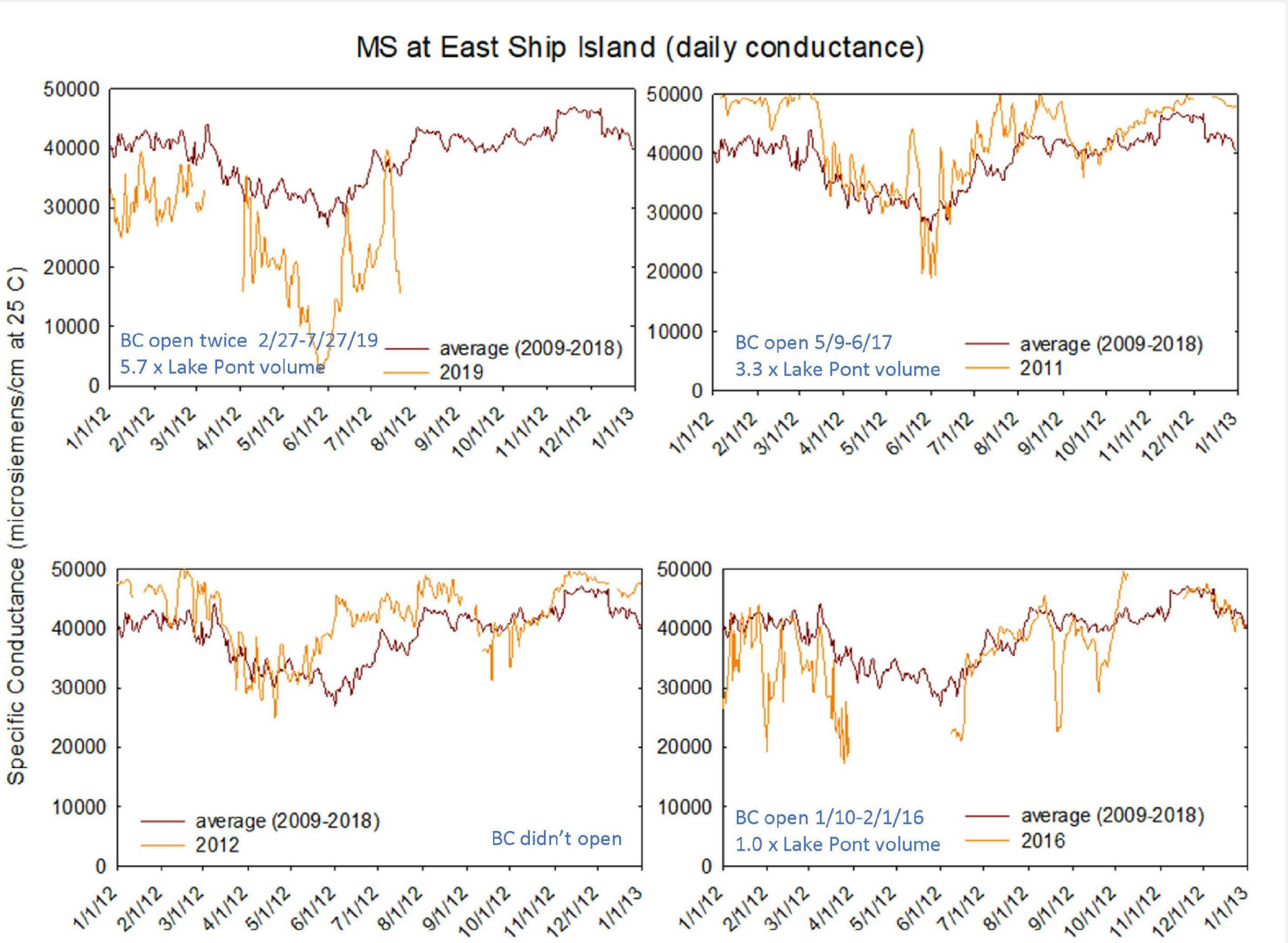


Preliminary data
Subject to revision

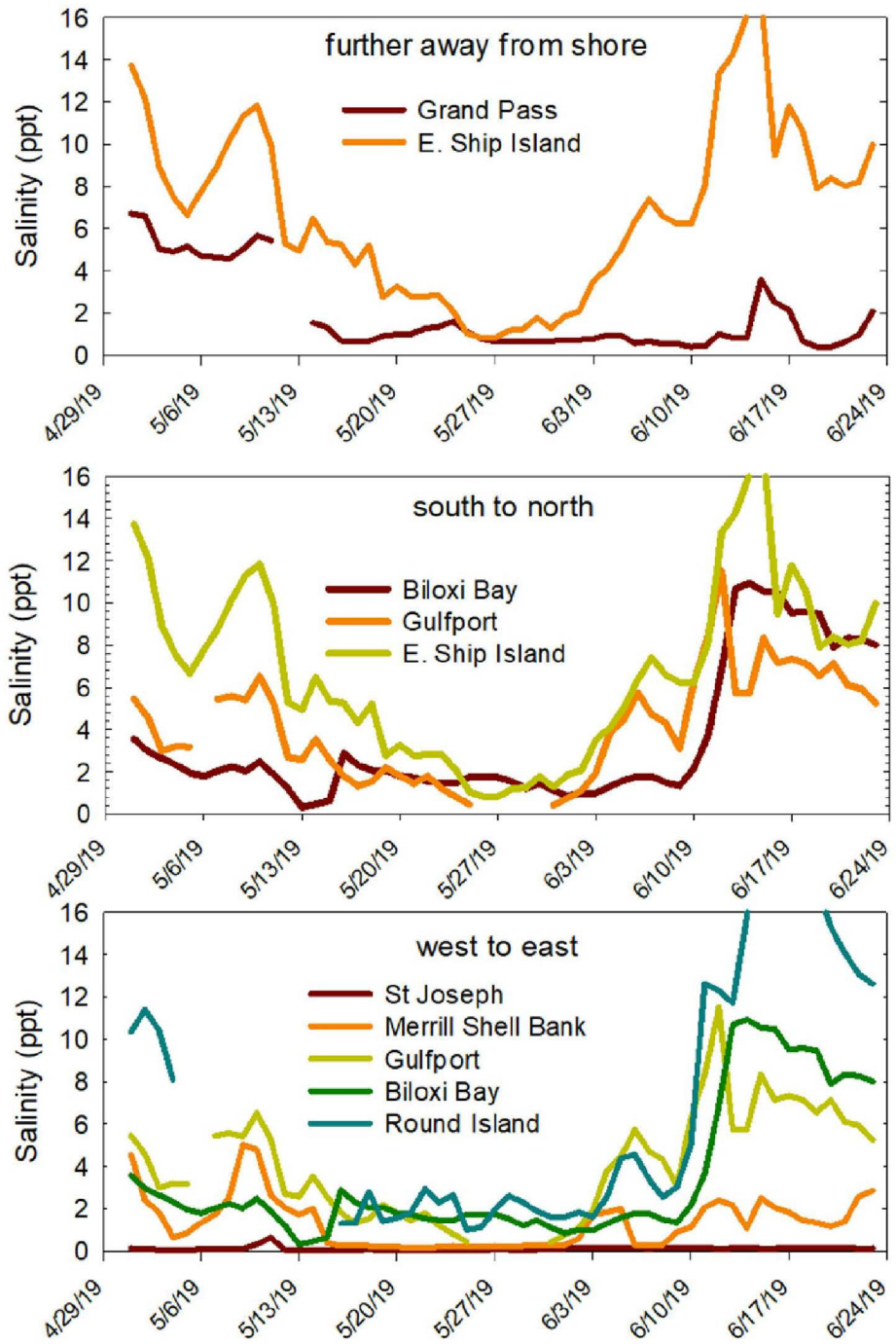
USGS science for a changing world



Preliminary data
Subject to revision

USGS science for a changing world

Daily minimum salinity value at continuous stations in the Mississippi Sound

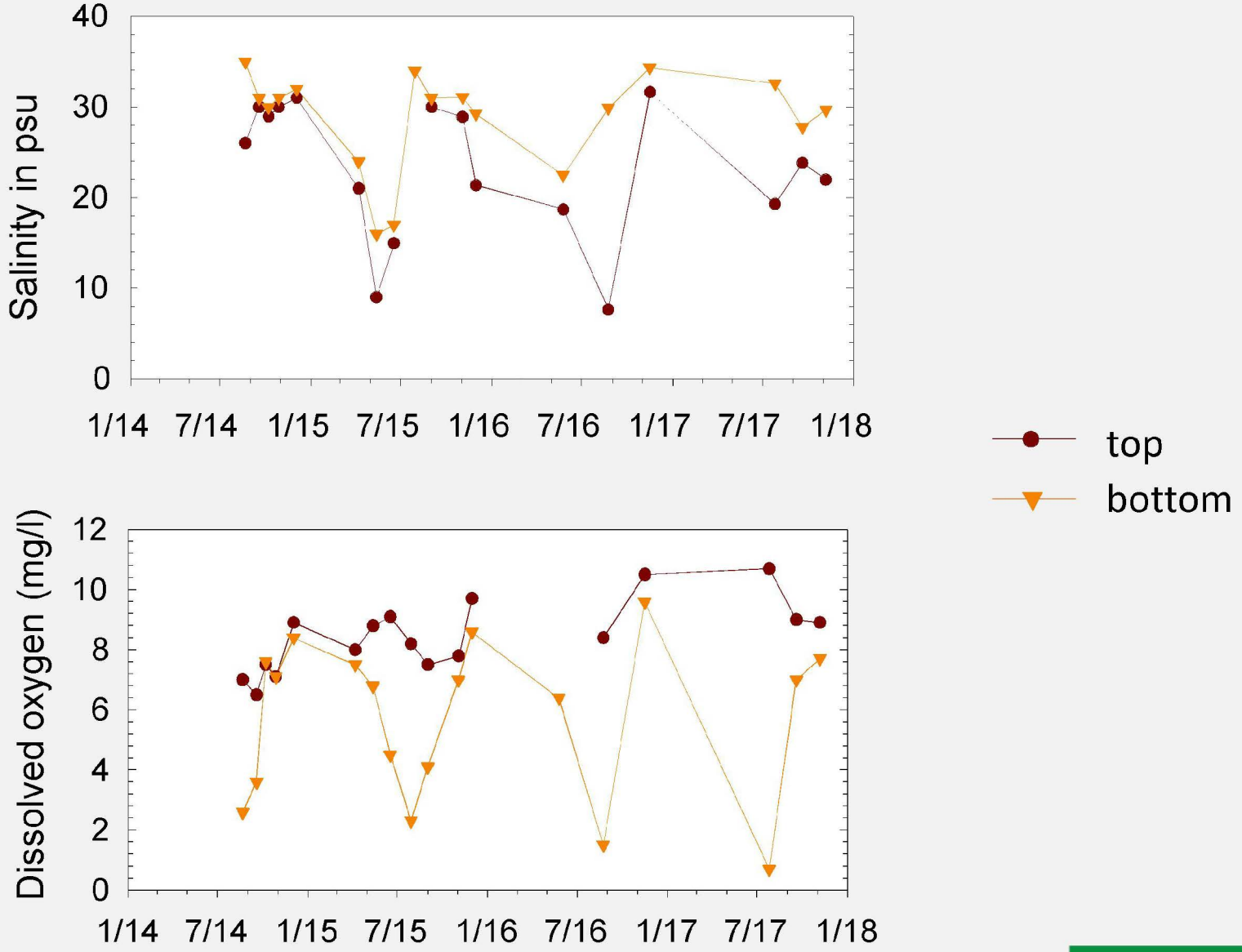


Preliminary data
Subject to revision

USGS science for a changing world

BCS_00059307

WATER-QUALITY: Summer hypoxia is common throughout the Mississippi Sound, and follows salinity stratification (ie between Cat and Ship Island)



Preliminary data
Subject to revision

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$\delta^{18}O$ isotopic tracking
A. Shiller, USM

Hurricane Barry
July 11 – 19, 2019

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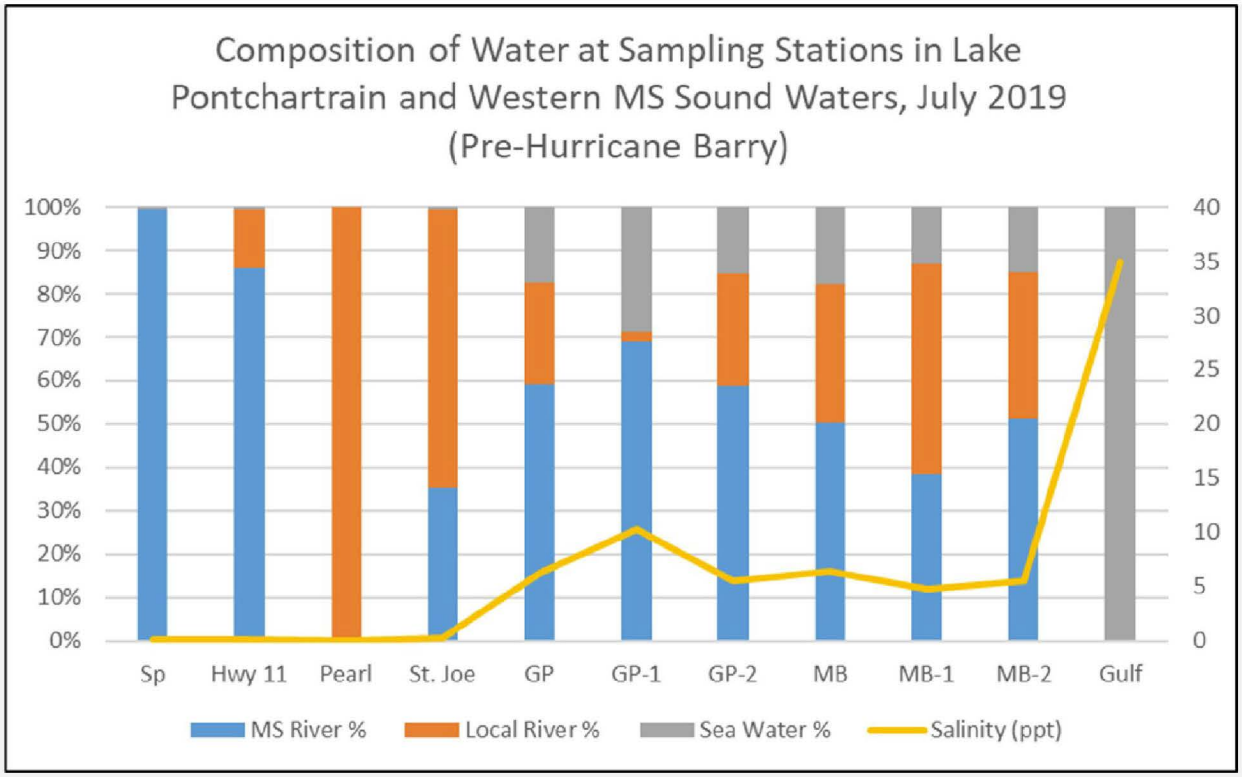
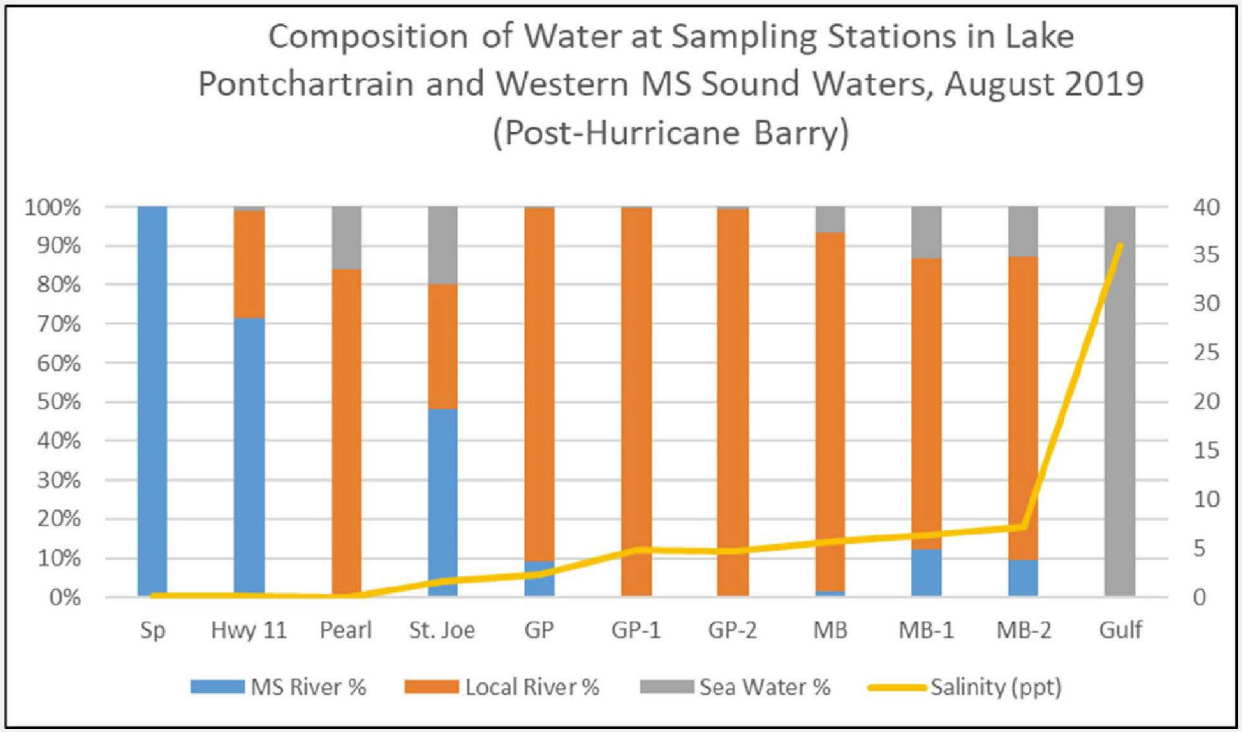
Preliminary data
Subject to revision

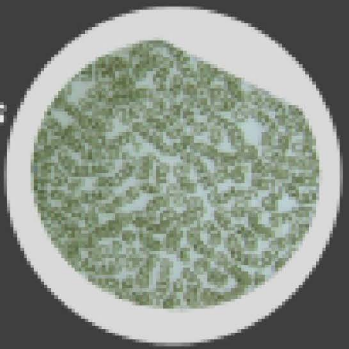




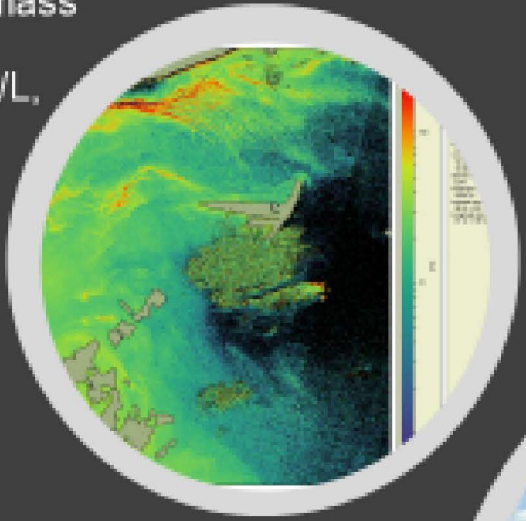
Algae Blooms

Algae blooms along Mandeville Beach on north shore lake Pontchartrain, LA (June 2019).
- *Anabeana* sp. & *Microcystis* sp.

Cyanobacteria:
Anabaena circinalis
Lake Pontchartrain



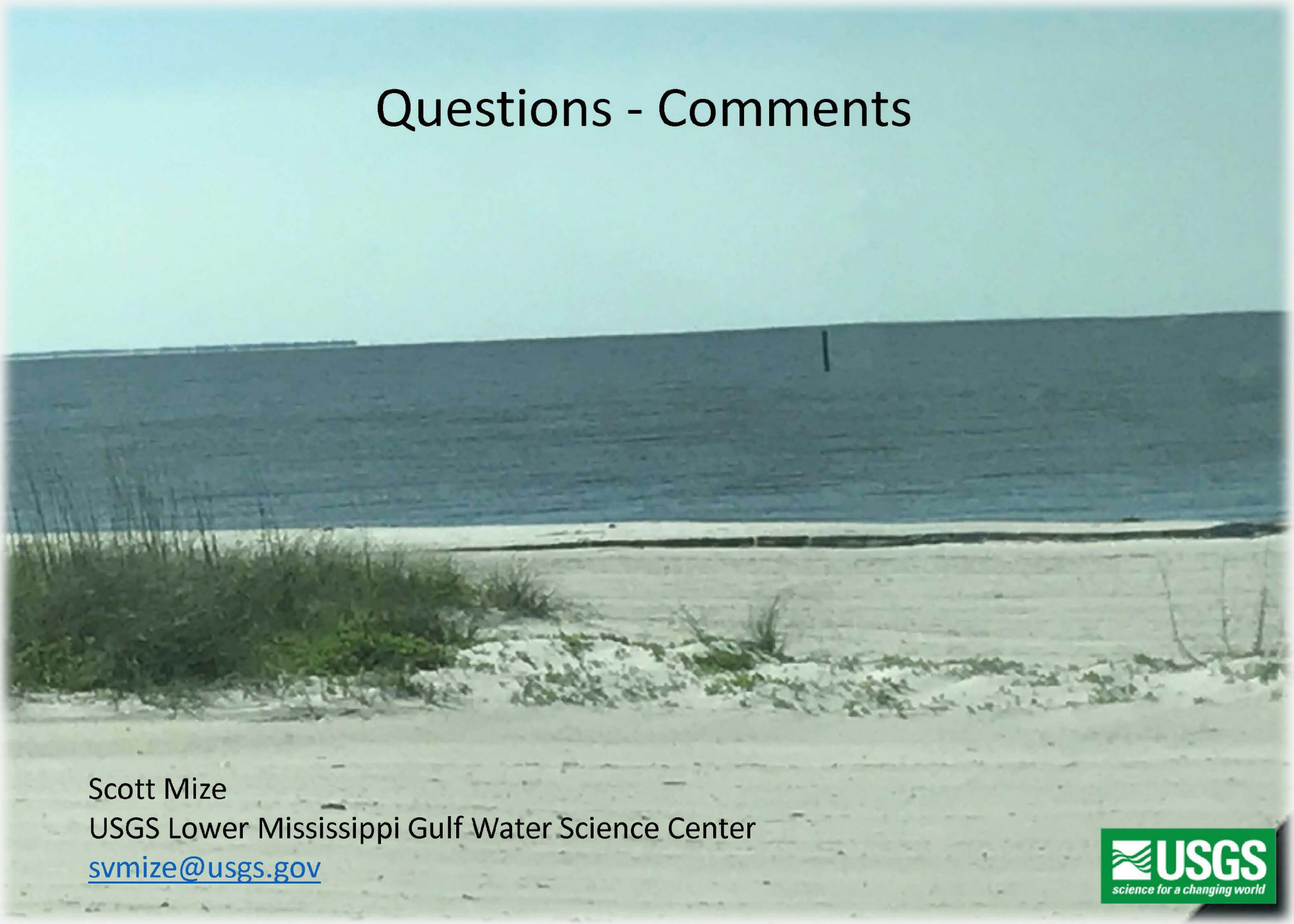
NOAA Chlorophyll-a estimates of algal biomass using Sentinel 2 imagery: showing high chlorophyll-a concentrations above 100 mg/L, *red*, near Pass Christian, MS (July 2019).



USGS Merrill Banks Monitoring Station near oyster production in Mississippi Sound, MS

Cyanobacteria bloom on south shore Lake Pontchartrain, LA (August 2019)

Questions - Comments



Scott Mize
USGS Lower Mississippi Gulf Water Science Center
svmize@usgs.gov

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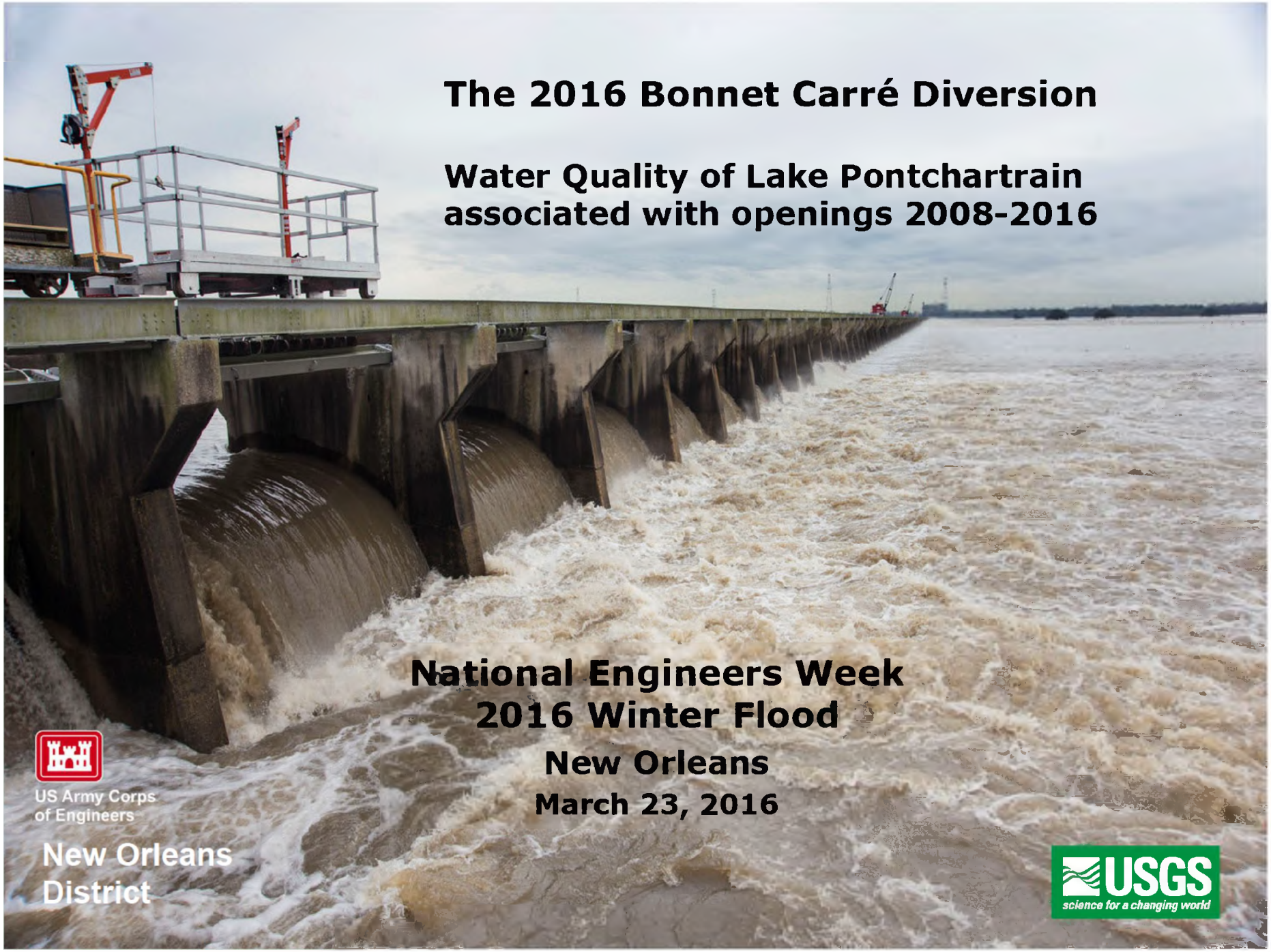
The 2016 Bonnet Carré Diversion
Water Quality of Lake Pontchartrain
associated with openings 2008-2016
National Engineers Week
2016 Winter Flood
New Orleans
March 23, 2016
US Army Corps
of Engineers
New Orleans
District
USGS
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Problem:

The introduction of nutrient-rich fresh river water into nutrient-poor brackish Lake Pontchartrain is known to substantially change the chemistry and ecology of the lake. The assessment of lake chemical and biological conditions during diversion events is important to evaluate for potential impacts to lake resources (recreation, fisheries, wetlands, etc.)

Also, the need for monitoring during a non-diversion years is important to determine seasonal, climatic, and other annual variability for comparison to diversion-year sampling.

Objectives:

Objective is to spatially and temporally characterize surface-water quality and phytoplankton communities as indicators of eutrophic conditions in Lake Pontchartrain in diversion and non-diversion years.

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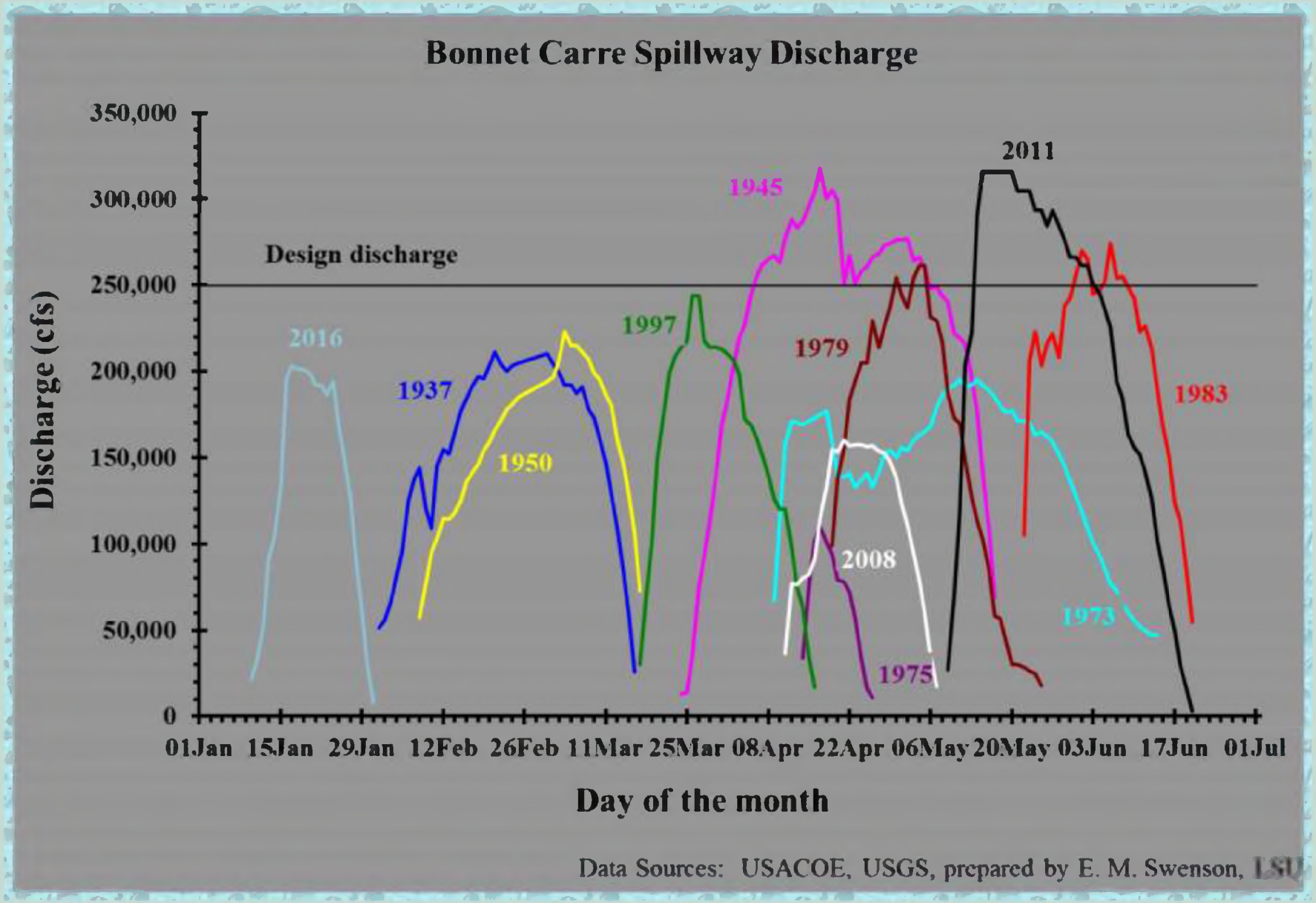
Bonnet Carre Spillway Discharge
Discharge (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Design discharge
2016
1937
1950
1997
1945
2011
1979
1983
2008
1973
1975
01Jan 15Jan 29Jan 12Feb 26Feb 11Mar 25Mar 08Apr 22Apr 06May 20May 03Jun 17Jun 01Jul
Day of the month
Data Sources: USACOE, USGS, prepared by E. M. Swenson, LSU

Highway 61 bridge

Discharge and Suspended sediment collection during spillway opening 2016

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North site:
(Crossover 2)
MS Sound site
BC Spillway at LA-Hwy 61
South site:
(Crossover 7 & Mile 9)
Outlet site:
Hwy 11 nr. Slidell, LA
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of Engineers
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NASA MODIS image, 4/29/08

Water-Quality constituents

- Physiochemical properties (temp, ph)
- Major ions (Ca, Mg, Si)
- Nutrients – total & dissolved N&P
- Total organic carbon
- Chlorophyll *a*
- Atrazine
- Phytoplankton communities
- Algal toxins

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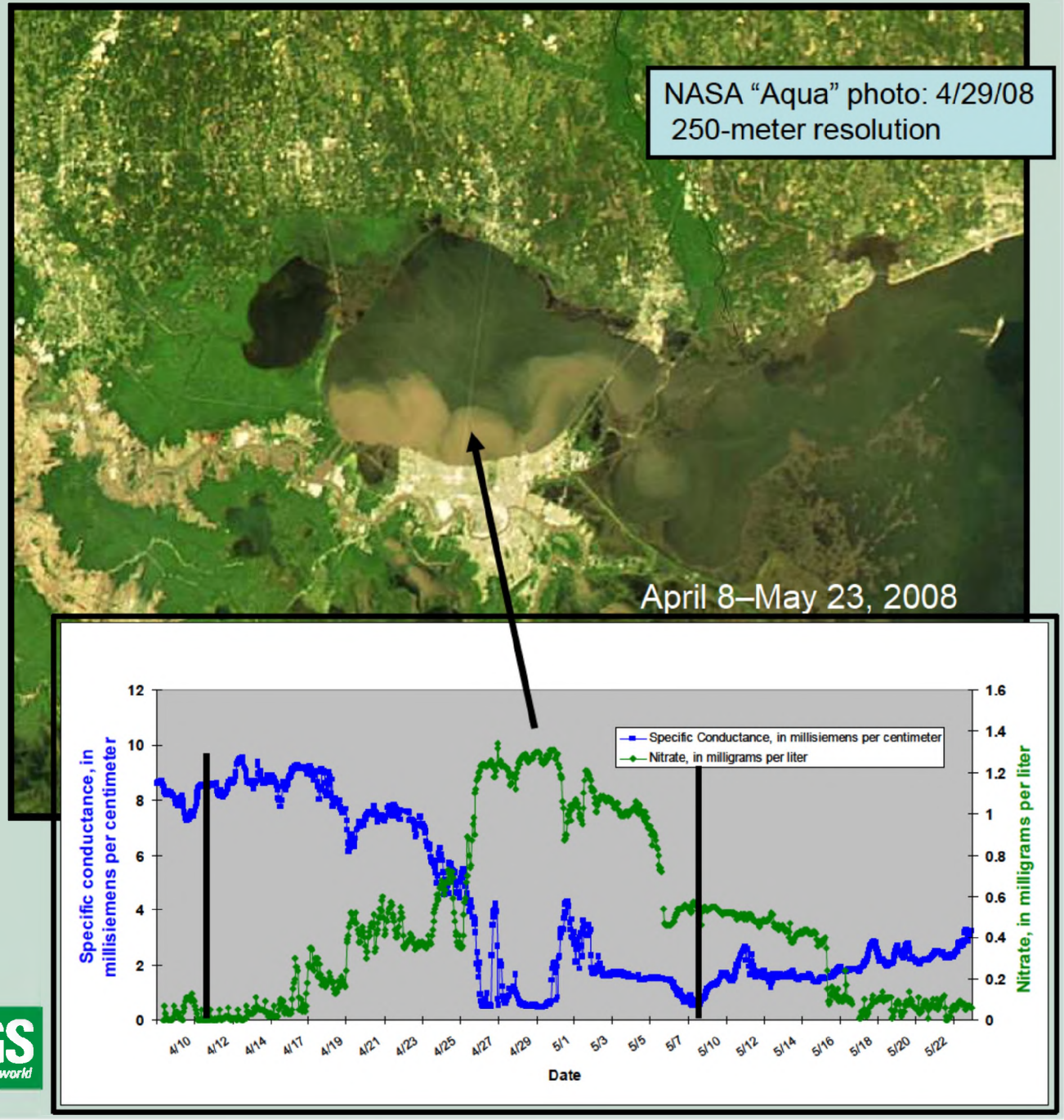
Approach: Weekly and monthly water quality and phytoplankton sampling for 6 months from diversion.

Sampling design and data analysis uses four sampling periods to capture changes in lake water quality.



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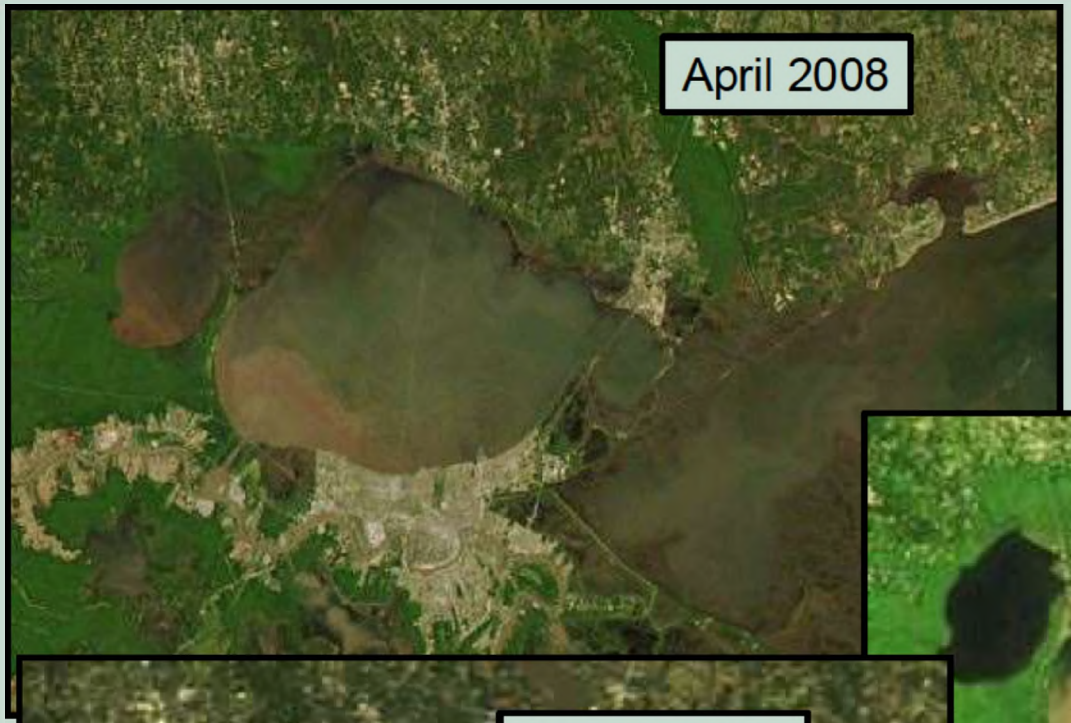

Period 1: time prior to river water arrival at the causeway

Non-diversion:
March-April 2013

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Period 2: time river water was present at the causeway

Non-diversion:
April-May 2013

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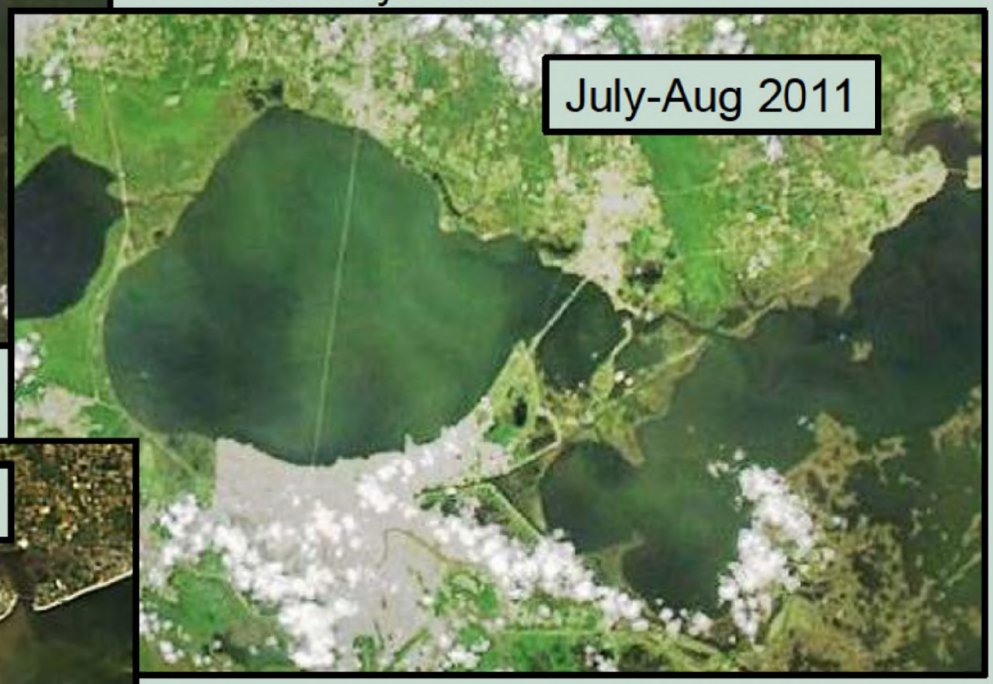
Period 3: time after diversion had closed and river water departed from the causeway

Non-diversion:
June-July 2013



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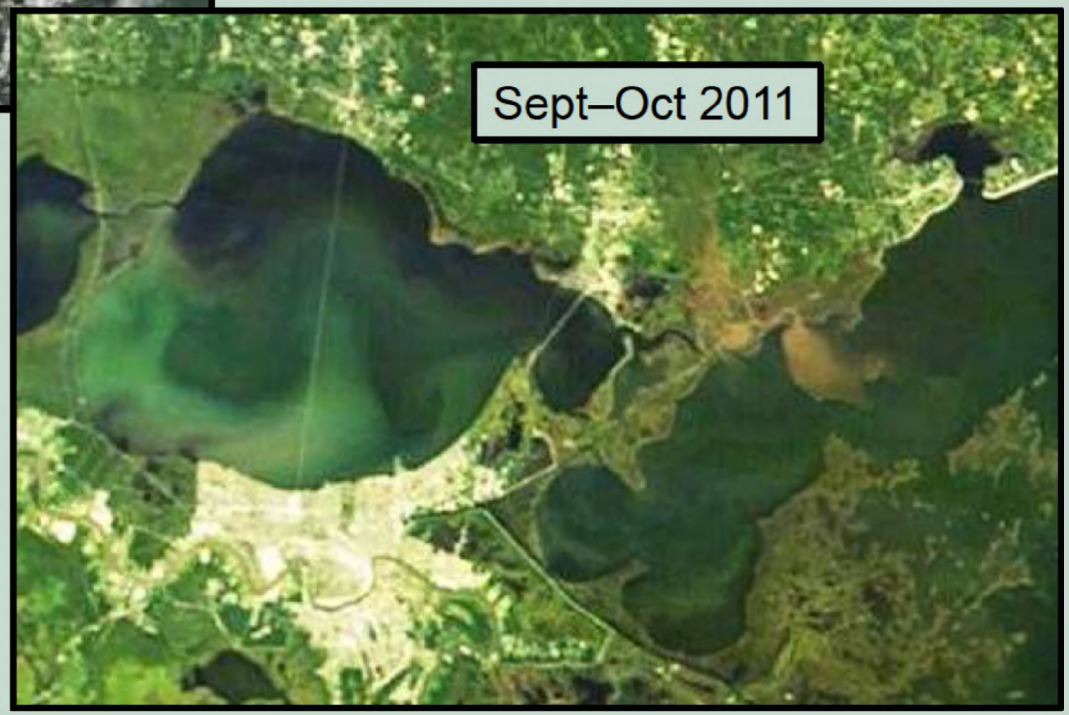
Period 4: time after river water departed from the lake

Non-diversion:
Aug – Sept 2013



Hurricane Ike –Sept 11, 2008

Tropical Storm Lee – Sept 4, 2011

2016 El Niño year –
tropical system?

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2016 Realtime continuous data: at Mile 9 Causeway

http://waterdata.usgs.gov/la/nwis/uv/?site_no=300904090075200&PARAmeter_cd=00400,00095,00010,00011,32234,00301,00300,00631,00480,00076

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USGS 300904090075200 Lk Pont. Causeway at mile 9 near Metairie, LA

PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site | Time-series: Current/Historical Observations | GO

This station managed by the Baton Rouge Field Office.

Available Parameters	Available Period
☐ All 7 Available Parameters for this site	
☑ 00010 Temperature, water	2015-01-12 2016-03-22
☑ 00095 Specific cond at 25C	2015-01-12 2016-03-22
☑ 00480 Salinity	2015-01-13 2016-03-22
☑ 00400 pH	2015-01-12 2016-03-22
☑ 00300 Dissolved oxygen	2015-01-12 2016-03-22
☐ 63680 Turbidity, Form Neph	2015-01-12 2016-03-22
☐ 70969 DCP battery voltage	2015-02-18 2016-03-22

Output format
- ◉ Graph
- ○ Graph w/ stats
- ○ Graph w/o stats
- ○ Graph w/ (up to 3) parms
- ○ Table
- ○ Tab-separated

Days (65) GO

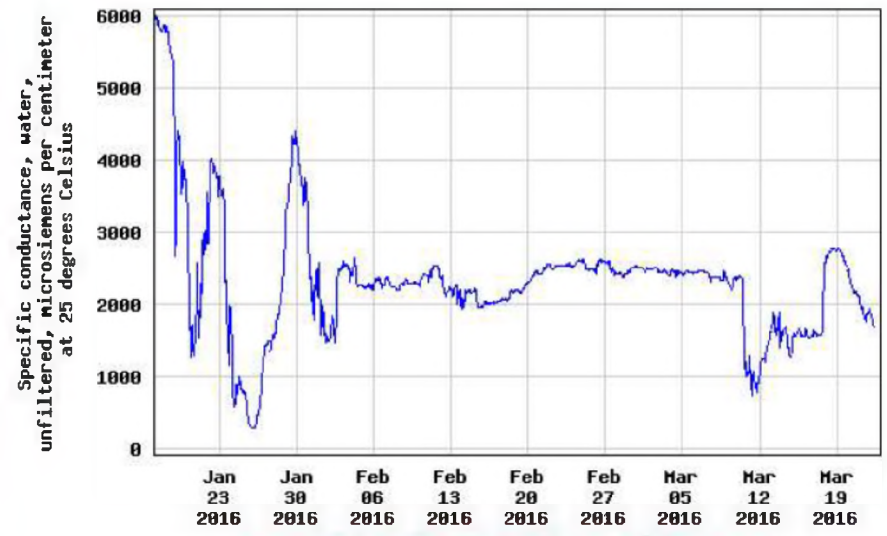
-- or --

Begin date 2016-01-17

End date 2016-03-22

USGS

USGS 300904090075200 Lk Pont. Causeway at mile 9 near Metairie, LA



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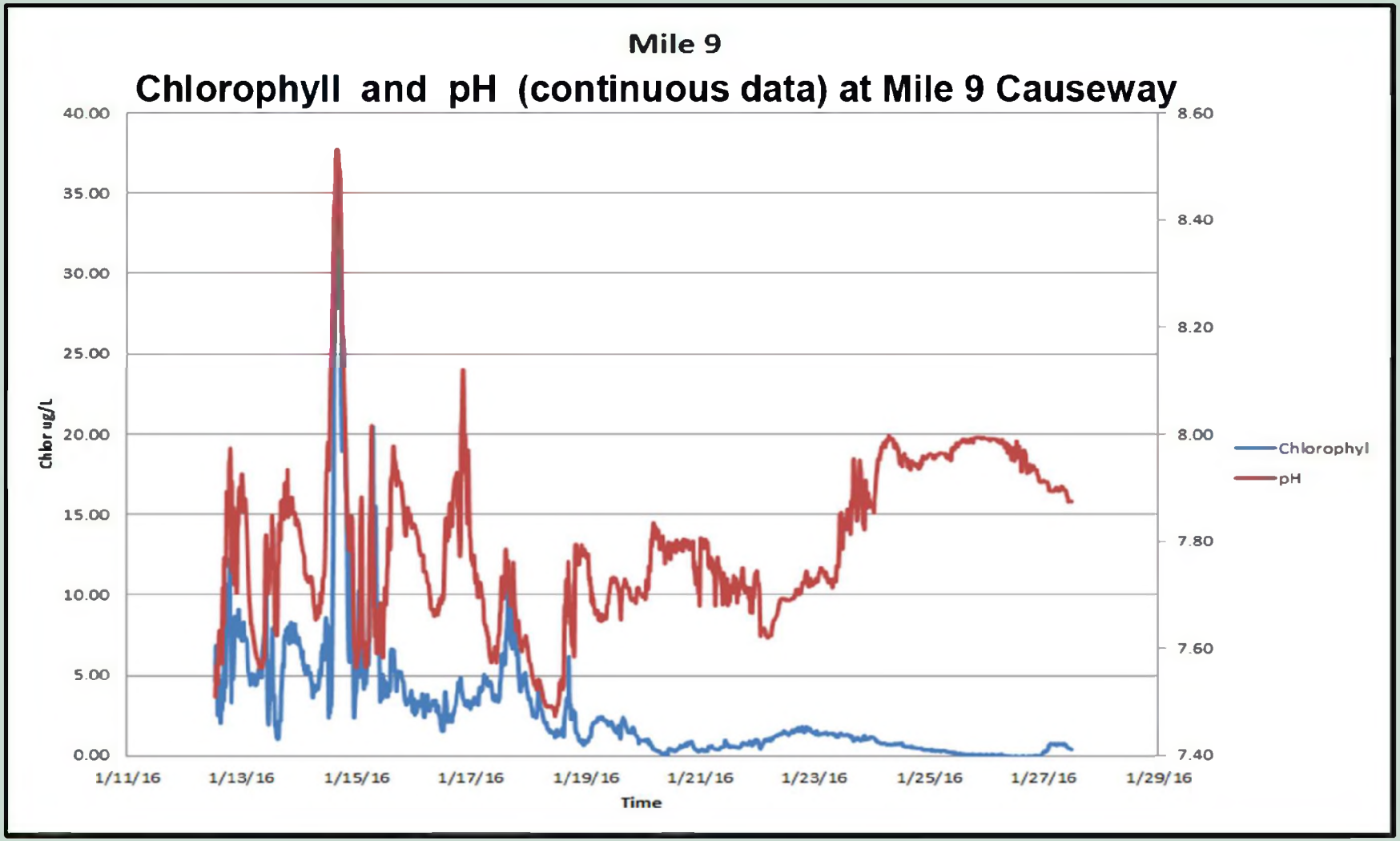

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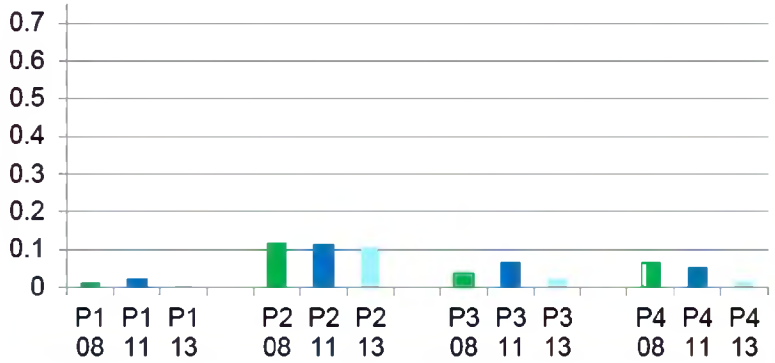
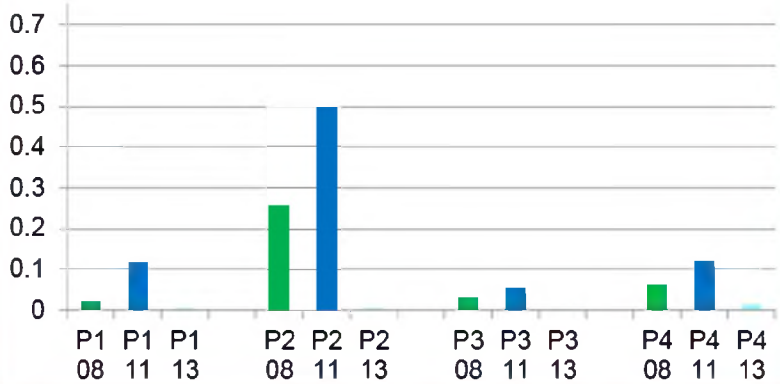
Median Nitrate Concentrations (mg/L)

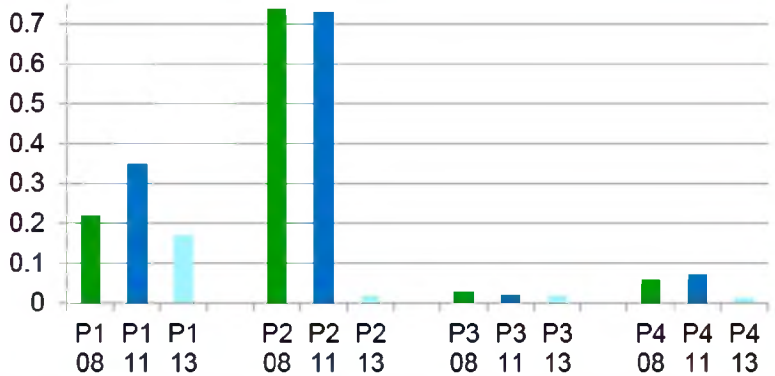
Nitrate (north)



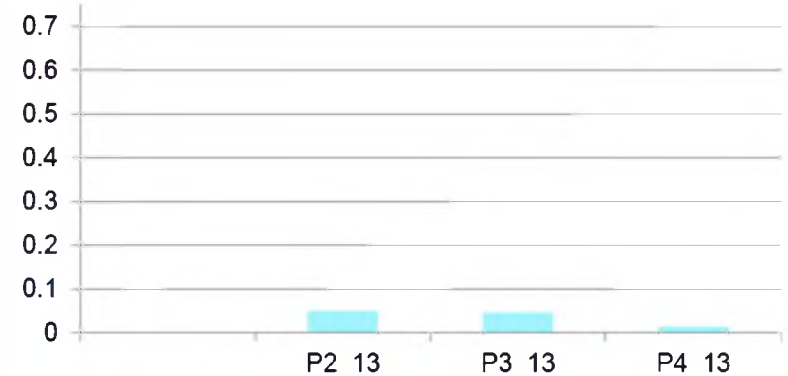
Nitrate (outlet)



Nitrate (south)



Nitrate (MSound)



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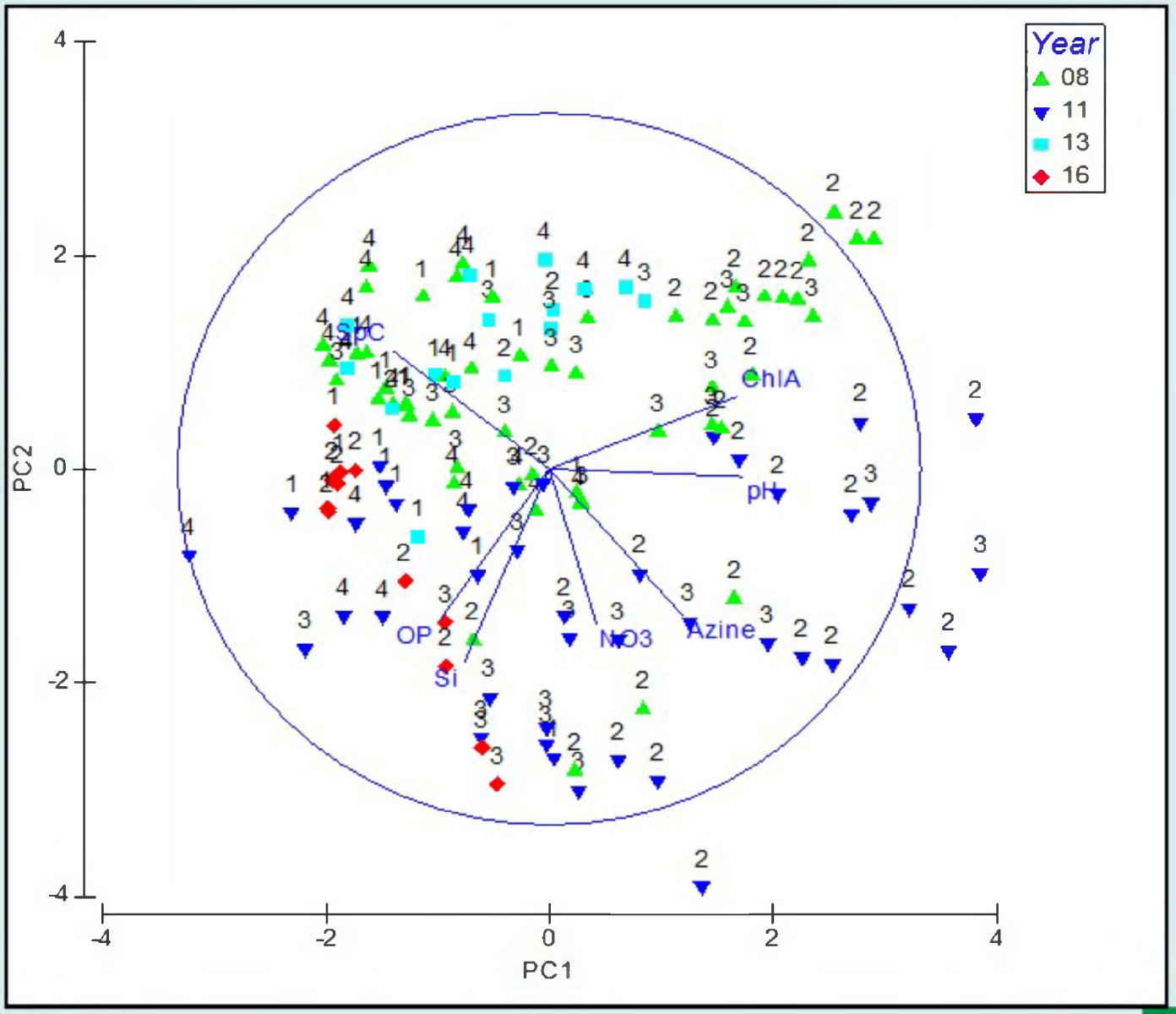
BCS_00149536

Principal Components Analysis (all WQ)



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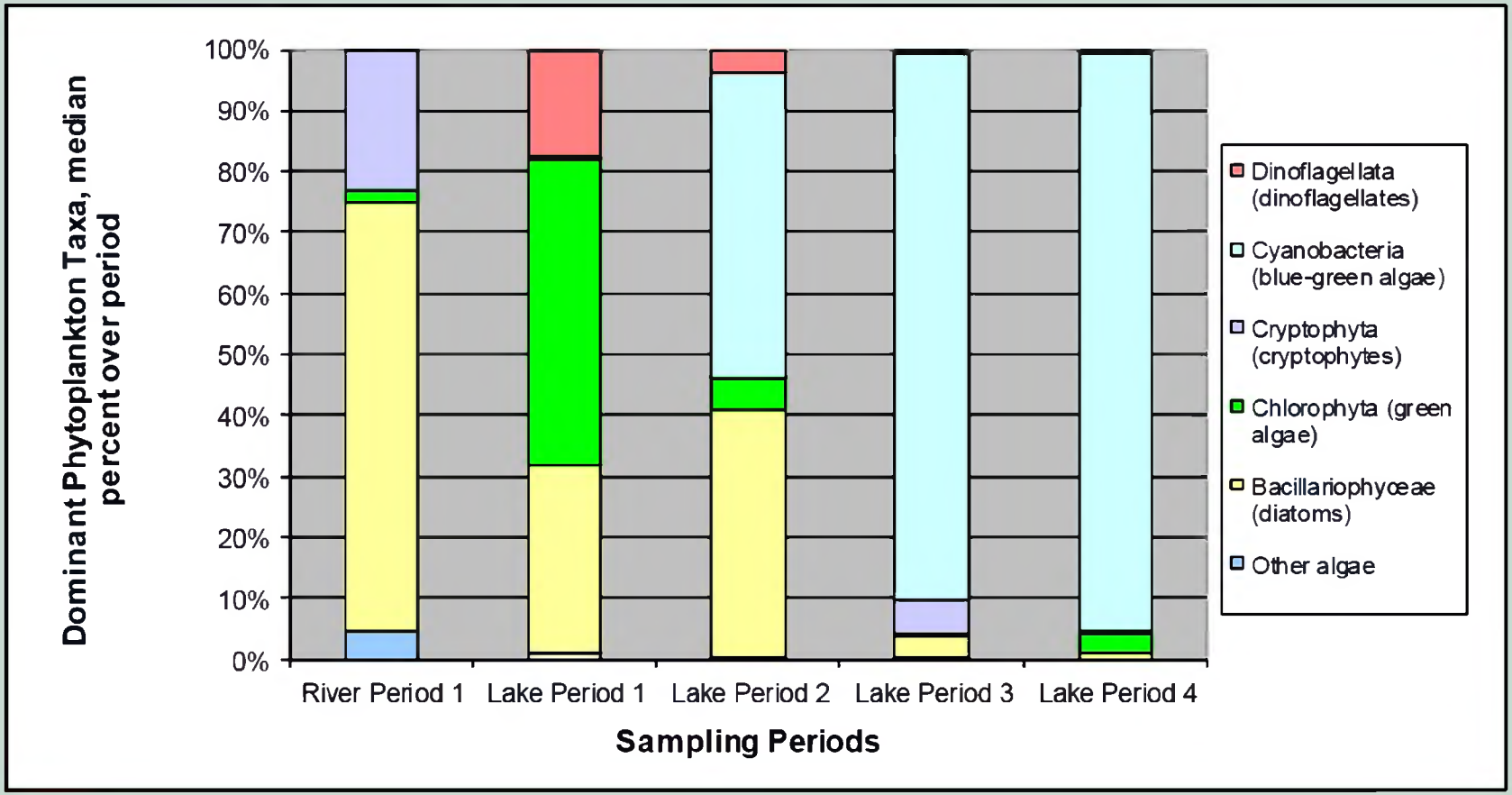
Phytoplankton taxa composition 2008



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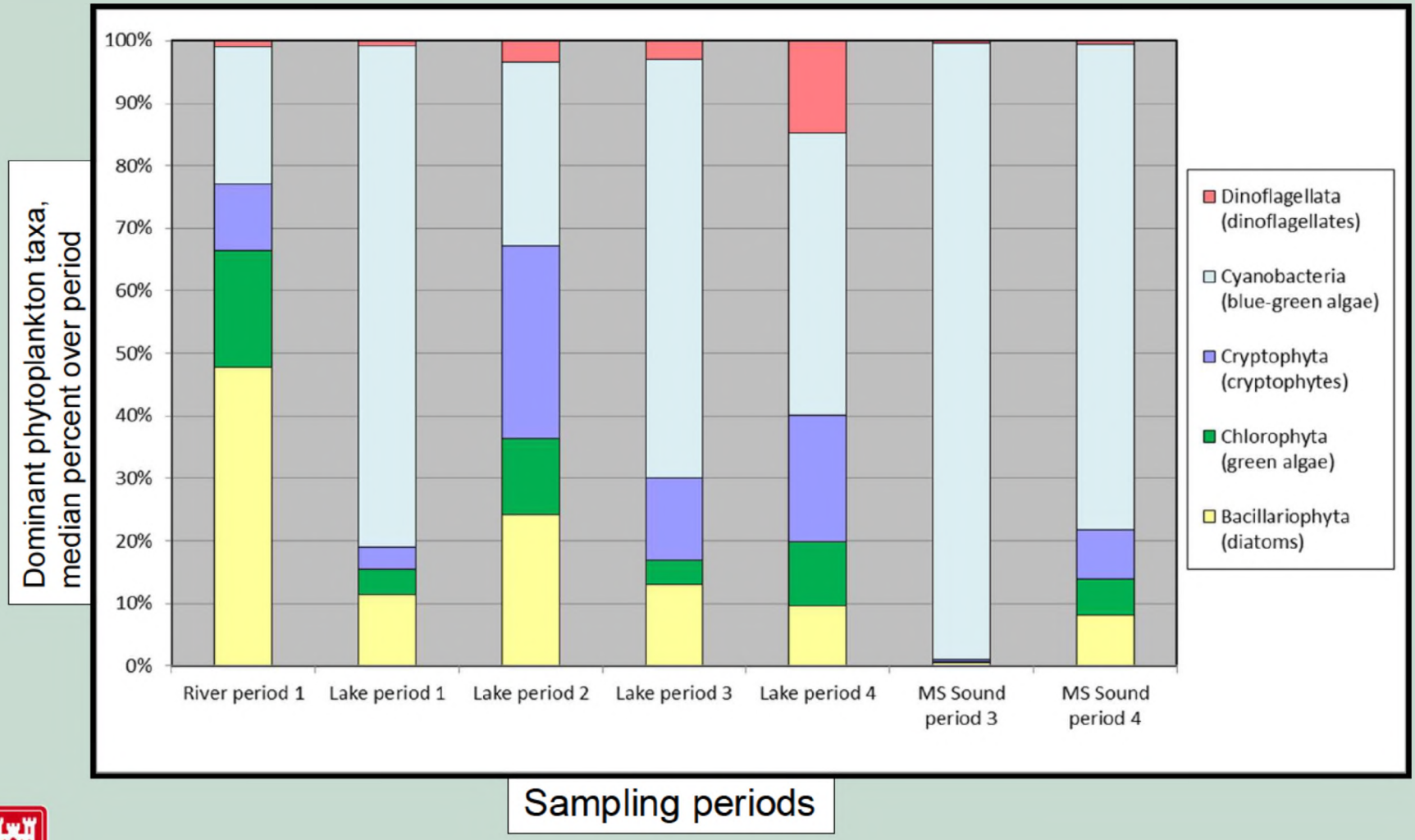
Phytoplankton taxa composition 2011



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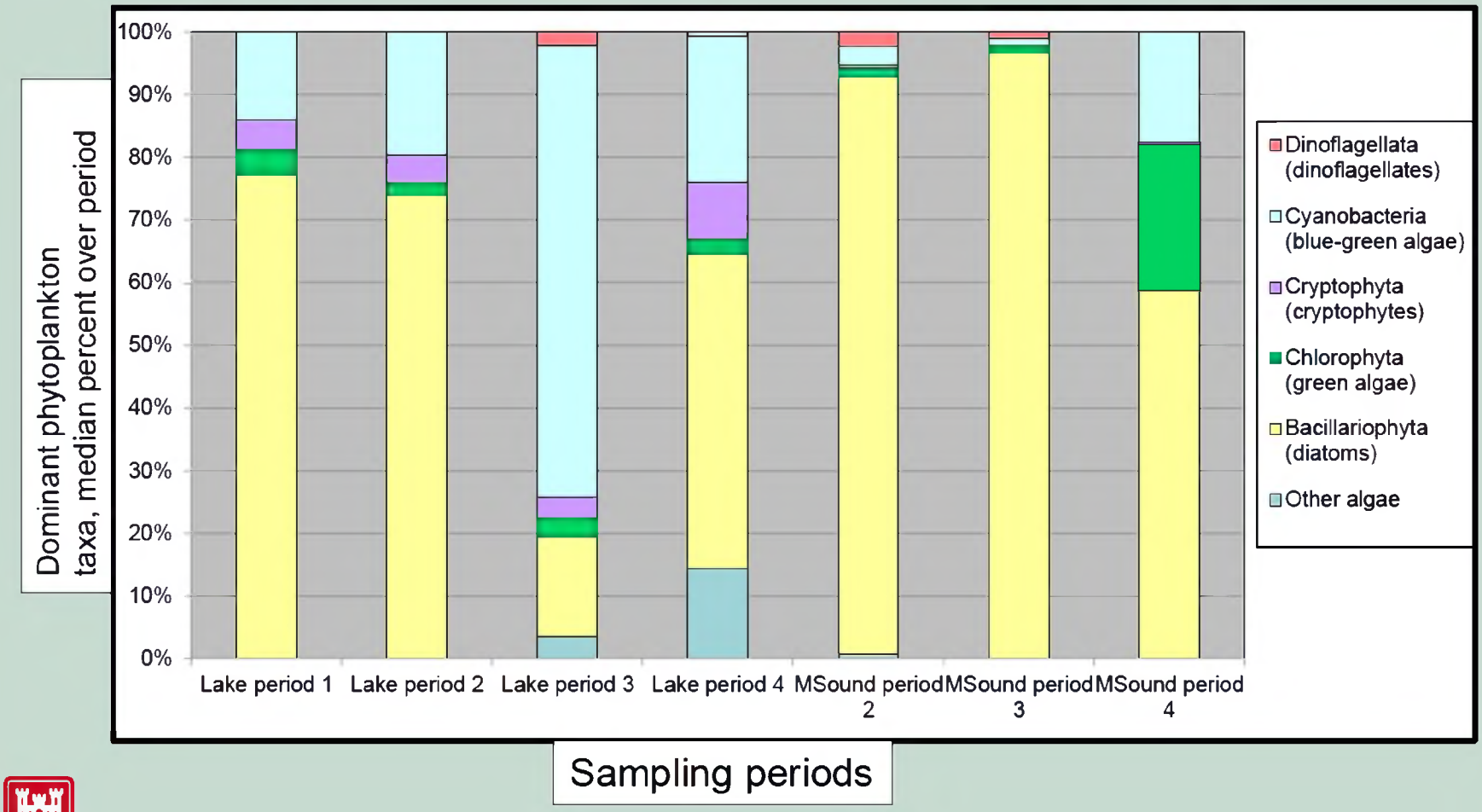
Phytoplankton taxa composition 2013



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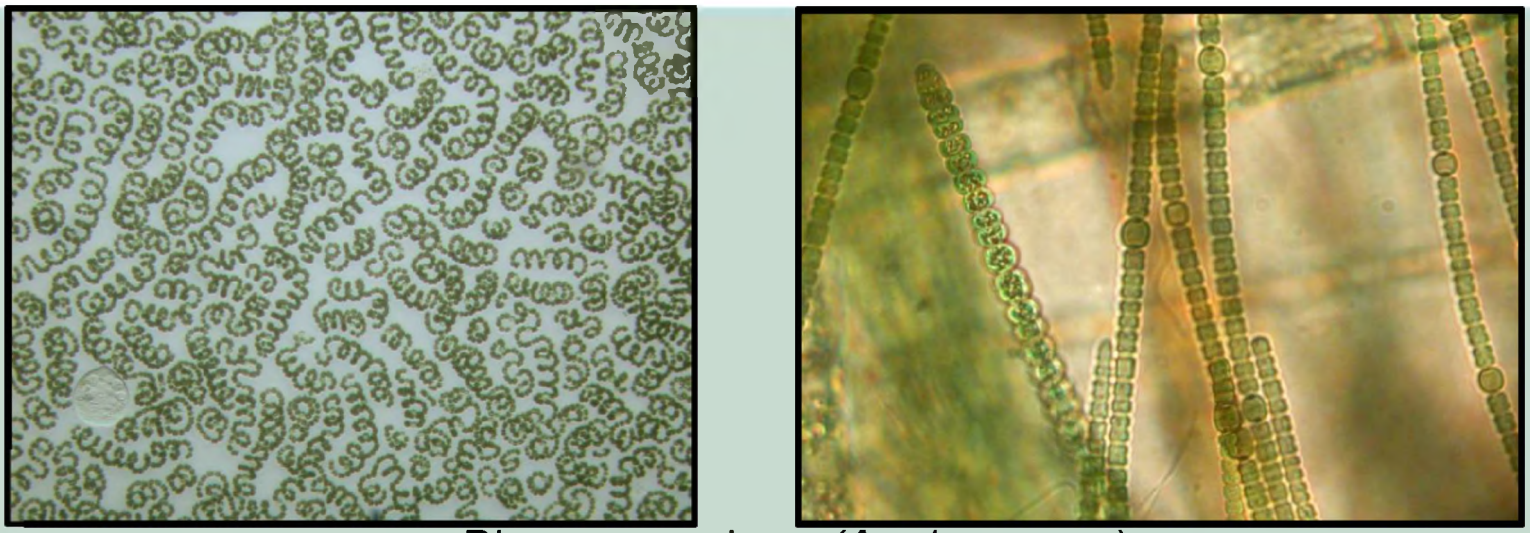
Algal Toxins

- **Common toxin-producing algal species found in Lake Pontchartrain (Anabaena, Microcystis, Pseudanabaena, Cylindrospermopsis)**
- Microcystins detected in 11 of 15 samples in 2011.
- Max. conc. **0.38 µg/L** on 6/07/11 at Crossover 2 (north shore)
- Algal toxins were not detected in 2013

Microcystins in water 6-10µg/L (most states)

WHO guideline in drinking water 1µg/L.



Blue-green algae *(Anabaena sp)*

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Summary

Year	Time of Opening	Est. Magnitude	Climate	Chemical change	Biological change
2008	April	1.5x lake vol	Tropical system	large	Lk Pont bloom
2011	May	4x lake vol	Tropical system	large	MS Sound bloom
2013	no diversion	leakage		minimal	seasonal
2016	Jan	2x lake vol	El Niño, TS?	?	?

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QUESTIONS?
Thanks to the monitoring crew:
Dennis Demcheck
Paul Frederick
Chris Swarzenski
Eric Glisch (USACE)
Causeway Commission
US Army Corps of Engineers
New Orleans District
LAKE PONTCHARTRAIN CAUSEWAY
WORLD'S LONGEST BRIDGE
USGS
science for a changing world