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Supplementary Material

Recovery and Restoration of Biloxi Marsh in the Mississippi River Delta

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1. Supplementary Figures

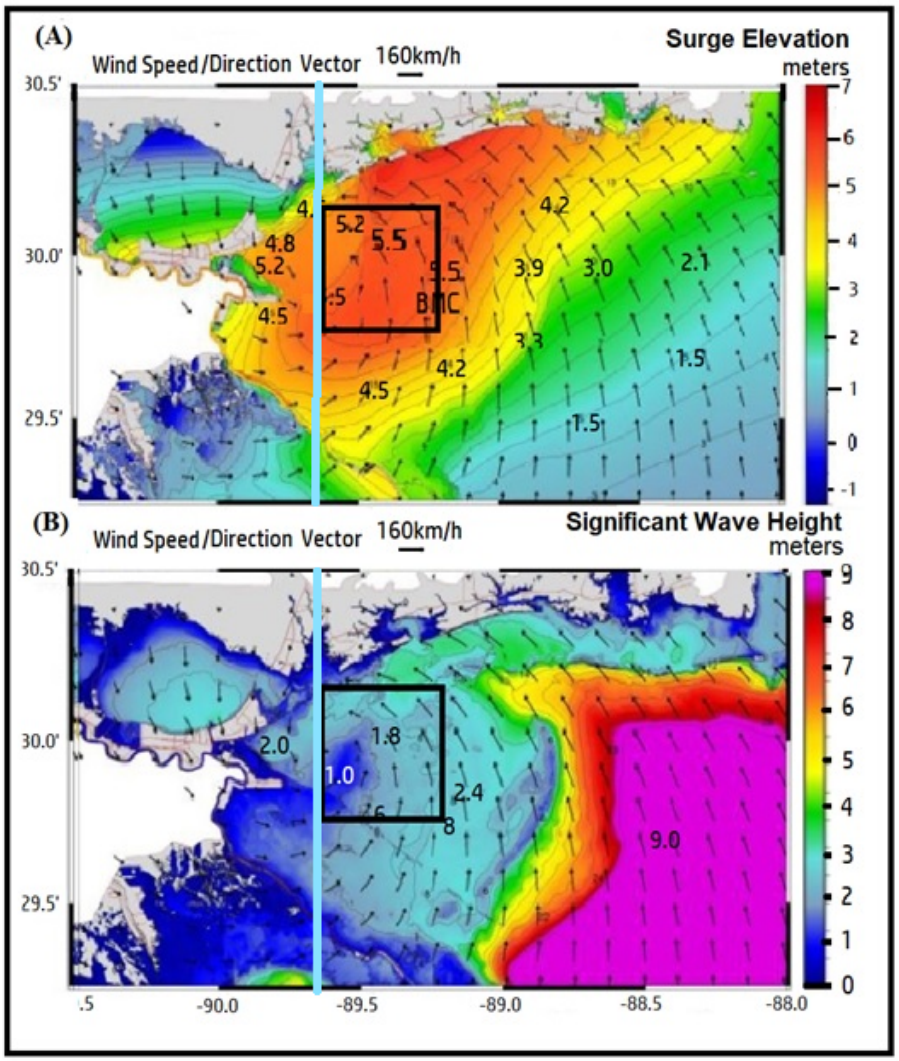

Figure S1. Effect on surge and waves in the Lake Borgne–MRGO "Funnel" at 0900 CDT, August 29, 2005. South to north rack of Hurricane Katrina overlaid in light blue on simulation of a tightly coupled SWAN+ADCIRC (wave+surge) model hindcast (ADCIRC SL16). (**A**) The steepest rise in surge

elevation is on eastern margin of Biloxi Marsh study area (black box). Surge is lower in Lake Borgne and Lake Pontchartrain. (**B**) Bottom friction and wave breaking on the Chandeleur Islands and shoals, and similar interactions on the Biloxi Marsh reduce significant wave height in the Funnel. Modified from [23].

While coastal topography and bathymetry changes little from year to year, the storms themselves vary greatly in speed and direction of approach, which affects duration and speed of winds from any direction. Wetlands generally provide more protection to New Orleans from faster moving, smaller diameter storms than from slower, larger ones, but the Biloxi Marsh is well situated to have a beneficial reduction for most storms tracking east of the city.

Figure S2. Lake Borgne Marsh Site A1b behind detached breakwaters built in 2013. Bottom panel shows monitoring poles placed along base of marsh edge scarp on February 20, 2018. Top panel show pole positions on November 16, 2018, demonstrating advance of vegetated shoreline over 9 months into Lake (86 cm +/– 10 cm) behind the CPRA breakwaters [37].

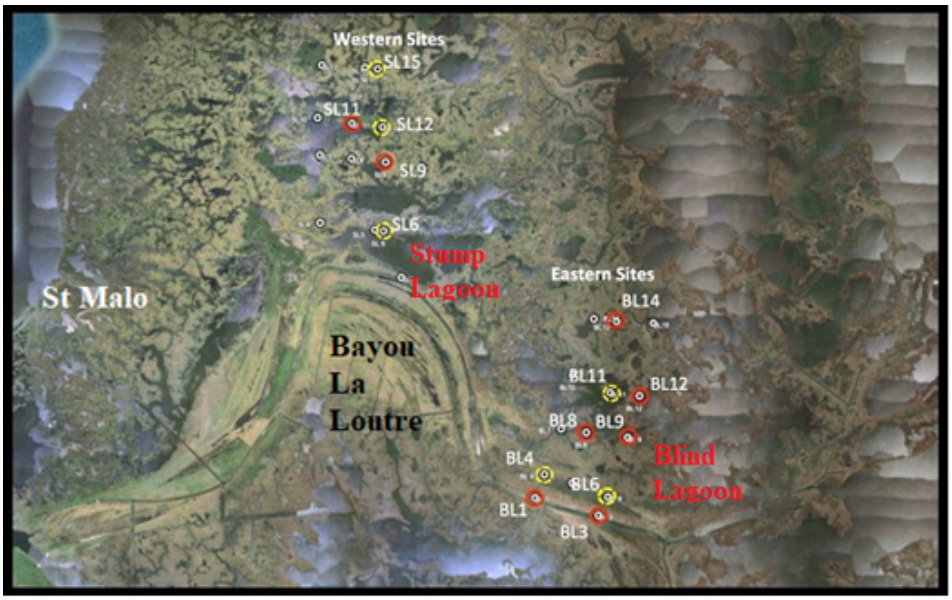

Figure S3. Location of interior marsh sites established by University of New Orleans researchers in 2003 and 2004, and reoccupied in 2018 by Lane et al. [19].

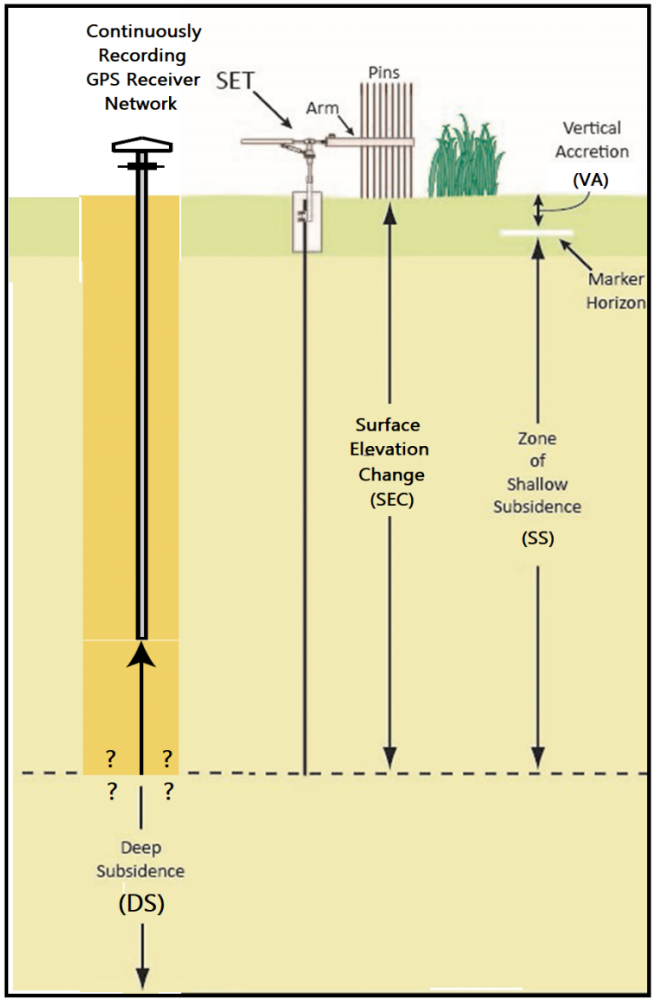

Figure S4. Using the Sediment Erosion Table (SET) and Marker Horizon (MH) techniques in tandem to determine Surface Elevation Change (SEC), Vertical Accretion (VA), Shallow Subsidence (SS = VA–SEC), Deep Subsidence (DS), and Total Subsidence (TS = SS+DS), Local Sea Level Rise (MSLR), and Relative Sea Level Rise (RSLR = TS + LSLR). Modified from [69].

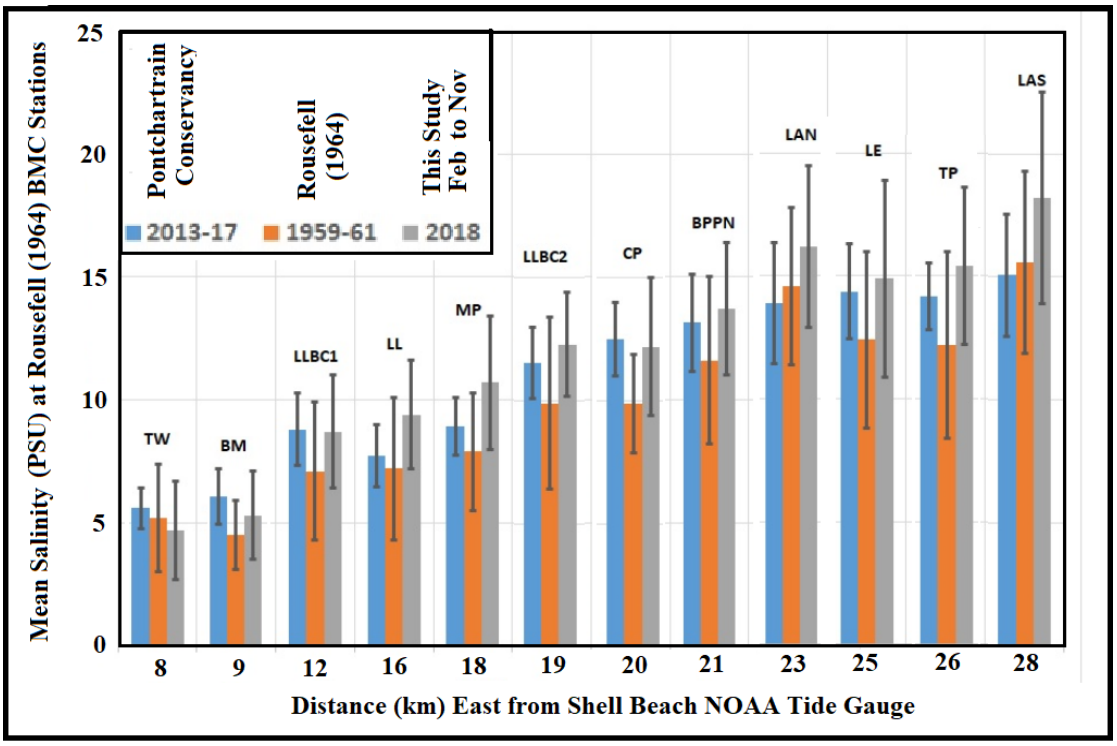

Figure S5. Comparing salinity at sites established by Rounsefell [72] from 1959–61 (Figure 2), Pontchartrain Conservancy from 2013–18, and from this 2018 sampling [18]. Stations are ranked by distance from the NOAA Shell Beach Gauge at the south end of Lake Borgne. No significant differences between the three datasets were found.

2. Supplementary Tables

Table S1. Salinity (psu from Conductivity) at 2018 Marsh Sites and Rounsefell Stations from March to November, 2018; See Figure 2 for locations.

Site	3/20/2018	4/25/2018	6/26/2018	7/5/2018	8/13/2018	9/12/2018	11/16/2018	Mean (SD)
2018 Marsh Sites								
A1a	4.2	1.7	1.7	1.8	–	9.7	8.1	4.5 (3.6)
A1b	4.4	1.4	2.2	1.6	5.1	10.1	7.0	4.5 (3.2)
A1c	–	1.7	1.9	–	–	10.0	7.5	5.3 (4.1)
A2	22.8	12.3	14.5	–	–	22.9	12.7	17.0 (5.4)
A3	7.3	4.6	4.4	–	–	8.4	6.8	6.3 (1.7)
B1	7.9	4.7	9.5	7.8	–	12.4	9.6	8.7 (2.6)
B2	6.5	7.1	11.0	–	–	10.9	8.5	8.8 (2.1)
C1	8.2	6.7	11.8	10.4	–	13.7	10.7	10.3 (2.5)
C2	16.0	11.6	14.8	–	–	16.9	13.5	14.6 (2.1)
2018 Rounsefell Stations								
BM	4.3	3.4	3.7	–	6.1	7.1	7.4	5.3 (1.8)
BPPN	15.4	9.6	13.9	–	16.3	15.7	11.1	13.7 (2.7)
CP	12.3	8.2	13.0	–	15.7	14.3	9.8	12.2 (2.8)
LAN	18.3	12.3	13.7	–	18.5	20.4	13.8	16.2 (3.3)
LAS	23.0	11.9	14.3	19.5	19.5	21.2	15.7	17.9 (4.0)
LE	18.1	11.6	10.6	–	18.7	18.8	11.8	14.9 (2.1)
LL	5.8	6.8	10.8	9.7	11.2	11.2	10.2	9.4 (2.2)
LLBC1	7.5	6.0	11.9	7.6	11.9	8.3	7.9	6.3 (1.7)
LLBC2	11.0	8.6	13.1	13.1	14.9	13.8	11.5	12.3 (2.1)
MP	8.4	6.6	11.8	–	12.8	13.8	10.6	10.7 (2.7)
TP	18.6	10.3	15.0	15.0	17.7	18.8	12.7	15.4 (3.2)
TW	4.8	1.6	3.8	3.7	5.1	7.9	6.3	4.7 (2.0)
Mean (SD)	11.2 (6.3)	7.2 (3.8)	9.9 (4.7)	9.0 (5.8)	13.3 (5.2)	13.6 (4.7)	10.2 (2.6)	10.5 (4.4)

Table S2. Shoreline erosion and accretion at the 2018 marsh study sites. See Figure 2 for location.

Site	A1a	A1b	A1c	A2	A3	C2	Mean
			Bayside Stations				
Bulk Density (g/cm³)	0.21	0.24	0.46	0.36	0.36	0.33	0.33
Lateral Shore Movement							
Advance (+) Retreat (–)	R	A	R	R	R	R	
10 mo. Total (cm)	–283 (33)	+86 (10)	–122 (29)	–124 (11)	96 (29)	99 (11)	+/– 135
Estimated Annual (cm/y)	–401	+121	–172	–175	–135	–140	+/– 191
Surface Elevation Change							
10 mo. VA (mm) 5 m	28 (1)	16 (1)	210*	13 (1)	17 (2)	15 (1)	18
Est. Annual 5 m (mm/y)	39	23	Shell	18	24	21	25
10 mo. VA (mm) 25 m	13 (1)	15 (1)	14 (3)	22 (3)	20 (3)	11 (2)	16
Est. Annual 25 m (mm/y)	18	21	20	31	28	16	22
10 mo. VA (mm) 50 m	5 (0.4)	9 (0.4)	21 (1)	17 (1)	21 (1)	6 (1)	13
Est. Annual 50 m (mm/y)	7	13	30	25	2	9	14
			Inland Marsh Pond Stations				
Site	B1	B2	C1	–	–	–	Mean
Bulk Density (g/cm³)	0.12	0.11	0.07	–	–	–	0.10
Lateral Shore Movement							
Advance (+) Retreat (–)	R	R	R	–	–	–	–
10 mo. Total (cm)	–9 (7)	–26 (7)	–26 (8)	–	–	–	–20
Estimated Annual (cm/y)	–13	–37	–37	–	–	–	–29
Marsh Surface Elevation	Change						
10 mo. VA (mm) 5 m	16 (1)	13 (1)	22 (1)	–	–	–	17
Est. Annual 5 m (mm/y)	22	19	31	–	–	–	24
10 mo. VA (mm) 25 m	7 (1)	10 (1)	6 (1)	–	–	–	8
Est. Annual 25 m (mm/y)	11	14	8	–	–	–	11
10 mo. VA (mm) 50 m	3 (0.2)	8 (1)	6 (1)	–	–	–	6
Est. Annual 50 m (mm/y)	4	12	9	–	–	–	8

* Only 1 measurement taken; shell beach berm deposit above marker layer.

Table S3. Soil Properties and Processes at CRMS stations active for more than a decade in the BMC and Breton Marshes (See Figure 3 for locations).

CRMS Station	LatitudeDegrees North	Marsh Elev. NAVD88 (mm)	SEC (mm/y)	VA (mm/y)	SS = VA–SEC (mm/y)	DS (mm/y)	TS =SS+DS (mm/y)	RSLR = TS + LSLR (mm/y)	OM (%)	BD (g/cc)	Sal (psu)
0003	30.10	274	53	20.1	14.8	1.0*	15.8	17.8	5.2	0.64	14.1
4572	30.07	233	5.7	8.7	3.1	1.0*	4.1	6.1	15.7	0.36	6.2
4596	30.06	170	4.3	10.4	6.1	1.0*	7.1	9.1	5.7	0.69	6.8
1069	30.05	288	1.7	11.6	9.8	1.0*	10.8	12.8	3.5	1.11	15.0
0108	29.96	254	6.8	11.4	4.6	1.0*	5.6	7.6	23.1	0.28	8.5
1024	29.87	226	8.4	11.3	2.9	3.3	6.2	8.2	16.5	0.42	11.0
4548	29.86	197	7.0	9.7	2.7	1.0*	3.7	5.7	11.0	0.53	4.1
4551	29.85	116	8.2	13.6	5.4	1.0*	6.4	8.4	15.0	0.31	4.1
4557	29.82	170	10.3	17.0	6.7	3.5	10.2	12.2	24.3	0.22	11.1
BMC Mean SD	**29.96 0.11**	**214.27 55.84**	**6.4 2.5**	**12.6 3.7**	**6.2 3.9**	**1.5 1.5**	**7.8 3.9**	**9.8 3.9**	**15.68. 9**	**0.51 0.28**	**9.0 4.1**
BRETON MARSH SOUTH OF BAYOU TERRE AUX BOEUFS											
0146	29.73	174	7.1	14.2	7.1	3.8	10.9	12.9	23.3	0.26	2.6
0135	29.69	248	0.1	10.6	10.5	4.0	14.5	16.5	30.0	0.28	1.6
0131	29.69	301	–2.1	7.9	10.0	4.0	14.0	16.0	28.2	0.29	0.6
0132	29.66	221	0.8	10.7	9.9	4.1	14.0	16.0	45.6	0.15	0.7
0147	29.66	189	4.6	7.0	2.4	4.1	6.5	8.5	18.9	0.39	5.0
0136	29.62	304	3.8	15.3	11.5	4.2	15.7	17.7	48.0	0.42	0.7
Breton Mean SD	**29.68 0.04**	**239.39 55.16**	**2.4 3.4**	**11.0 3.3**	**8.6 3.4**	**4.0 1.1**	**12.6 3.4**	**14.6 3.4**	**32.3 11.9**	**0.30 0.10**	**1.9 1.7**

Table S4. Subsidence and accretion data from Stump and Blind Lagoon SET Sites established in 2003, last monitored in 2008, and reoccupied 10 years later in 2018.

UNO Site	15–yr Marsh Elevation Change (mm)	SEC (mm/y)	15–yr Marsh Accretion (mm)	VA (mm/y)	15–yr Shallow Subsidence (mm)	SS (mm/y)	DS (mm/y)	TS (mm/y)	RSLR (mm/y)
Stump Lagoon Sites									
SL6	–88.5	–5.8	–	–	–	–	3.2	–	–
SL9	12.4	0.8	51.3	3.5	20.0	1.4	3.2	4.6	6.6
SL11	–95.2	–6.2	97.5	6.3	192.7	12.5	3.2	15.7	17.7
SL12	–53.4	–3.5	–	–	–	–	3.2	–	–
SL15	–41.2	–2.7	–	–	–	–	3.2	–	–
Mean (SD)	**–53.0 (43)**	**–3.5 (2.8)**	**74 (33)**	**4.9 (2.0)**	**106.0 (122)**	**7.0 (7.8)**	**3.2**	**10.2 (7.8)**	**12.2 (7.8)**
Blind Lagoon Sites									
BL1	53.0	3.4	77.6	5	24.6	1.6	3.2	4.9	6.9
BL3	89.0	5.7	109.7	7	20.7	1.3	3.2	4.6	6.6
BL4	69.9	4.5	–	–	–	–	3.2	–	–
BL6	74.2	4.7	–	–	–	–	3.2	–	–
BL8	52.2	3.3	94.8	6	42.6	2.7	3.2	6.0	8.0
BL9	70.3	4.5	147.4	9.4	77.1	4.9	3.2	8.2	10.2
BL11	42.2	2.7	–	–	–	–	3.2	–	–
BL12	59.0	3.7	89.6	5.7	30.6	1.9	3.2	5.2	7.2
BL14	61.6	3.9	85.0	5.4	23.4	1.5	3.2	4.8	6.8
Mean (SD)	**63.0 (14)**	**4.0 (0.9)**	**101.0 (25)**	**6.4 (1.6)**	**37.0 (22)**	**2.3 (1.4)**	**3.2**	**5.6 (1.4)**	**7.6 (1.4)**