ECOLOGICAL FLOW MODELING IN LOUISIANA AND TEXAS ESTUARIES

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The Nature Conservancy

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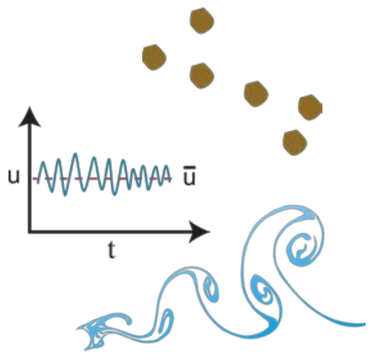
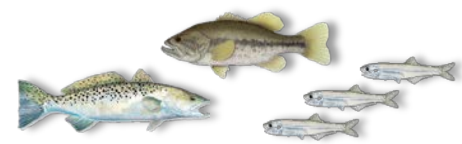
INTEGRATED COMPARTMENT MODEL (ICM)



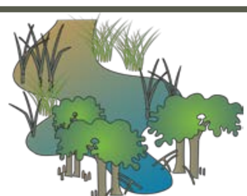
ICM-Hydro:
Hydrologic model
- Water surface elevation
- Water level variability
- Salinity
- Suspended sediment

Habitat Suitability Indices (HSI)
- Temperature
- Salinity
- % land

(Hijuelos et al., 2017)

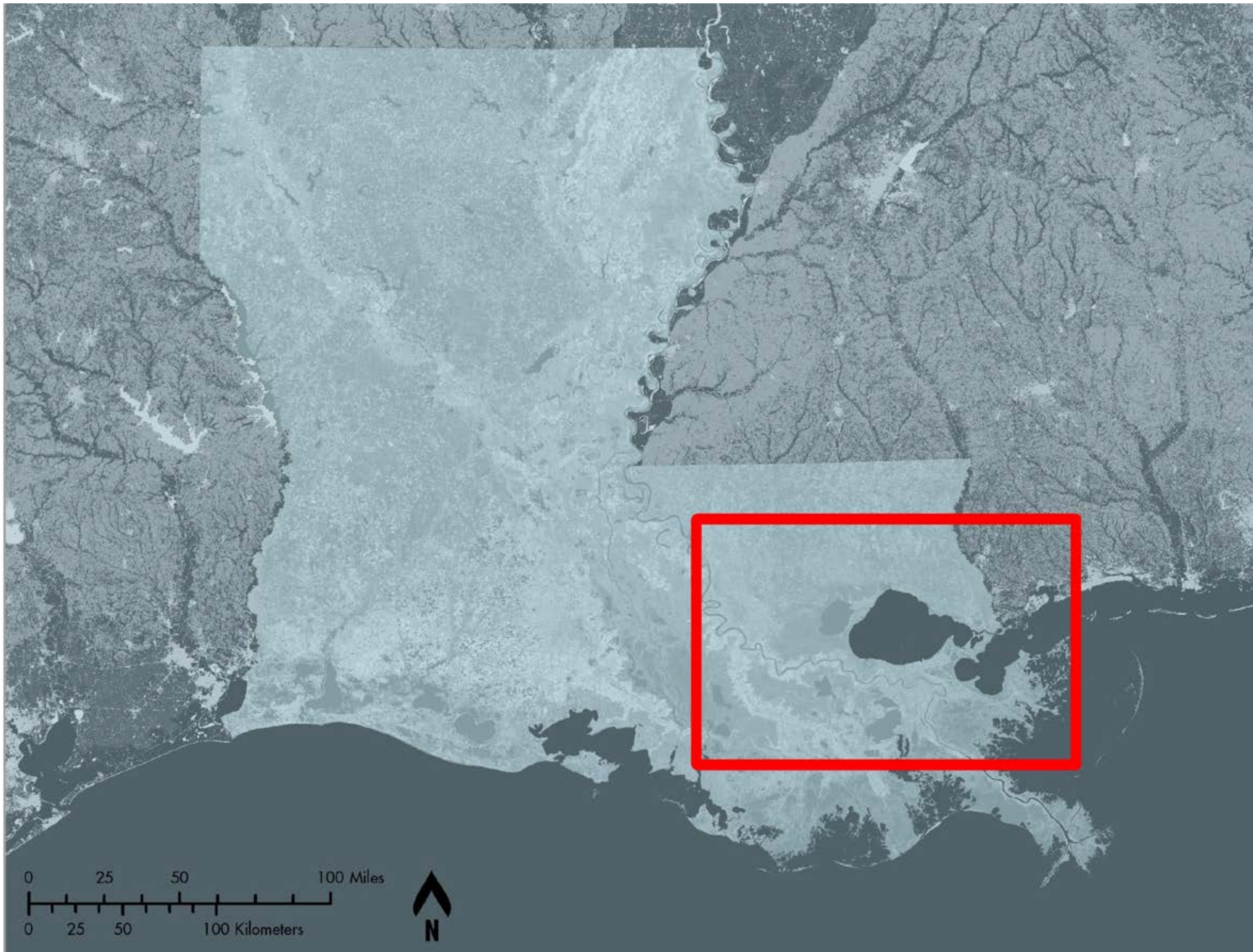


ICM-Morph:
Wetland morphology model
Long term landscape evolution, relative elevation model
(Couvillion et al., 2013)

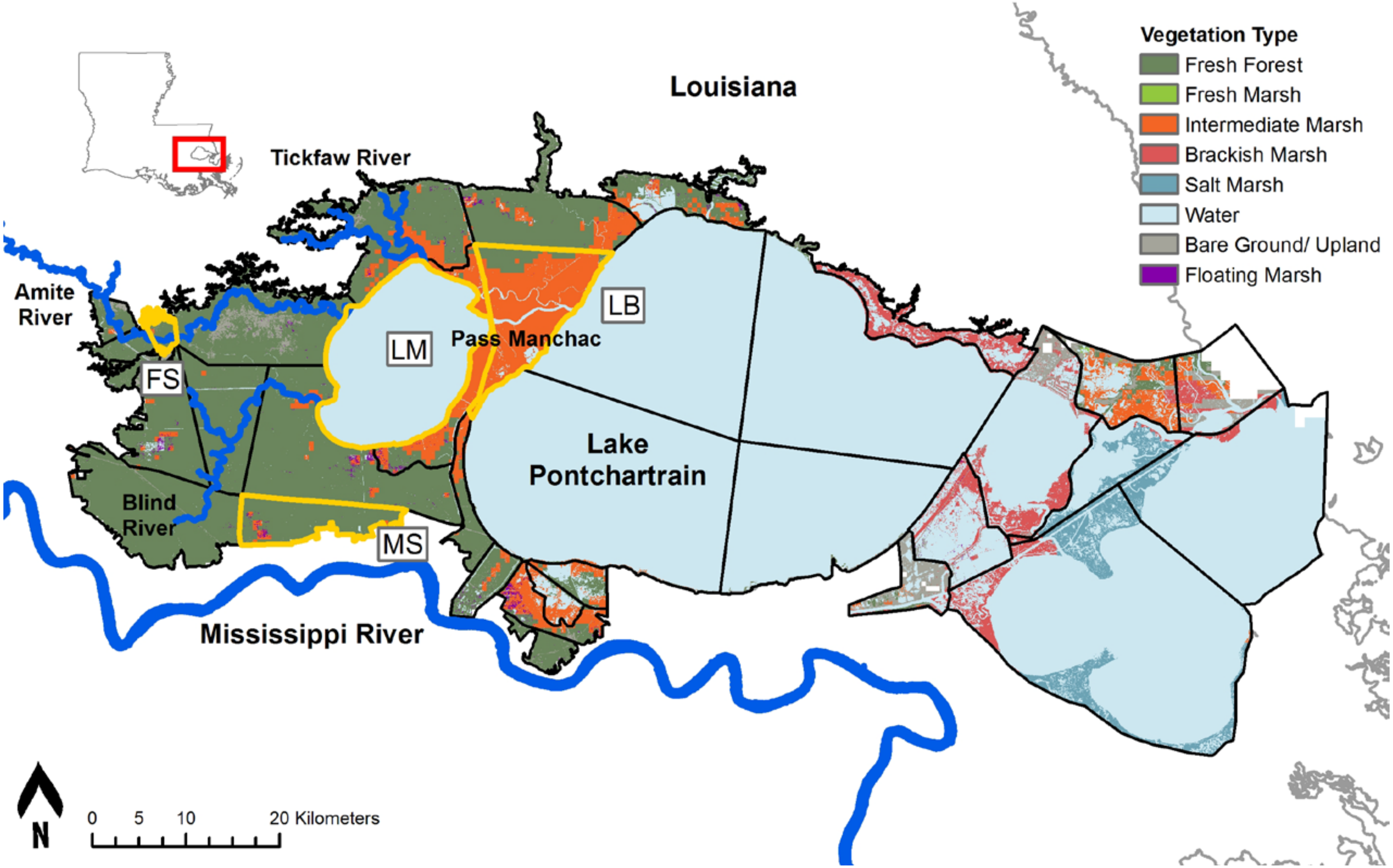


ICM-LAVegMod:
Vegetation model
Species coverage
(Visser and Duke-Sylvester, 2017)
(Visser et al., 2013)

STUDY AREA: MAUREPAS SWAMP LAKE PONTCHARTRAIN BASIN, LA



MAUREPAS SWAMP MODEL DOMAIN



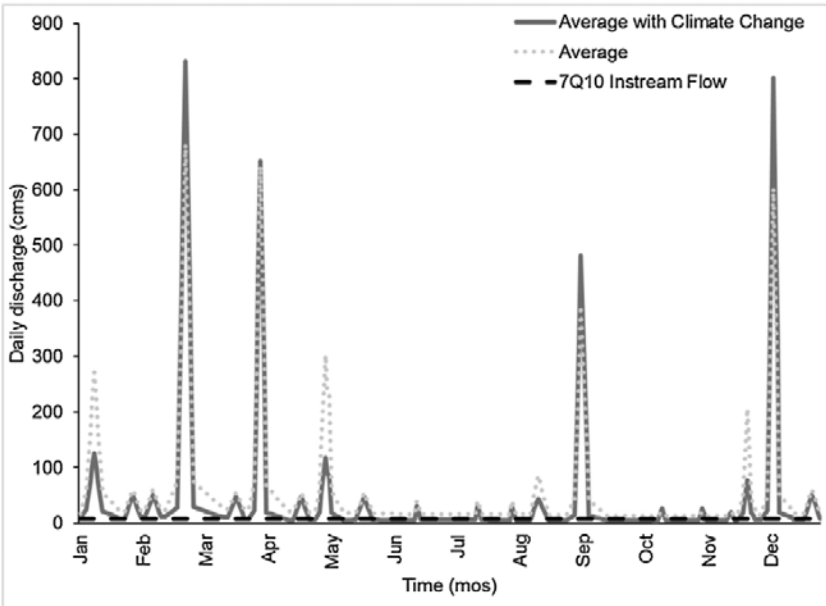
FS = French Settlement
LB = Land Bridge

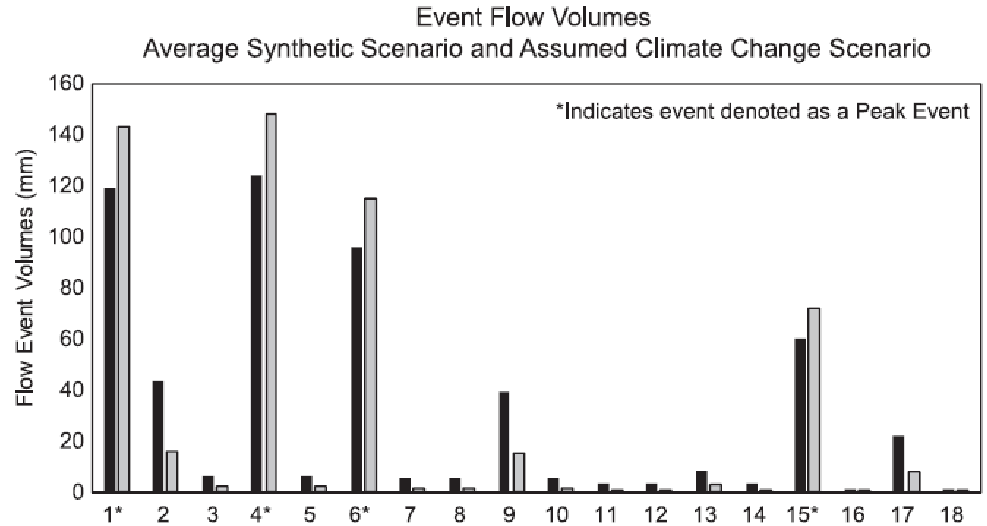
LM = Lake Maurepas
MS = Maurepas Swamp

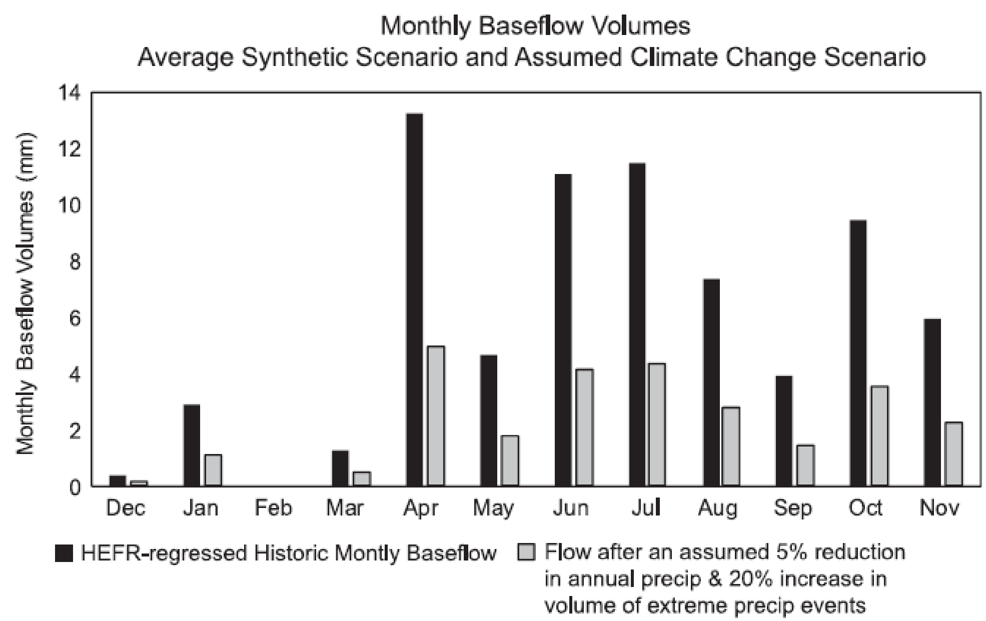
MODEL SIMULATIONS

	Without Restoration	With Restoration
Normal Rainfall	“Base”	“Base_CD” Comite diversion “Base_MP” Draft MP2017 projects
Climate Change Rainfall	“Base_CC”	“Base_CC_MP” Draft MP2017 projects “Base_CC_MP_AD” Draft MP2017 projects + hypothetical diversion

AMITE RIVER : CLIMATE CHANGE HYDROGRAPH







Over the past several decades, the southeastern United States has seen, on average, a 27% increase in volume of the largest precipitation event in each year.

Potential change in seasonal precipitation volumes in coastal Louisiana at the end of 21 st century, compared to 20th century values. Values are estimated from the U.S. National Climate Assessment and relative confidence in model conclusions are not included in this table (Melillo et al., 2014).

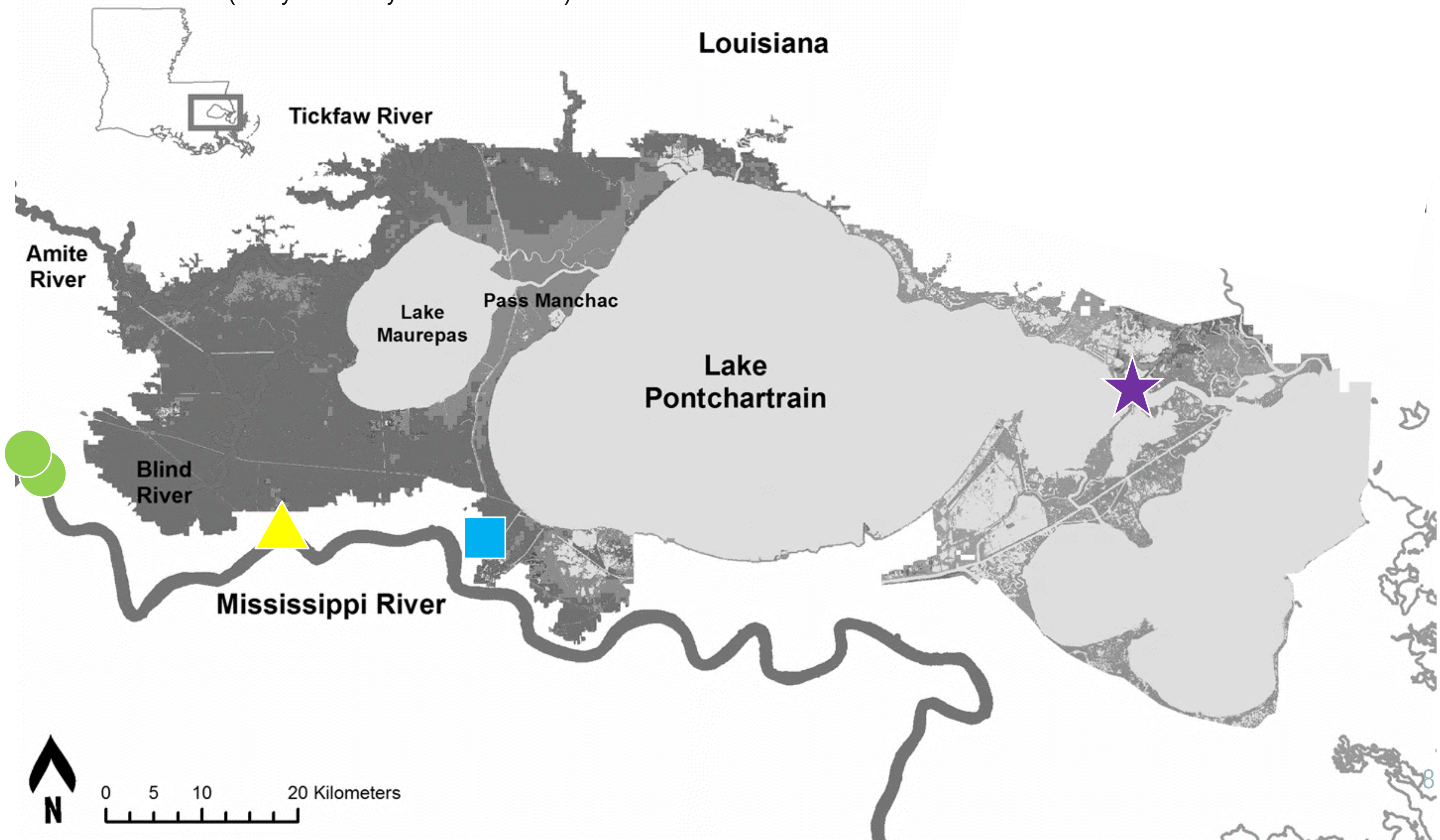
Season	A2 Scenario[a]	RCP 2.6 Scenario[b]	RCP 8.5 Scenario[a]
Winter	0 – 20% Reduction	no significant change	0 – 10% Reduction
Spring	10 – 20% Reduction	no significant change	0 – 10% Reduction
Summer	10 – 20% Reduction	no significant change	10 – 20% Reduction
Fall	0 – 20% Reduction	0 – 10% Increase	0 – 10% Increase

[a] A2 & RCP8.5 are roughly equivalent and are “continued emissions” scenarios.
[b] RCP2.6 is an emissions scenario representing a rapid reduction in greenhouse gas emissions.

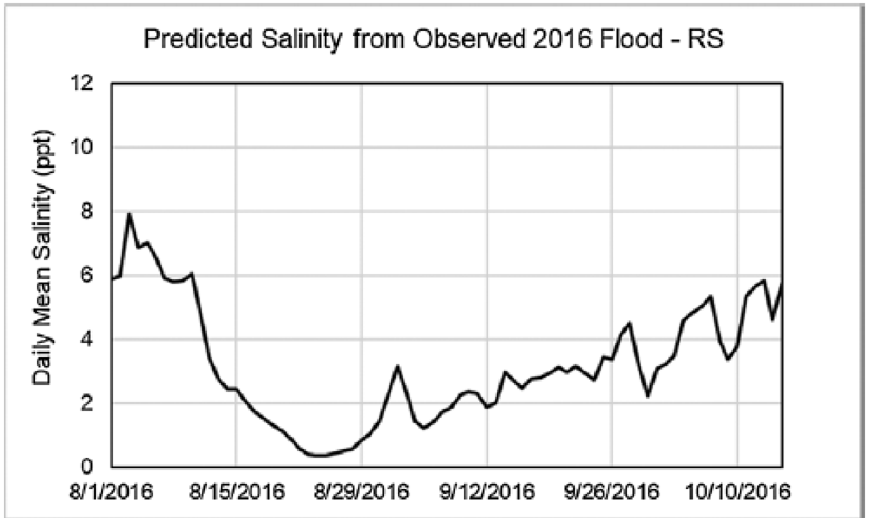
SIMULATION DETAILS

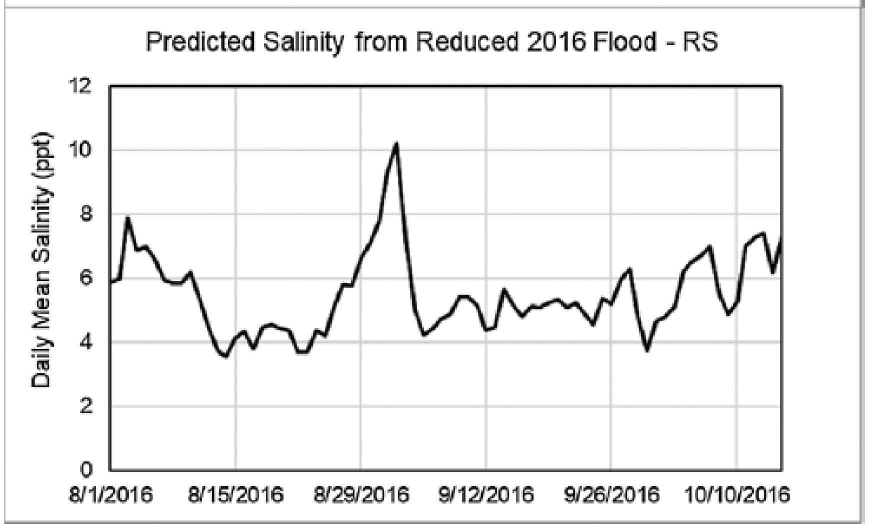
“Draft” Coastal Master Plan Projects

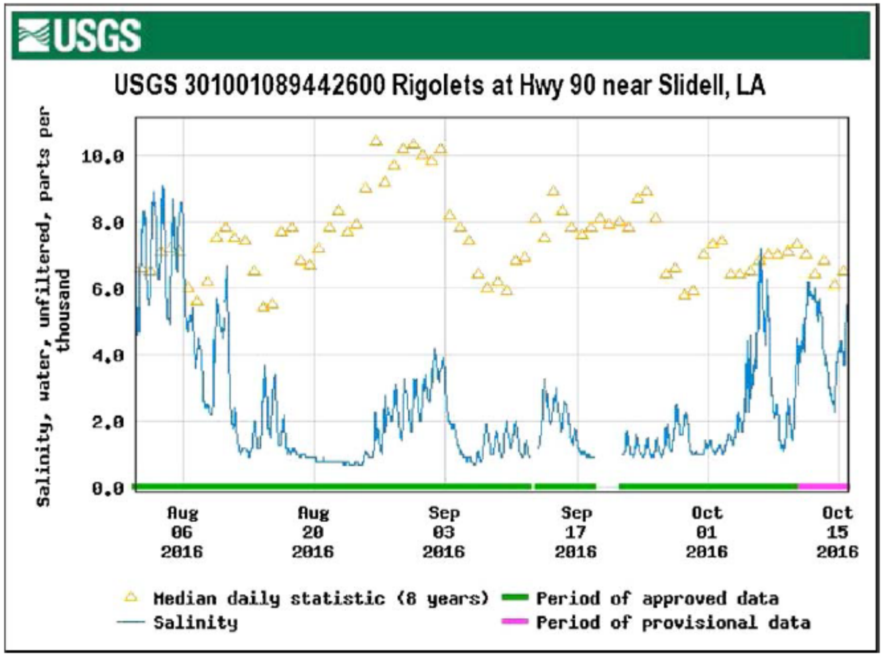
- Union Freshwater Diversion
- Manchac Landbridge Diversion
- East Maurepas Diversion (newly funded by Restore Council)
- Lake Pontchartrain Barrier



SIMULATION RESULTS

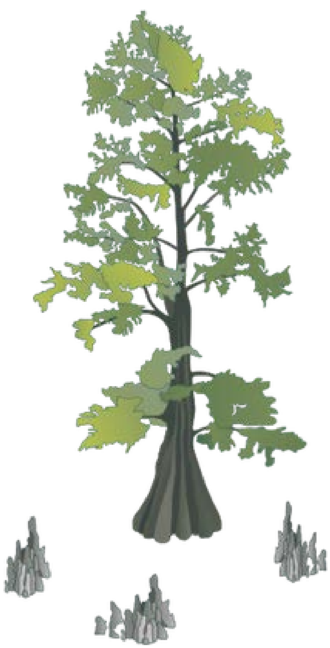


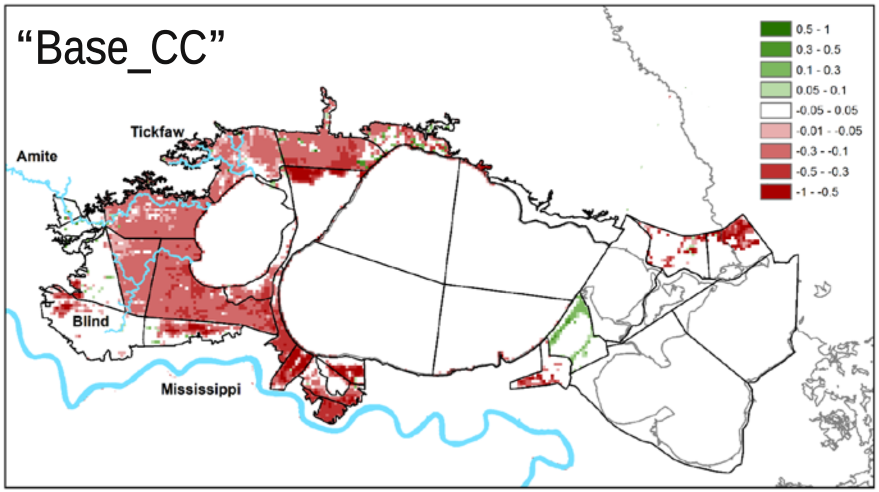


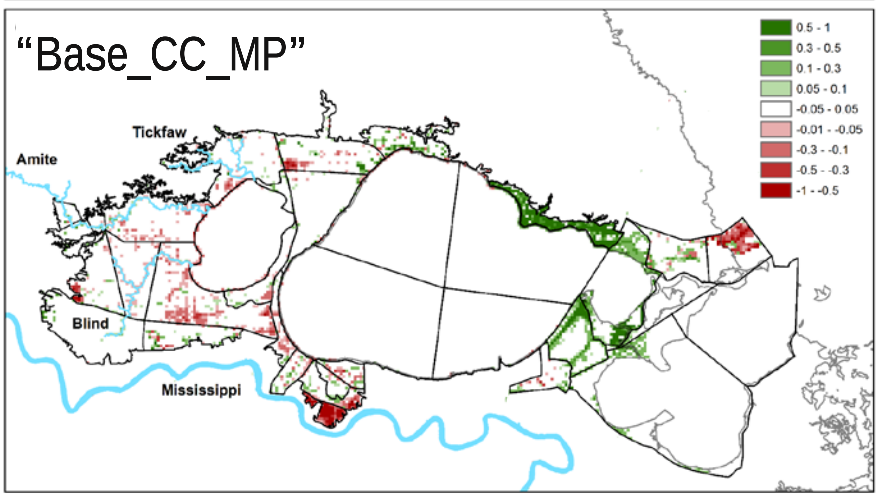


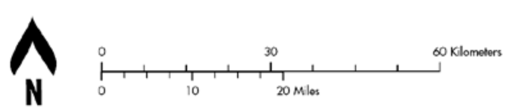
August 2016 flood event had substantial impact on salinities in Lake Pontchartrain.

BALD CYPRESS 50-YEAR DIFFERENCE MAP









Without Restoration

"Base_CC" Climate change rainfall

With Restoration
(Coastal Master Plan Projects)

"Base_CC_MP" Climate change rainfall

CONCLUSIONS FROM MAUREPAS SWAMP HYDROLOGIC RESTORATION MODELING

- Fresh forested areas in Maurepas Swamp decrease significantly under all future climate and relative sea level rise scenarios except when there are restoration projects.

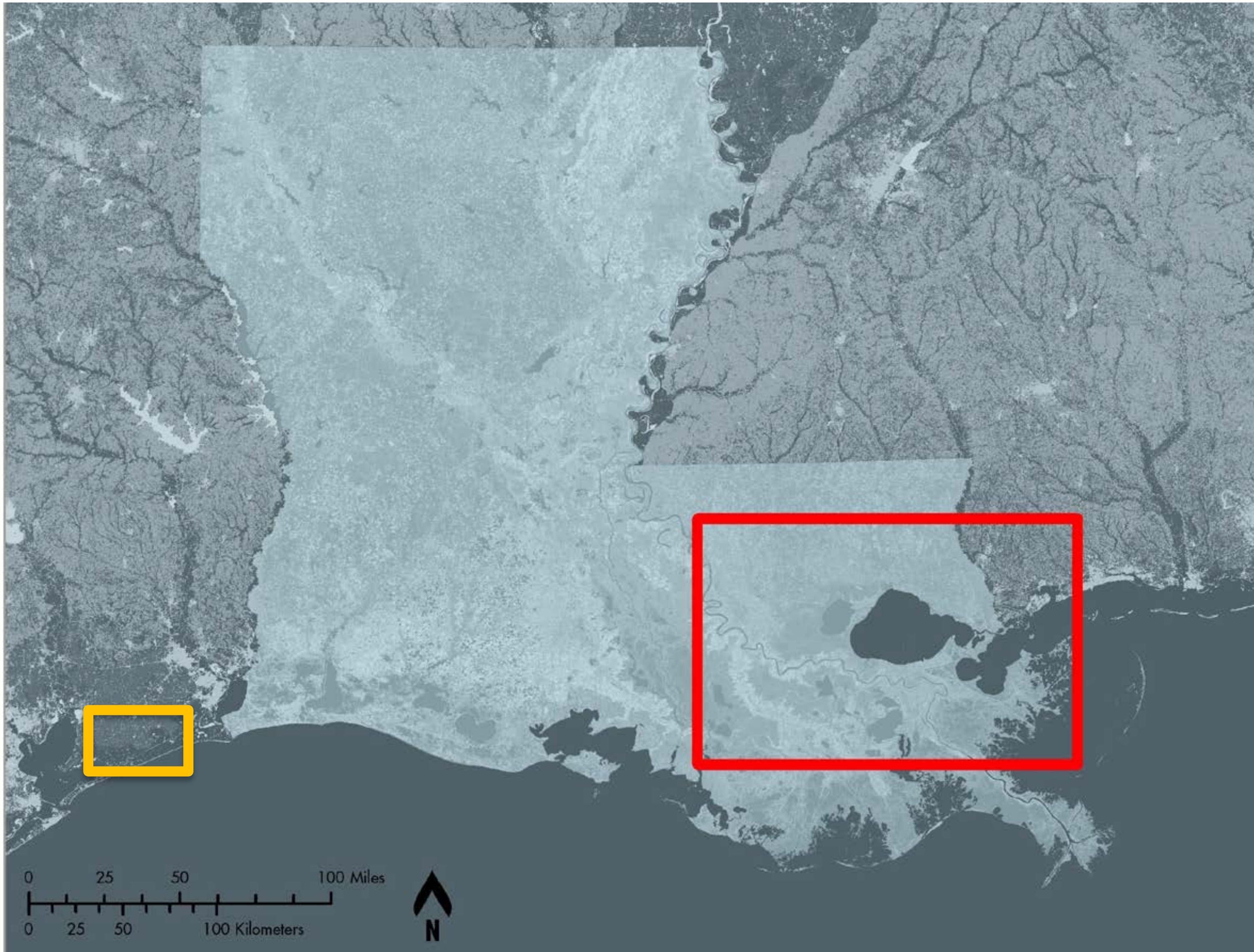
- Modeling suggests that the single biggest contributing factor in the freshwater supply to the Lake Maurepas area is the challenge of relative sea level rise - the combination of rising seas and sinking land.

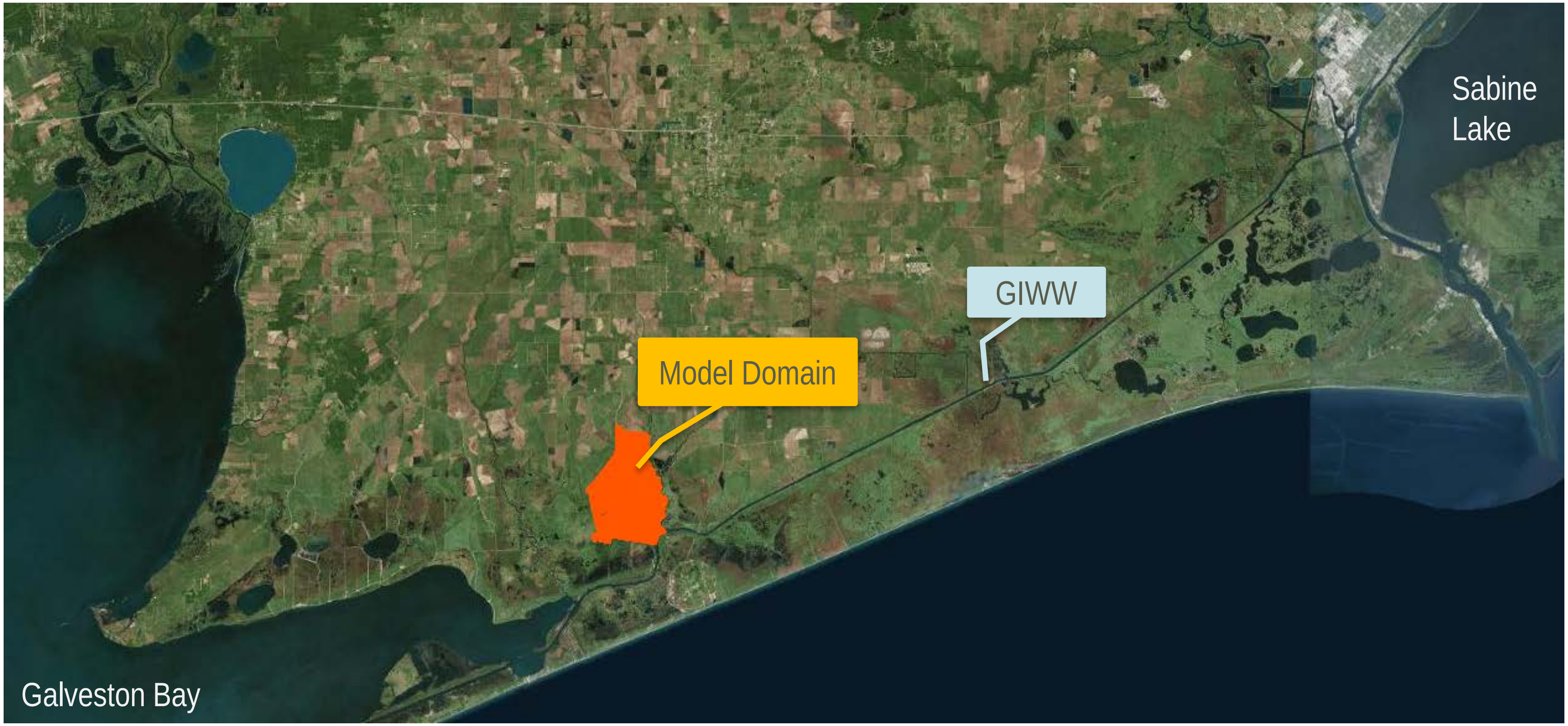
- Results indicate that the August 2016 flood event along the Amite River has little long-term impact on either fisheries or wetland forests.

- Taking additional fresh water from the Amite River via Comite Diversion doesn't appear to effect salinities or the amount of fresh forested wetland in French Settlement or Lake Maurepas areas.

Baustian et al., 2018. *Ecological Indicators*. https://doi.org/10.1016/j.ecolind.2017.10.005

STUDY AREA: ANAHUAC NWR CHENIER PLAIN, TX





HYDROLOGIC RESTORATION OF ANAHUAC NATIONAL WILDLIFE REFUGE

HYDROLOGIC RESTORATION OF ANAHUAC NATIONAL WILDLIFE REFUGE

Problem: During 2011 drought, wetlands in portions of the Anahuac National Wildlife Refuge (ANWR) experienced extreme salinity stress

Objective: Design freshwater flow delivery scenarios to reduce salinity stress during drought periods within ANWR. Restoration project would ultimately purchase water from local water management district to meet these goals.

HYDROLOGIC RESTORATION OF ANAHUAC NATIONAL WILDLIFE REFUGE

Phase 1 - hydrologic model proof of concept

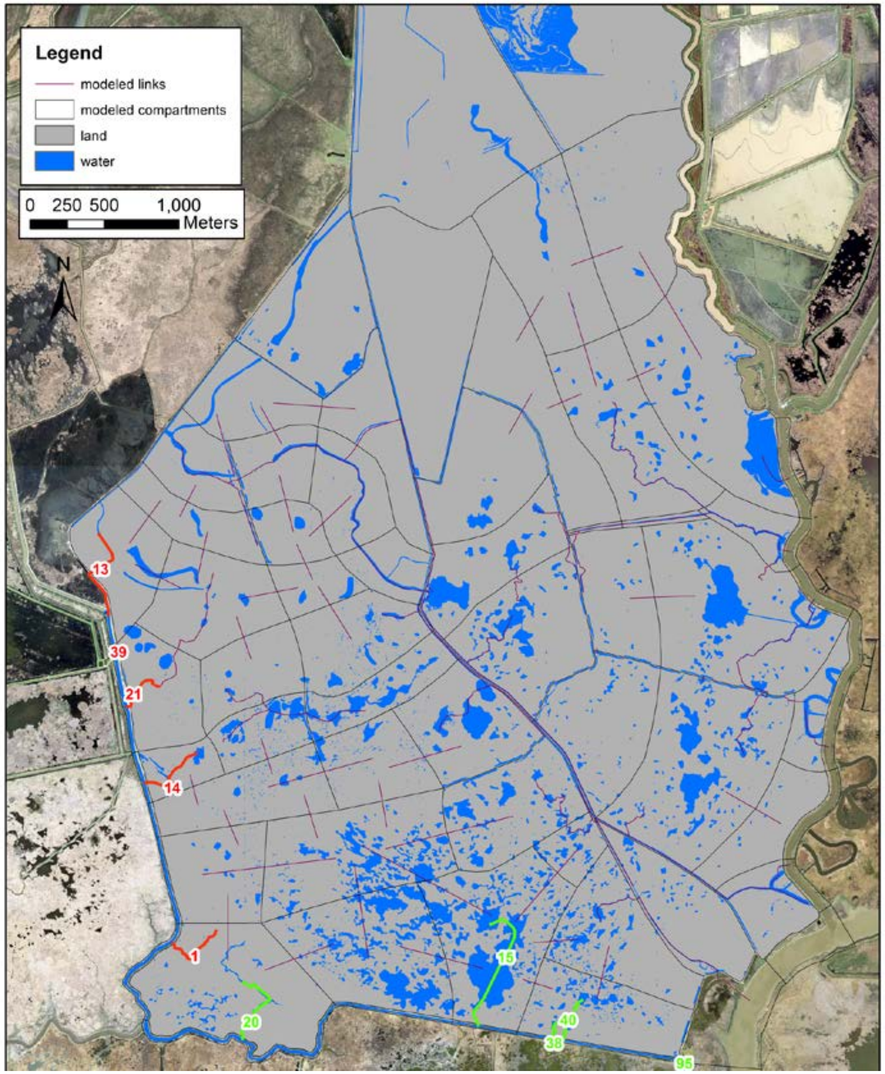
- Initialize ICM with high-resolution LiDAR DEM and aerial imagery
- Utilize limited set of hourly water level and salinity data for initial model calibration

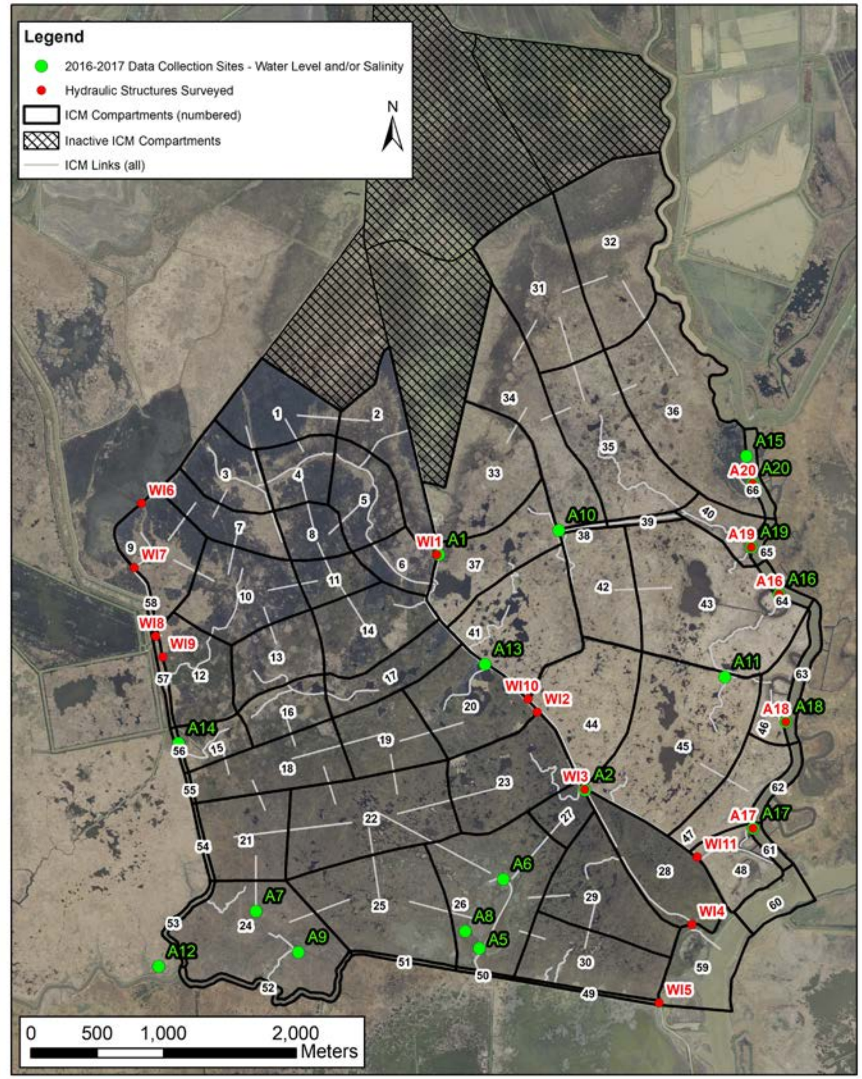
Phase 2 - operationalize vegetation response model

- Conduct drone-based vegetation survey
- Additional model calibration
- Simulate vegetation response to hydrologic restoration scenarios

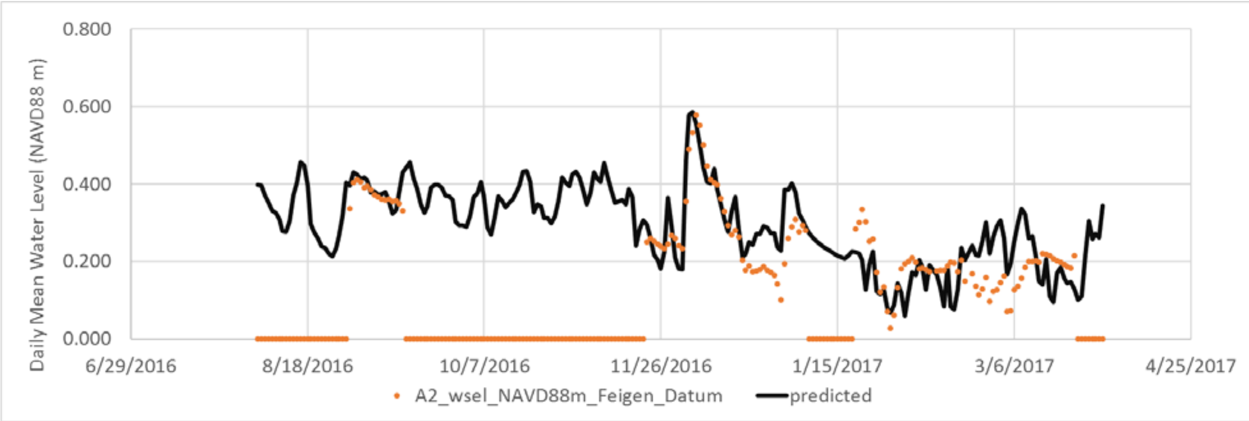
Phase 3 - test more complex restoration scenarios

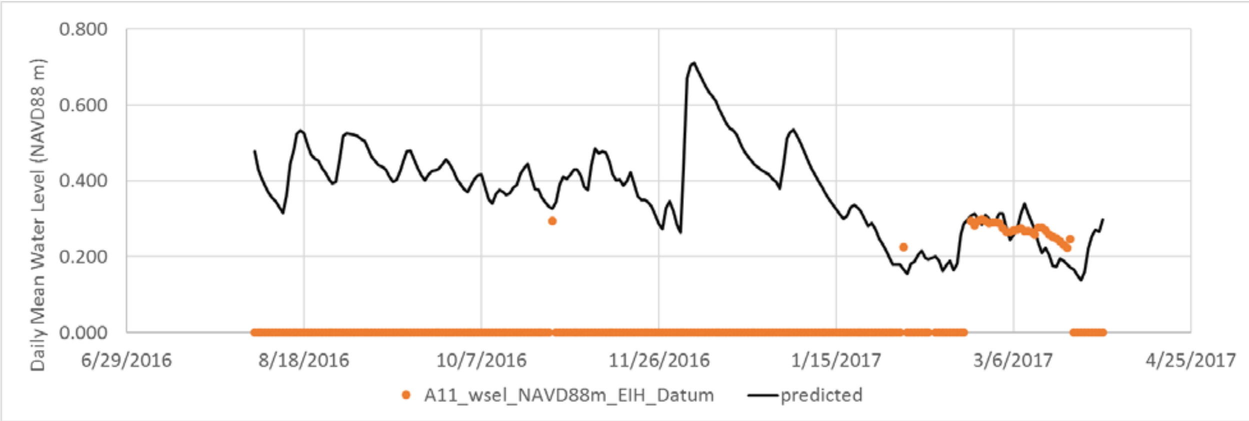
MODEL INITIALIZATION



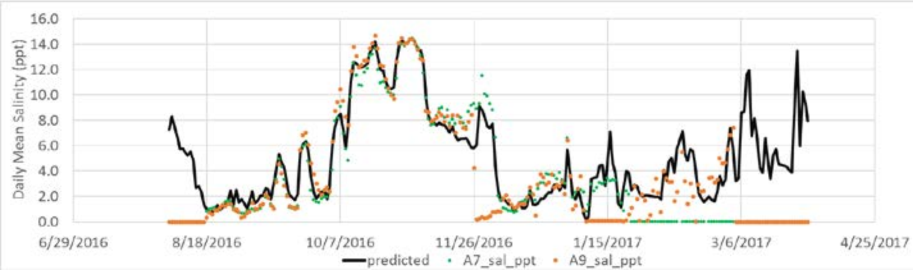


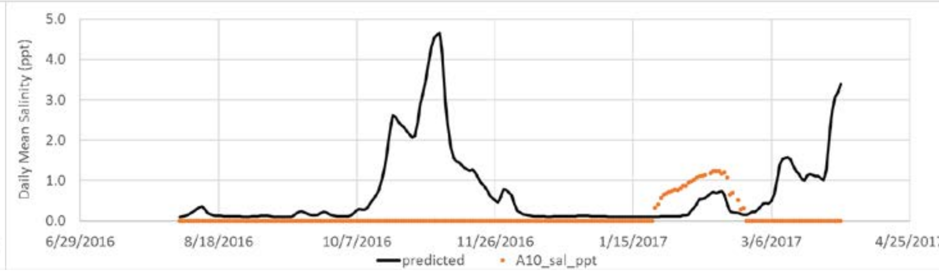
MODEL CALIBRATION: STAGE

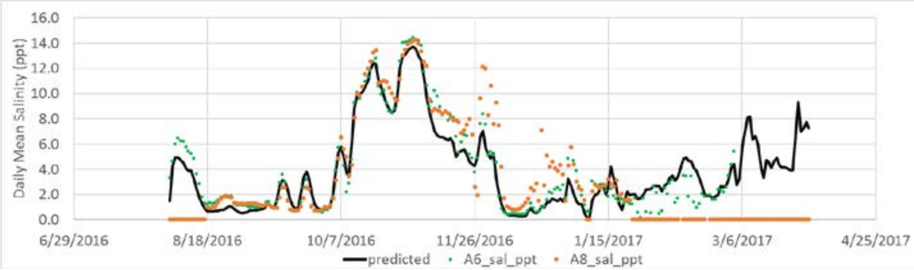


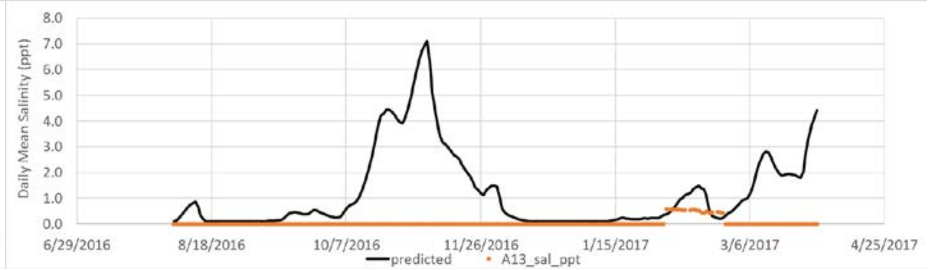


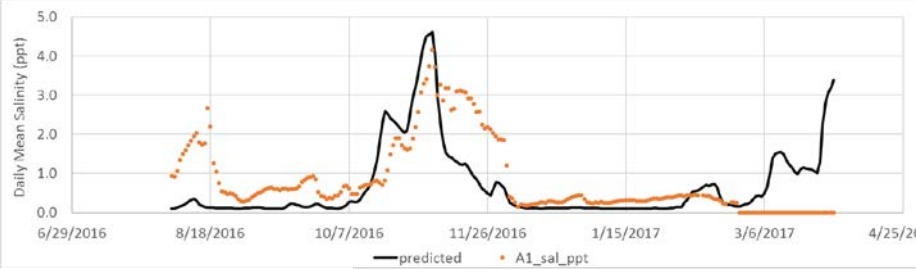
MODEL CALIBRATION: SALINITY

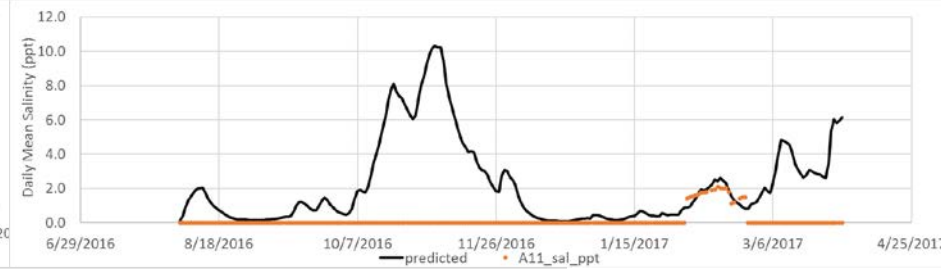


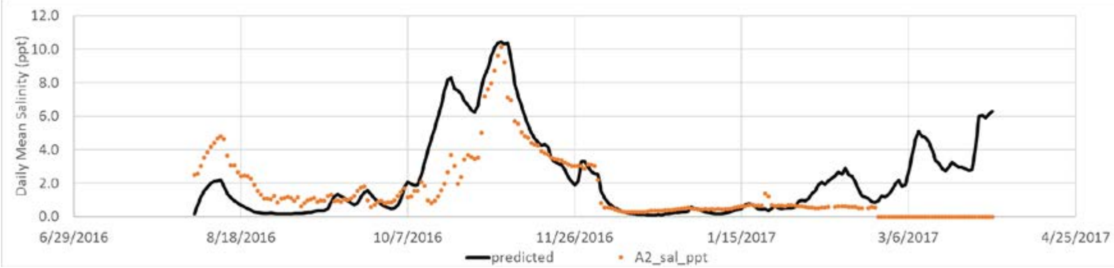






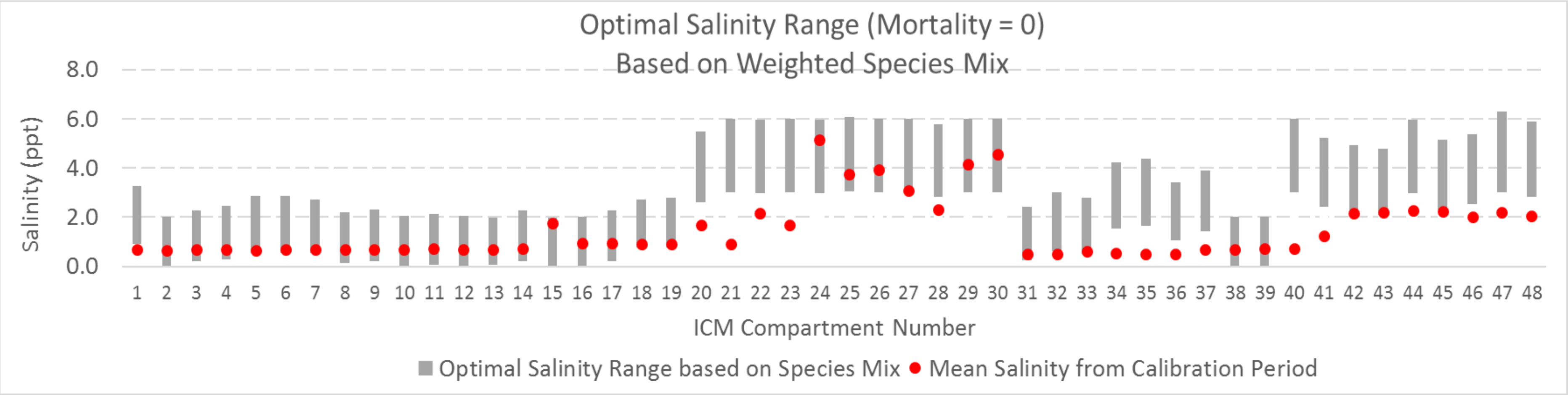






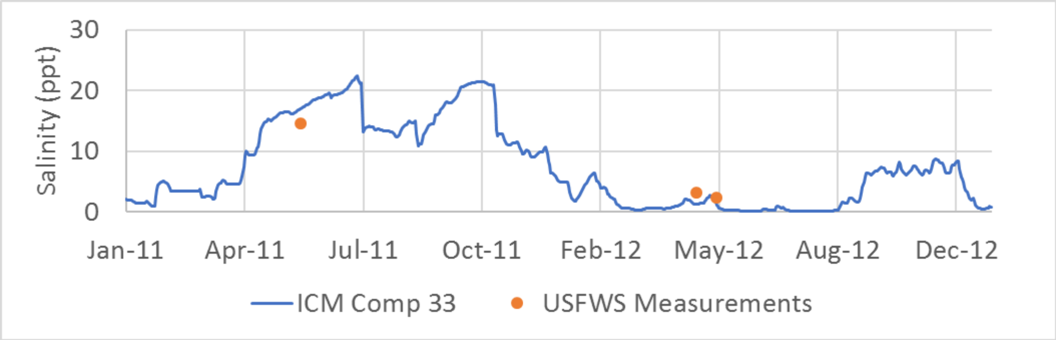
MODEL CALIBRATION: SALINITY

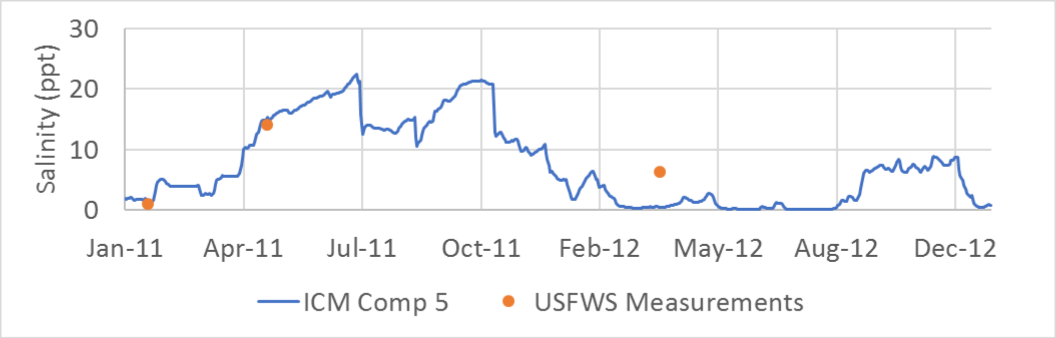
Scientific Names	Common Names	Habitat Type	Average Annual Salinity Range
Eleocharis baldwinii	ELBA	Fresh	0 to 2 ppt
Panicum hemitomon	PAHE2	Fresh	0 to 1 ppt
Typha domingensis	TYDO	Fresh	0 to 3 ppt
Phragmites australis	PHAU7	Intermediate	0 to 4 ppt
Schoenoplectus californicus	SCCA11	Intermediate	0.2 to 3 ppt
Iva frutescens	IVFR	Brackish	2 to 7 ppt
Spartina patens	SPPA	Brackish	3 to 6 ppt
Distichlis spicata	DISP	Brackish/Saline	3 to 9 ppt
Juncus roemerianus	JURO	Brackish/Saline	5 to 10 ppt
Spartina alterniflora	SPAL	Saline	9 to 18 ppt

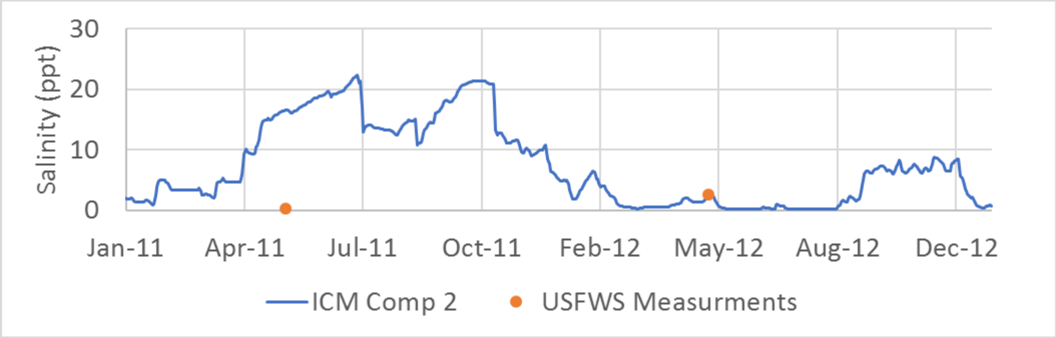


Modeled mean salinity (ppt) during the calibration period for each ICM-Hydro model compartment (red dots) and the preferred salinity range for vegetation species mix of each compartment (vertical gray bars).

MODEL VALIDATION: SALINITY DURING 2011 DROUGHT







Scenario Number	Model Case	Freshwater Flow Delivery			Flowrates	
		Volume (ac-ft)	Start Date	Duration (days)	JDT (cms)	EBBT (cms)
Calibration	G000	0	-	0	0.00	0.00
Dry Condition Baseline	G001	0	-	0	0.00	0.00
1*	G002	3000	July 1	100	0.43	0.00
2*	G003	6000	July 1	100	0.86	0.00
3*	G004	10000	July 1	100	1.43	0.00
4*	G005	3000	July 1	50	0.43	0.43
5*	G006	6000	July 1	50	0.86	0.86
6	G007	10000	July 1	50	1.43	1.43
7	G008	10000	Mar 15	210	0.34	0.34
8	G009	10000	Mar 15	210	0.00	0.68
9⁺	G010	10000	Mar 15	210	0.34	0.34
Dry Condition Baseline with Less Severe Drought in 2014	G011	0	-	0	0.00	0.00
Scenario 6 with Less Severe Drought in 2014	G012	10000	July 1	50	1.43	1.43
Scenario 7 with Less Severe Drought in 2014	G013	10000	Mar 15	210	0.34	0.34
Scenario 8 with Less Severe Drought in 2014	G014	10000	Mar 15	210	0.00	0.68
Drought in 2011 and Less Severe Drought in 2014 with RTC threshold of 9 ppt	G015	2000	varies	42	0.34	0.34
Drought in 2011 and Less Severe Drought in 2014 with RTC threshold of 25 ppt	G016	4857	varies	102	0.34	0.34
Drought in 2011 and Less Severe Drought in 2014 with RTC threshold of both 9 and 25 ppt	G017	5333	Varies	112	0.34	0.34
Dry Condition Baseline with connections open to East Bay Bayou	G018	0	-	-	0.00	0.00

*Scenarios 1, 2, 3, 4 and 5 were only run during the first phase analysis.

⁺Scenario 9 has a flow delivery location in JDT that was split between compartments 1 and 2, as compared to being delivered solely to compartment 3 in all other scenarios.

Hydrologic restoration options analyzed:

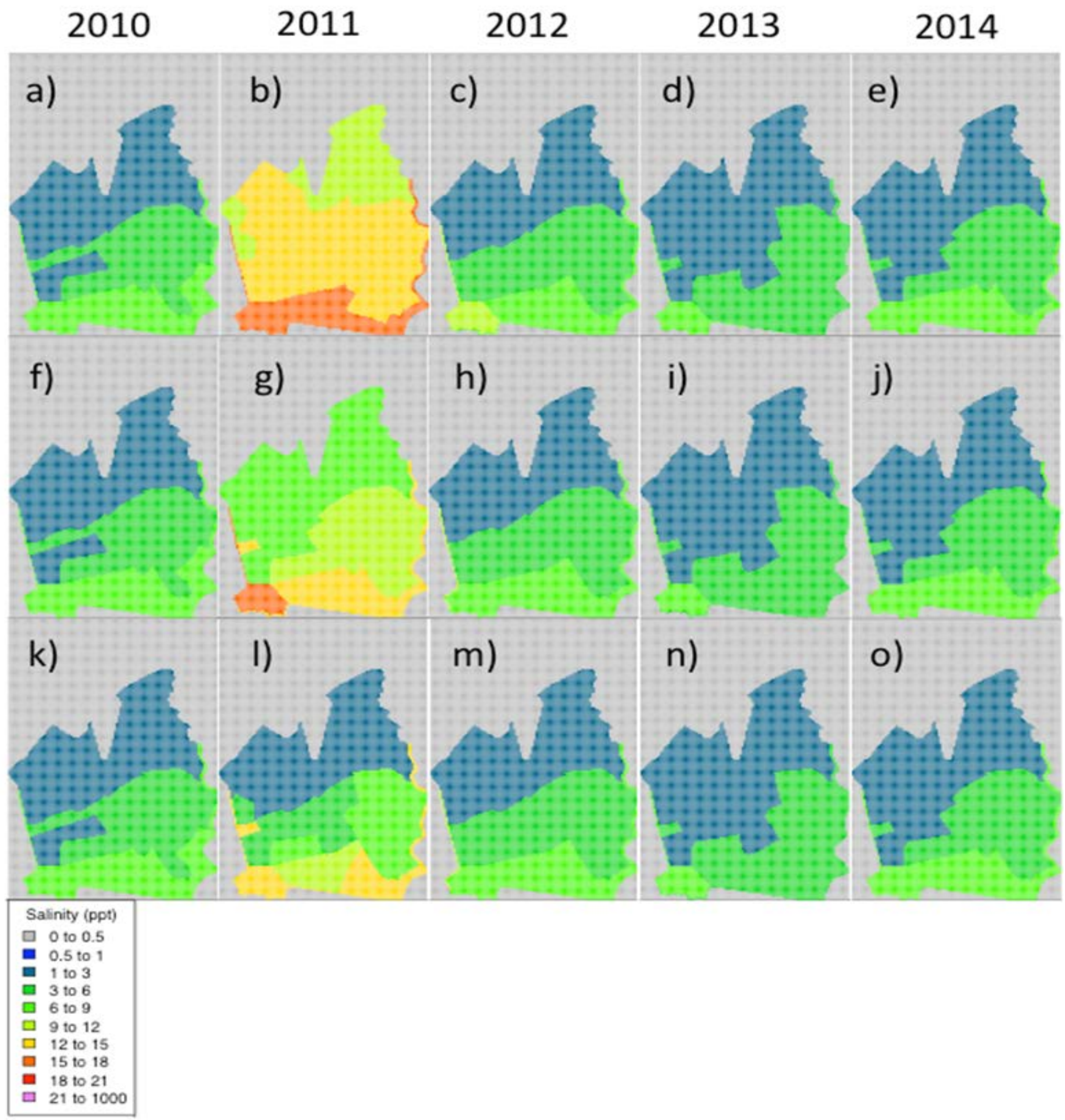
- Multiple water purchase volumes
- Delivery location and duration
- Lower flowrate, longer duration & multiple locations
- Less severe drought
- Vary purchase volume by using salinity threshold triggers
- No water purchase, remove control structures

FRESHWATER RESTORATION IMPACT ON SALINITY DURING GROWING SEASON

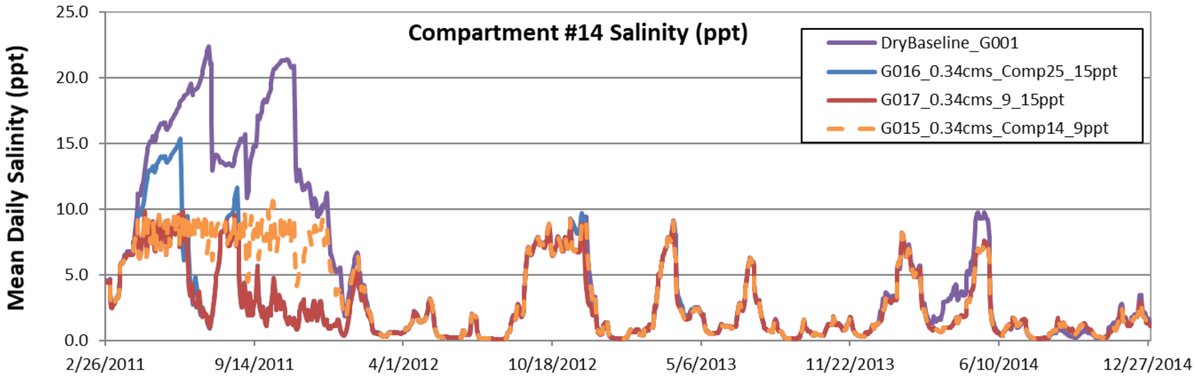
Dry Condition
Baseline Scenario

Scenario 6
50-day Flow
Delivery

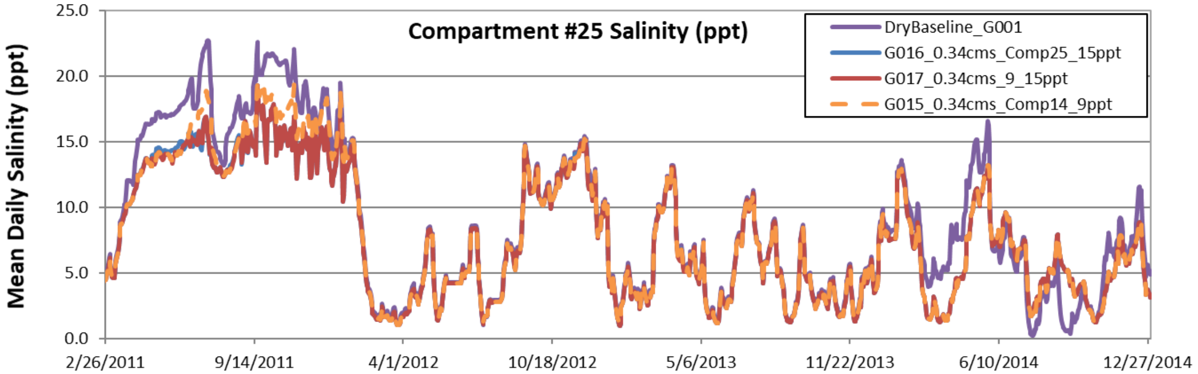
Scenario 7
210-day Flow
Delivery



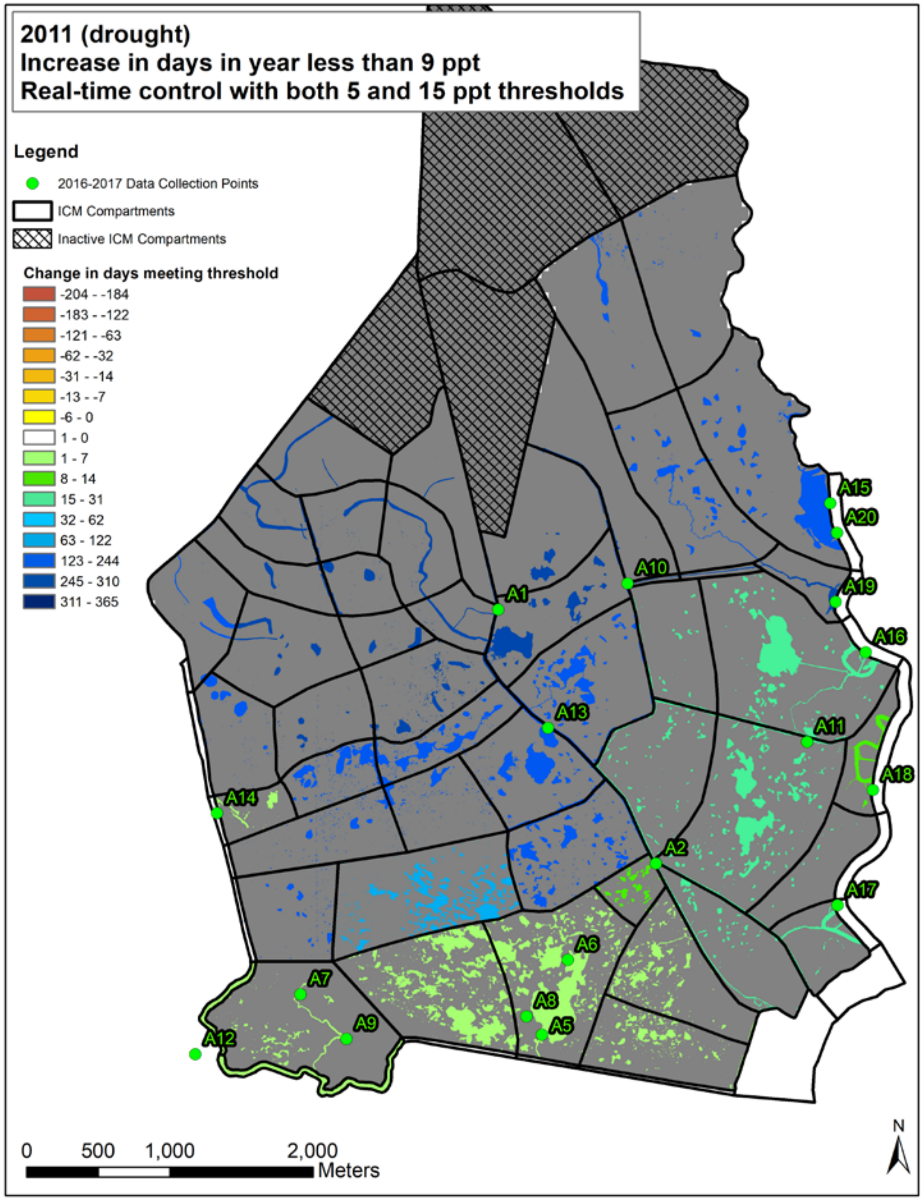
SALINITY-BASED RULES FOR FRESHWATER DELIVERY



Daily mean salinity from the Dry Baseline and three RTC scenarios for Compartment 14 located in the upper reaches of the Jackson Ditch tract.



Daily mean salinity from the Dry Baseline and three RTC scenarios for Compartment 25 located in the lower reaches of the Jackson Ditch tract.


2011 (drought)
Increase in days in year less than 9 ppt
Real-time control with both 5 and 15 ppt thresholds
Legend
2016-2017 Data Collection Points
ICM Compartments
Inactive ICM Compartments
Change in days meeting threshold
-204 - -184
-183 - -122
-121 - -63
-62 - -32
-31 - -14
-13 - -7
-6 - 0
1 - 0
1 - 7
8 - 14
15 - 31
32 - 62
63 - 122
123 - 244
245 - 310
311 - 365
A15
A20
A10
A1
A19
A16
A13
A11
A18
A14
A2
A17
A6
A7
A8
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0 500 1,000 2,000
Meters
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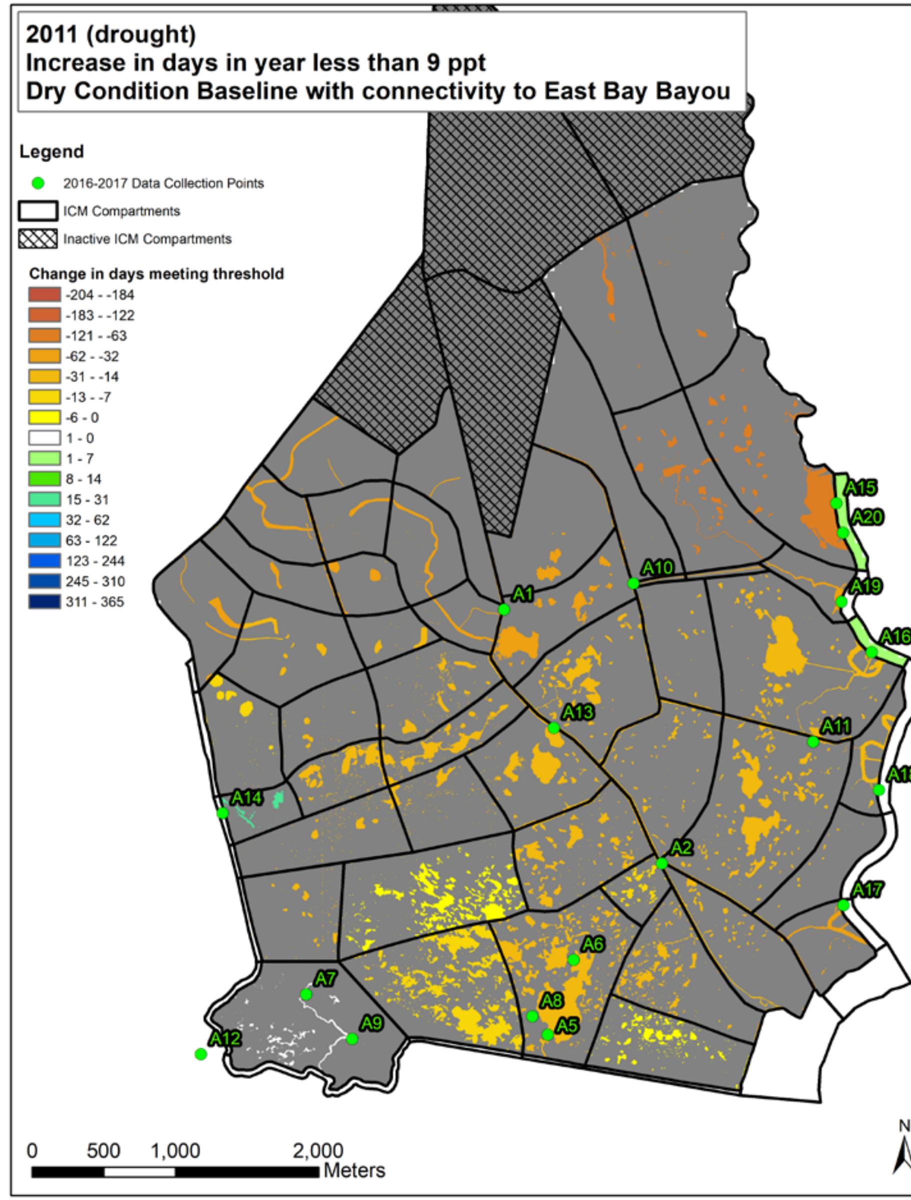
2011 (drought)
Increase in days in year less than 9 ppt
Dry Condition Baseline with connectivity to East Bay Bayou
Legend
2016-2017 Data Collection Points
ICM Compartments
Inactive ICM Compartments
Change in days meeting threshold
-204 - -184
-183 - -122
-121 - -63
-62 - -32
-31 - -14
-13 - -7
-6 - 0
1 - 0
1 - 7
8 - 14
15 - 31
32 - 62
63 - 122
123 - 244
245 - 310
311 - 365
A15
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A5
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0 500 1,000 2,000
Meters
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CONCLUSIONS FROM ANAHUAC NWR HYDROLOGIC RESTORATION MODELING

- The Integrated Compartment Model is well validated for water levels and salinity for a small fresh/intermediate wetland tract in the Texas Chenier Plain
  - vegetation species present are consistent with LAVegMod parameters
- Freshwater purchasing seems to be a more effective manner to reduce salinities during drought periods than removal of hydraulic control structures around wetland tracts
  - Further investigation/data collection for flow rates in tributaries draining into and alongside wetlands tracts may alter this conclusion
- Model simulations indicate that real-time control of freshwater delivery based upon salinity thresholds within the tract could provide cost-savings via reduced water usage

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THANK YOU

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