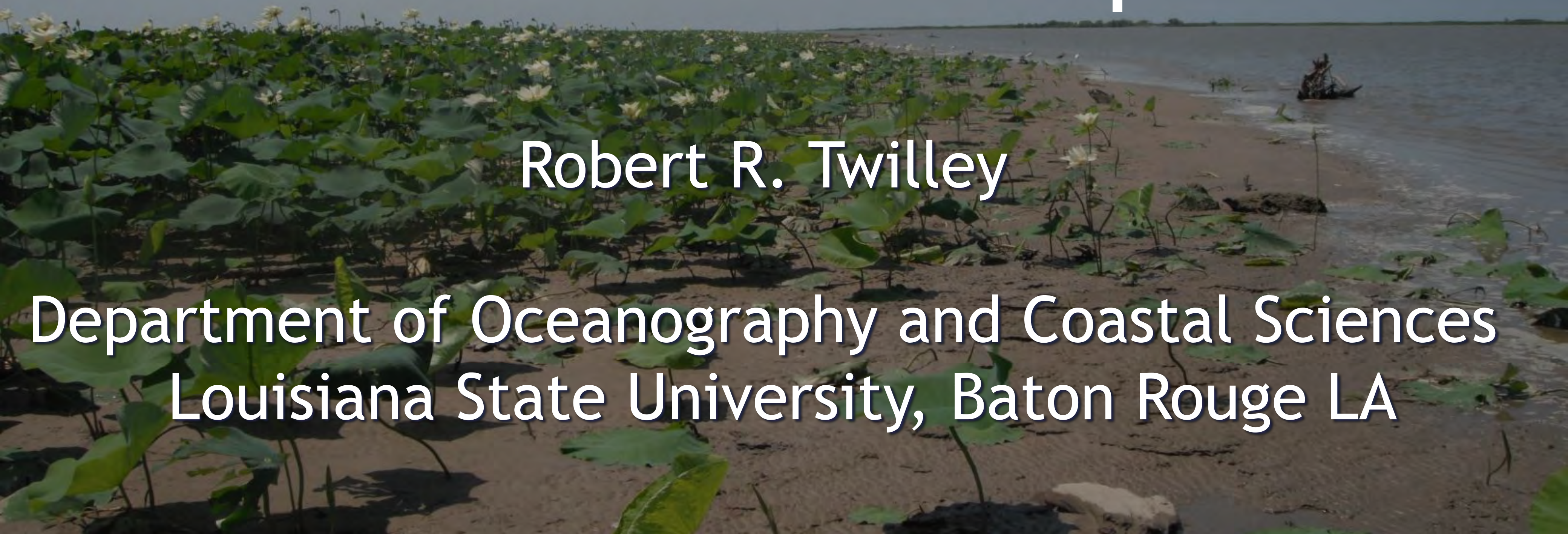
Disruptions to the Delta Cycle, Human Settlement, and Future River Management: Perspectives for the NOAA Diversion Workshop

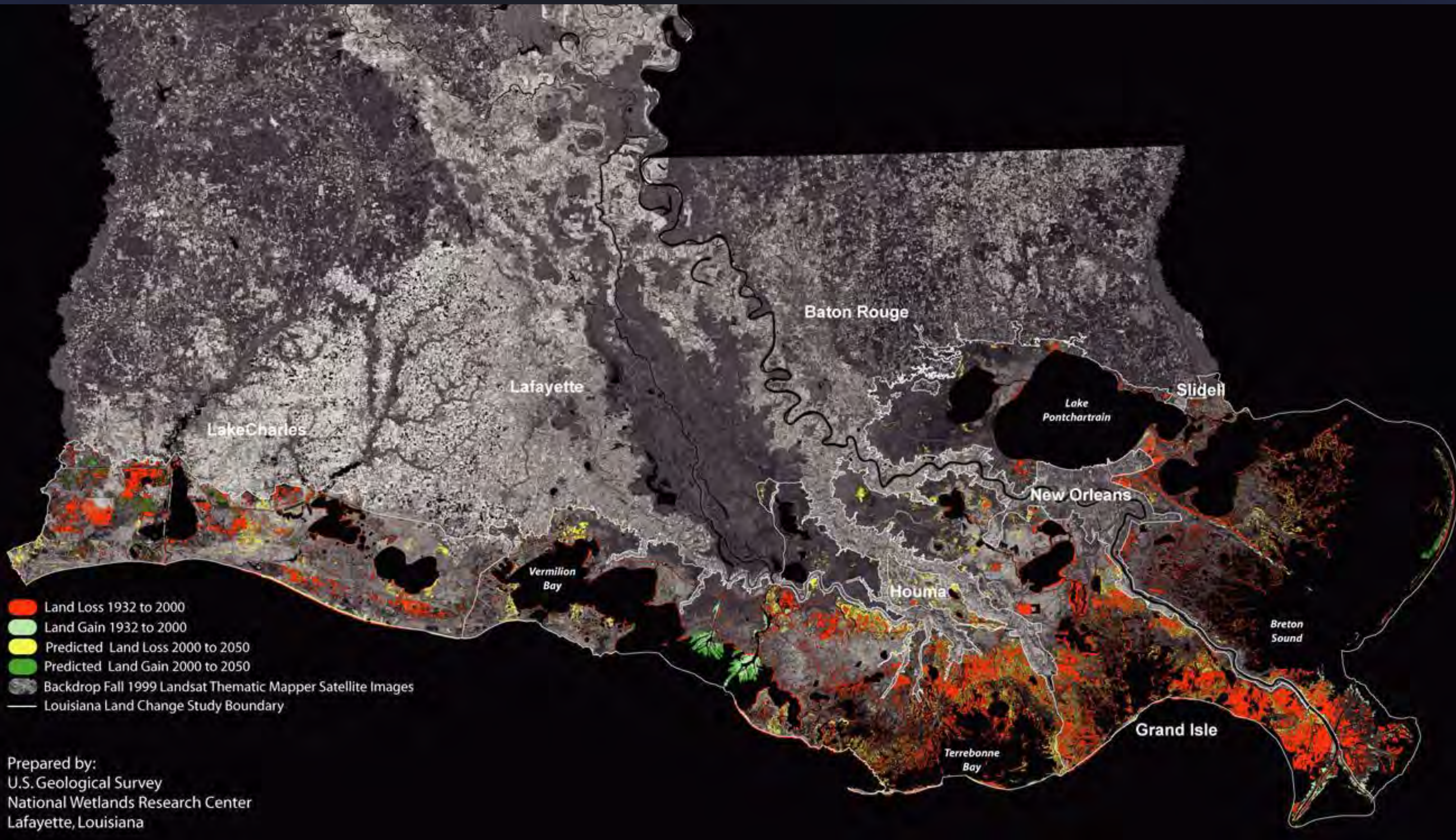


Robert R. Twilley

Department of Oceanography and Coastal Sciences
Louisiana State University, Baton Rouge LA

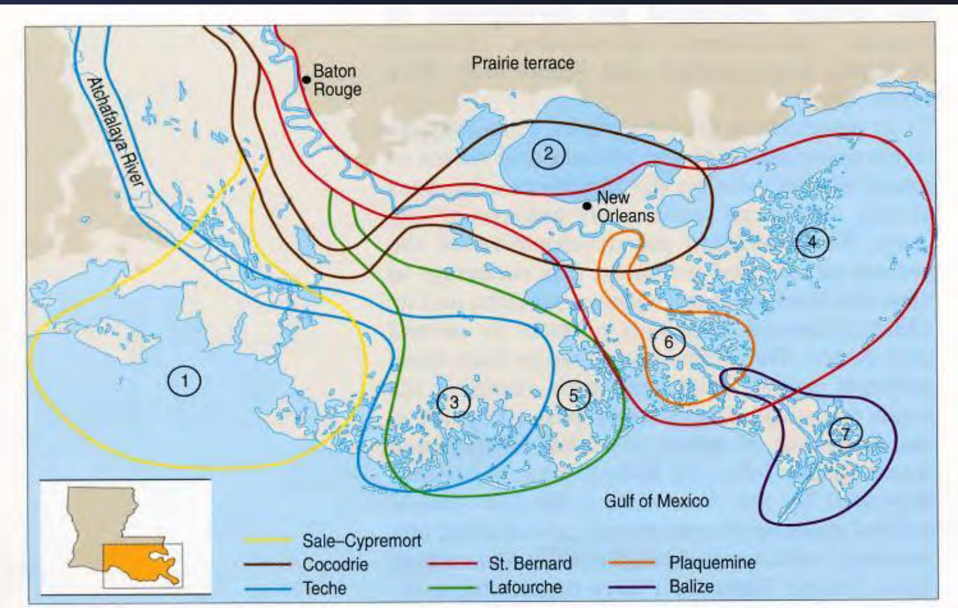
State of the Coast 2014
Biennial Meeting, 18-20 March 2014
New Orleans, LA

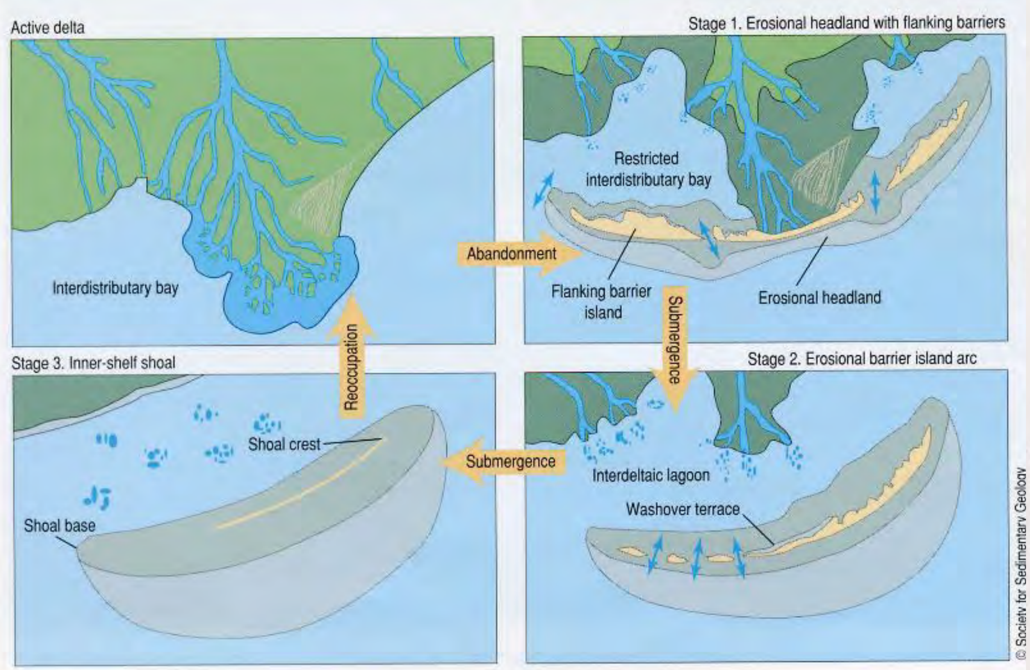
What is the Problem?



Passive adaptive management cycle – Engineering the Mississippi River for Flood Control and Navigation

What processes are at work? – Coastal Deltaic Floodplain





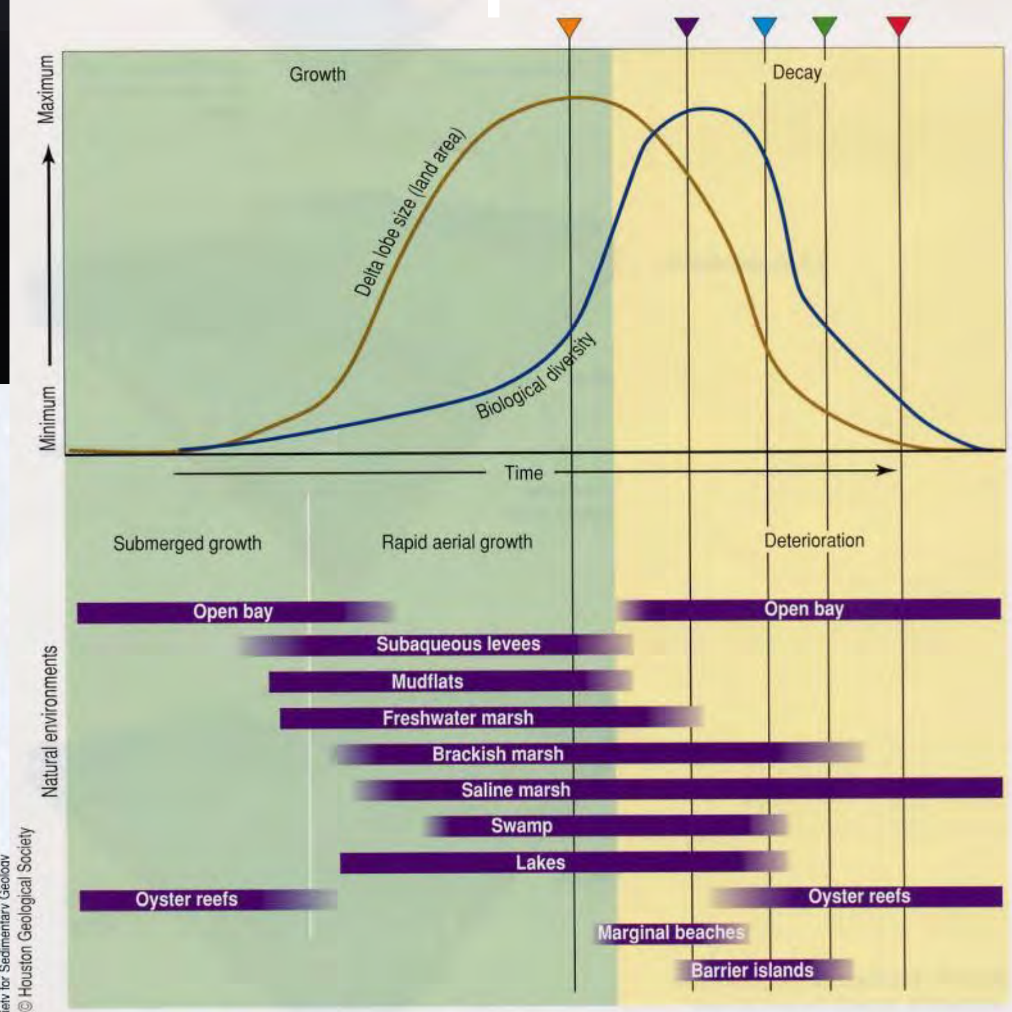
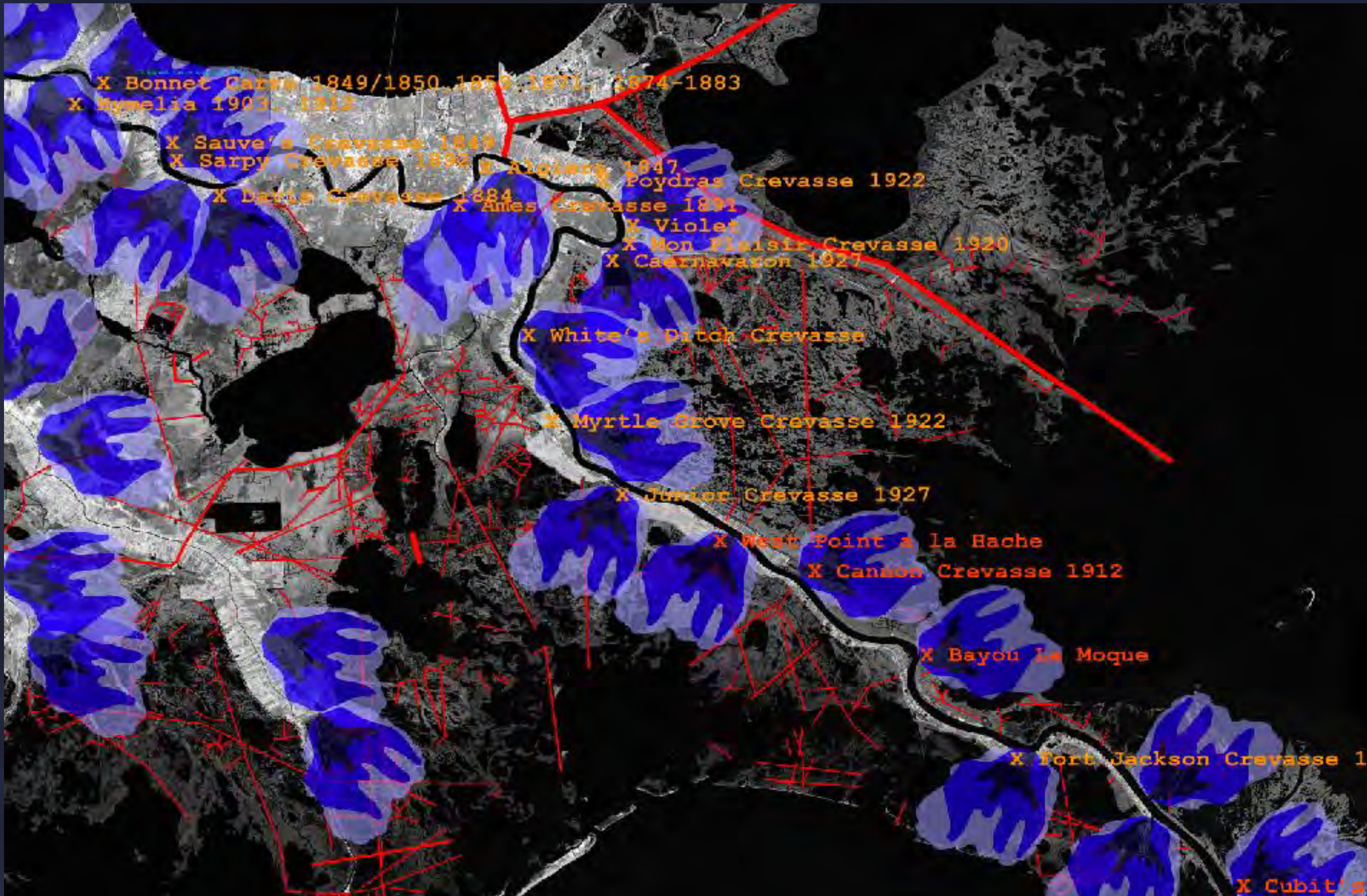
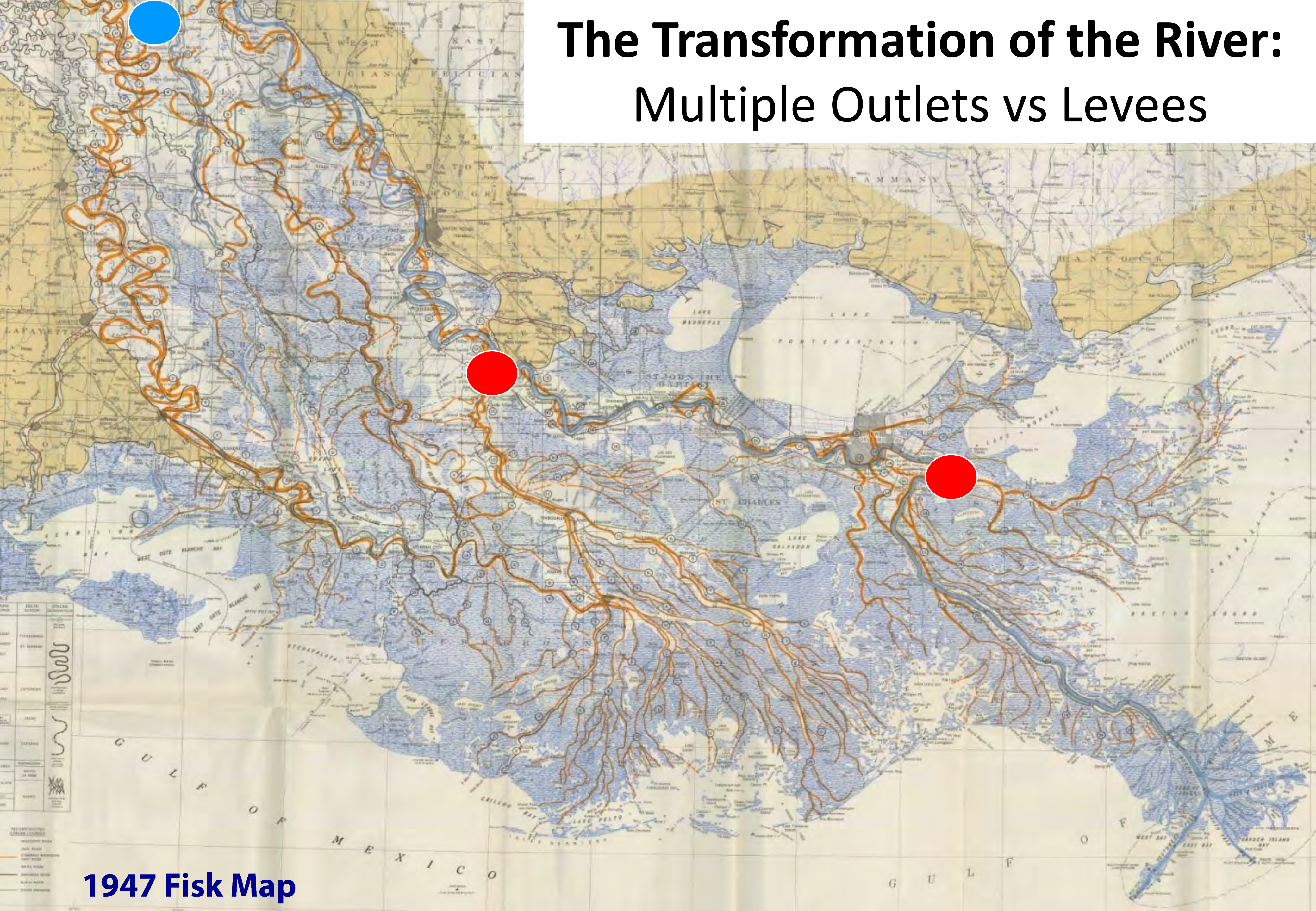


Fig. 18. Graphical depiction of the growth and decay of a delta lobe (adapted from Gagliano and Van Beek 1975; Neill and Deegan 1986). Habitat and biological diversity peak in the early to middle stage of the decay phase.



There were hundreds of crevasses along the lower Mississippi River since 1700.
A number occurred in the first part of the 20^{th} century.

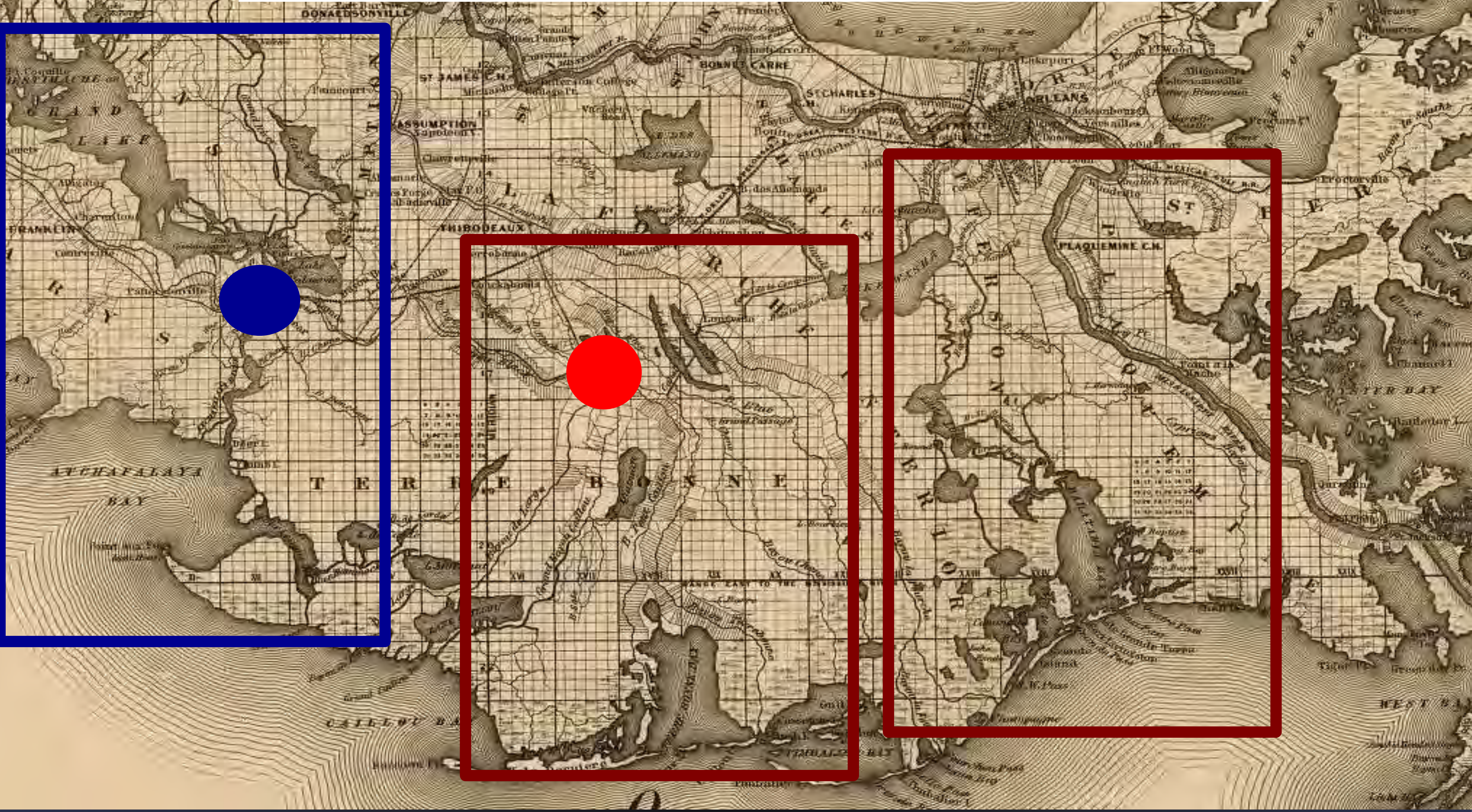
The Transformation of the River:
Multiple Outlets vs Levees



1947 Fisk Map

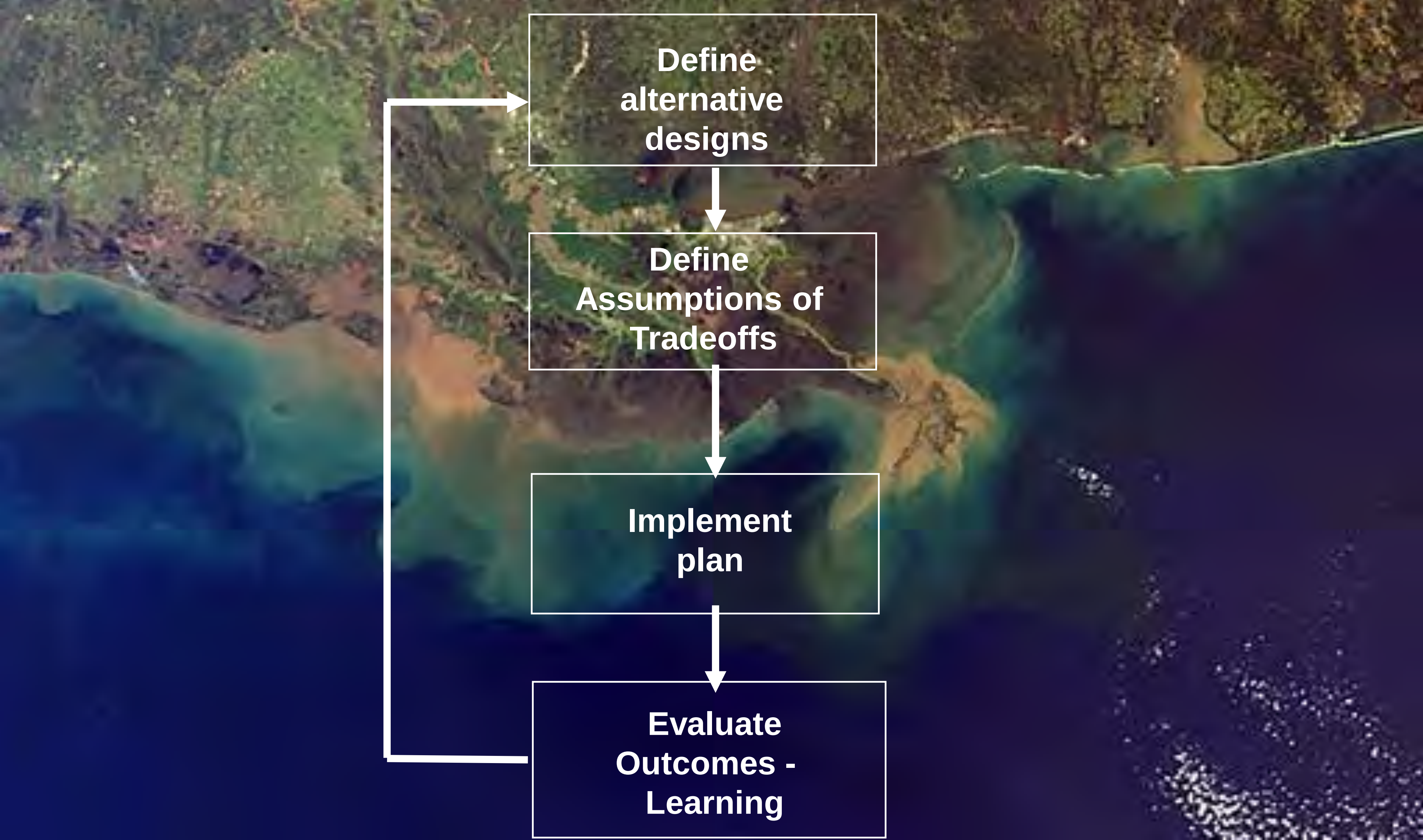
What processes are at work? – Coastal Deltaic Floodplain

Landscape Response to River Management: Levees rather than Multiple Outlets



Landscape Response to River Management: Levees rather than Multiple Outlets

Passive adaptive management cycle – Engineering the Mississippi River for Flood Control and Navigation



THIS WE HOPE TO RESTRAIN—

AND THIS WE HOPE TO SEE UNHAMPERED IN ITS ENTRANCE INTO THE GREAT MISSISSIPPI RIVER.

Riparian Lands of the Mississippi River: Preface by Frank Tompkins, 1901

LEVEES OR OUTLETS.

WHAT THE SENATORS THINK OF THE NEEDS OF THE MISSISSIPPI RIVER.

WASHINGTON, April 28.—A discussion of the relative merits of the levee and the outlet systems for relieving the Mississippi of its annual flood was brought into the regular business of the Senate to-day by the presentation of a memorial on the subject. Some Senators thought that as each of the systems had defects, a combination of the two would result in the most good. Senator Hawley favored this view; Senators Washburn and Harris had lost faith in the levee system during the last two months, and rather leaned toward a grafting of the outlet upon the present levee system. Senator Vest thought Congress should decide upon one or the other system.

The levee system found champions in Senators Barry, Paddock, Walthall, and Stewart. Every engineer except one had reported in favor of the levee as the only true system in the hearing given during the last Congress by the Committee on the Improvement of the Mississippi River. The people along the river had absolute faith in the levee system, and were opposed to the other. Senator Reagan was in favor of the outlet system, since the levee system had proved such a failure. He cited the devastating overflows that had taken place in the Yellow River of China, where the river bed had been raised. Senator Eustis thought the discussion inopportune on account of the inadequate evidence at hand. The steamboat Captains, however, favored the levee system.

The New York Times
Published: April 29, 1890
Copyright © The New York Times

- Charles Ellet, in 1852, suggested that human endeavors—upstream development and levees that climbed ever skyward—exacerbated the flood menace.

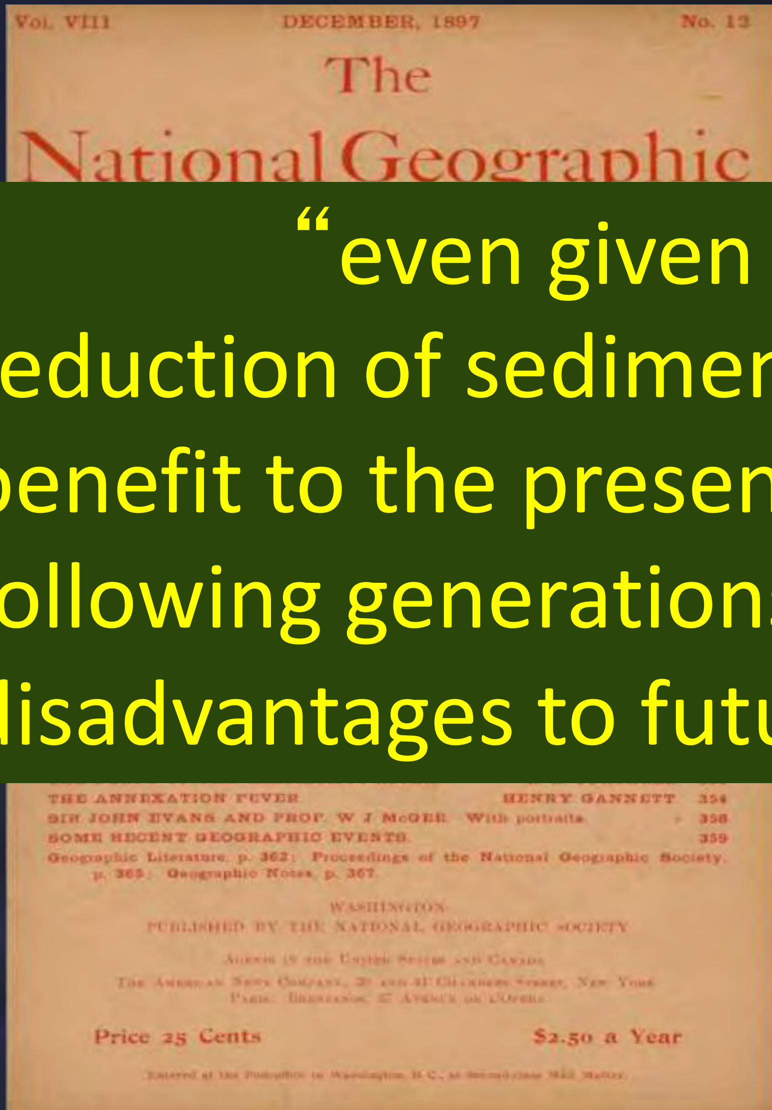
- He offered a multi-tiered alternative:
  - more levee improvements;
  - building outlets or spillways to shunt floodwater from the river;
  - and constructing massive reservoirs, artificial wetlands, to soak up excess rain before it ran off into the Mississippi.

Report of the Commission of Engineers Investigate and Report a Permanent Plan for RECLAMATION OF THE ALLUVIAL BASIN of the MISSISSIPPI RIVER Subject to Inundation, 1875

- Plan Recommended continued (page 33)
- The plan to consist, first, in keeping open the Atchafalaya and the La Fourche, and it borings shall show it to be safe, in re-opening the Plaquemine; second, in a general levee system extending from the head of the alluvial region to the Gulf, including the valleys of the tributary streams.
- Also recommendation of connecting river to Lake Borgne at English Turn

Societal Debate in 1897

"even given subsidence and reduction of sediment delivery…the great benefit to the present and two or three following generations…far outweighs the disadvantages to future generations…"



Vol. VIII DECEMBER, 1897 No. 12

The National Geographic

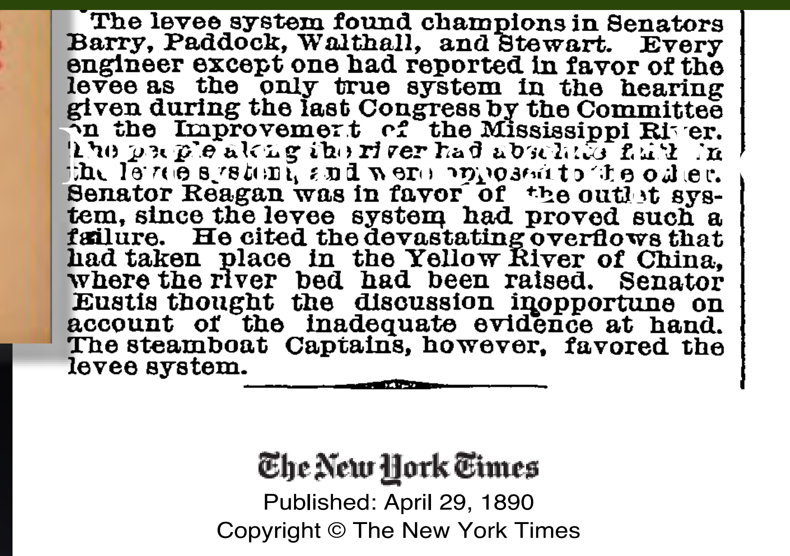
THE ANNEXATION FEVER	HENRY GANNETT	354
SIR JOHN EVANS AND PROF. W J McGEE. With portraits		358
SOME RECENT GEOGRAPHIC EVENTS		359

Geographic Literature, p. 362; Proceedings of the National Geographic Society, p. 365; Geographic Notes, p. 367.

WASHINGTON

PUBLISHED BY THE NATIONAL GEOGRAPHIC SOCIETY

Price 25 Cents $2.50 a Year



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The New York Times

Published: April 29, 1890

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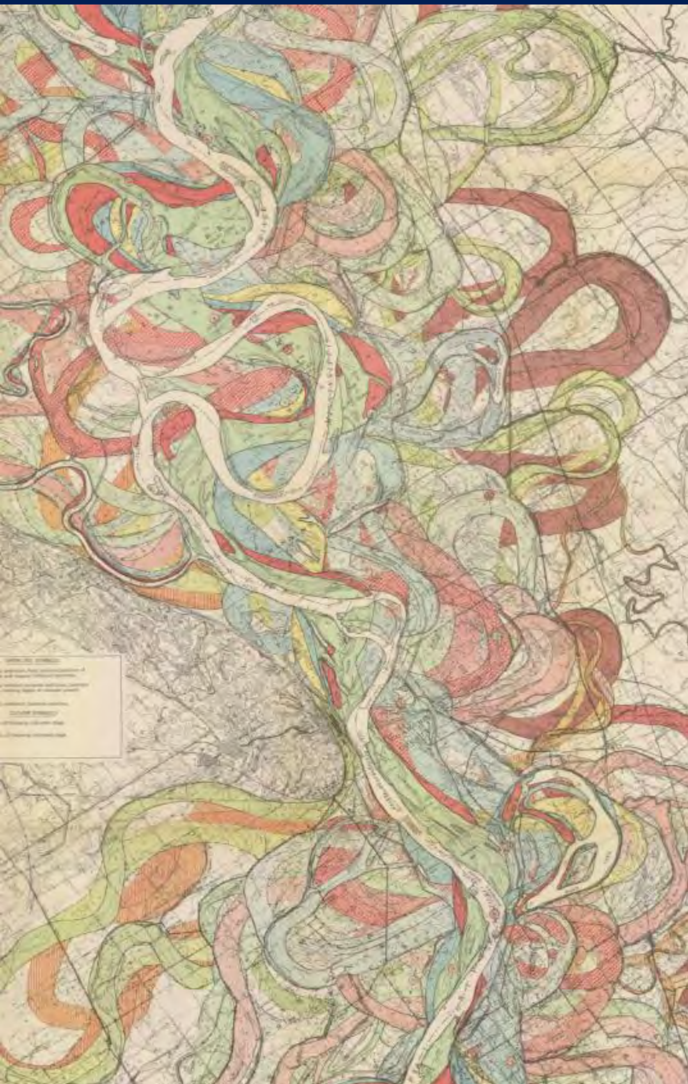
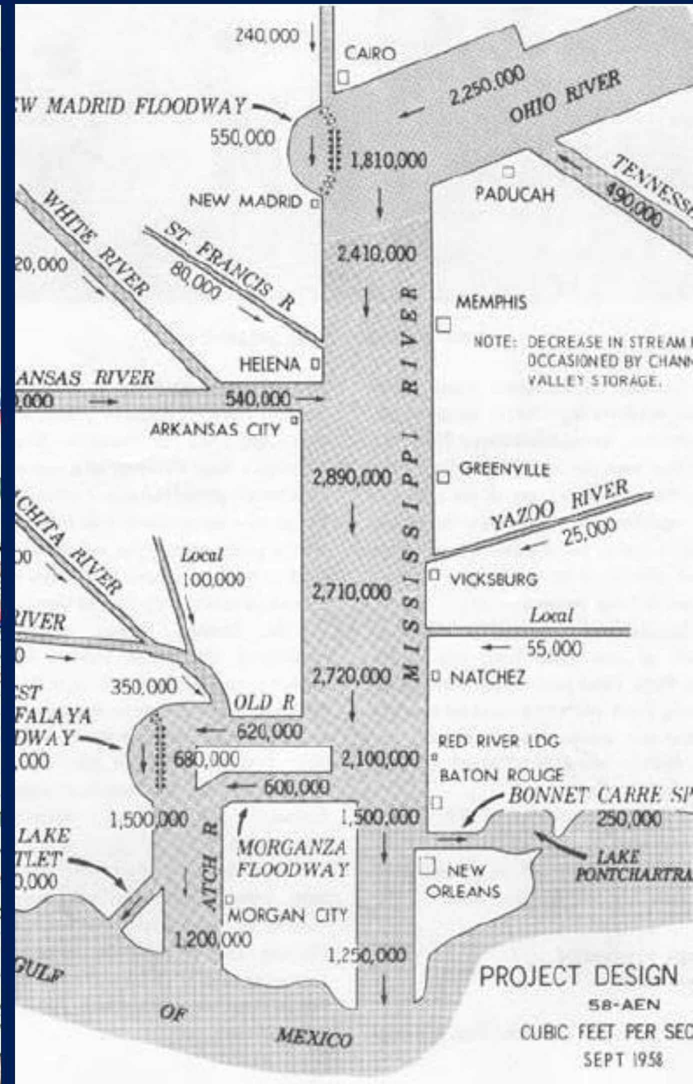
1897

Three visions of the Mississippi River



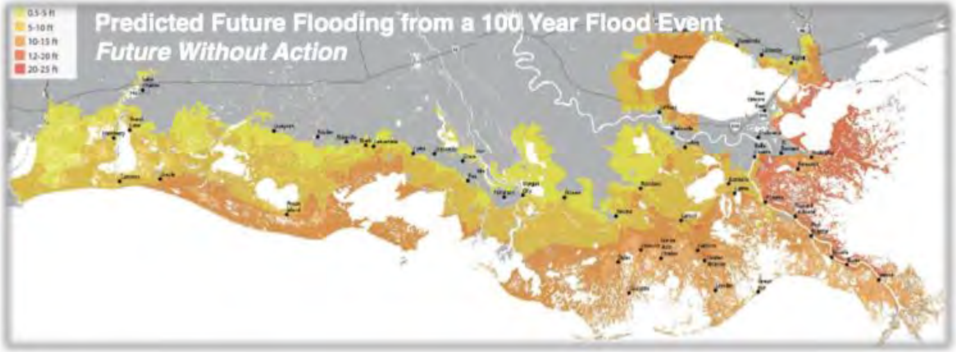
Ecological

Settlement



Infrastructural

Our Communities and Livelihoods at Risk



Potential for expected annual damages to reach **$7.7 to $23.4** billion

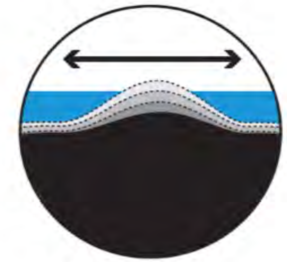
Key Decision Points

- Flood Risk Reduction and Land Built/Maintained as Decision Drivers

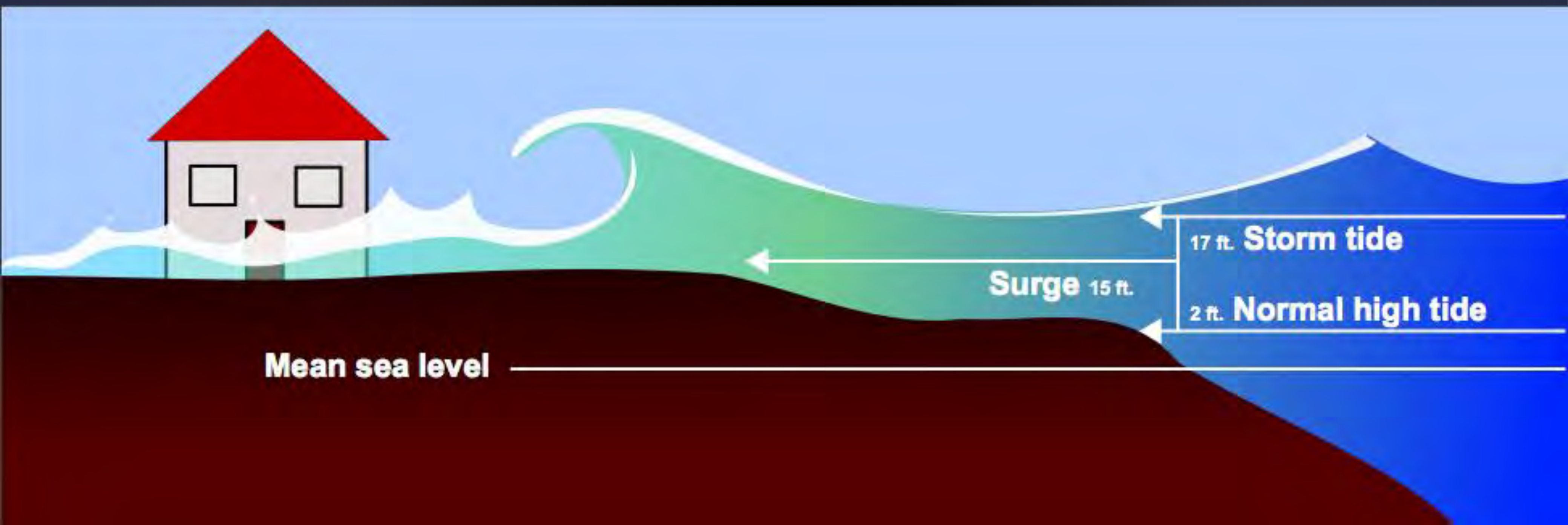
Risk Reduction

Expected Annual Damages

Restoration



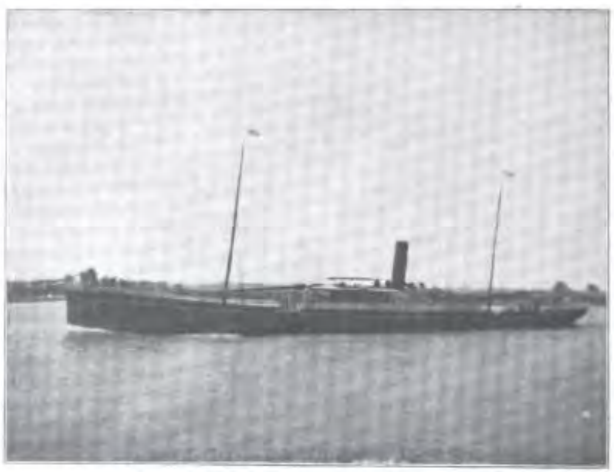
Land Area



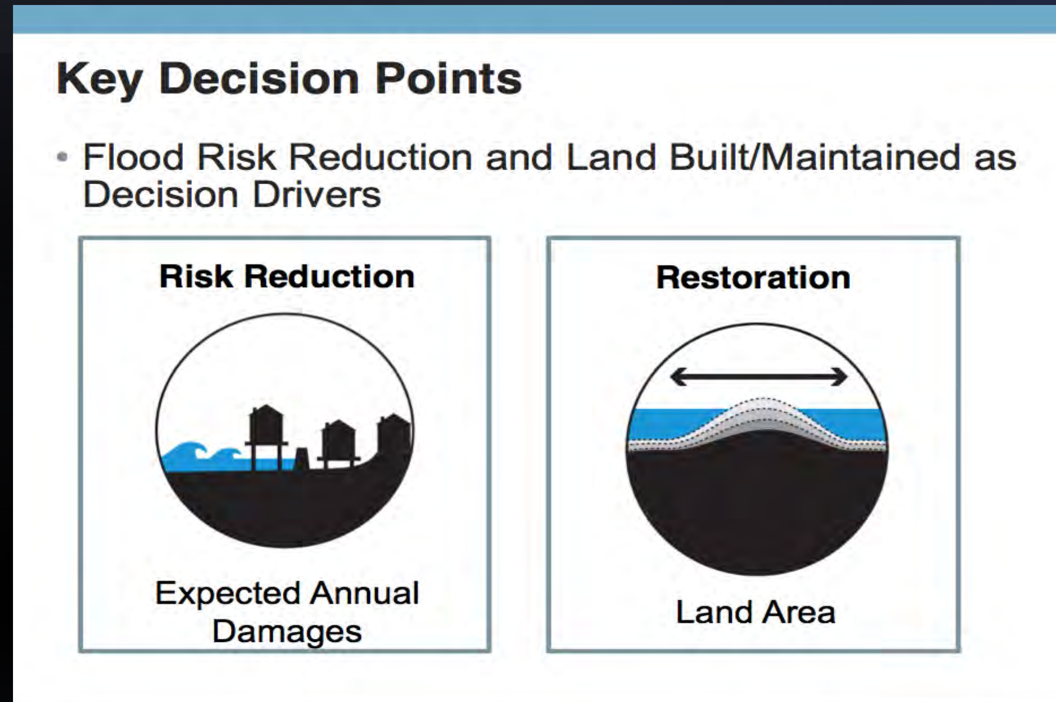
Report of the Commission of Engineers Investigate and Report a Permanent Plan for RECLAMATION OF THE ALLUVIAL BASIN of the MISSISSIPPI RIVER Subject to Inundation, 1875 Levee Report from Louisiana (Commission P.O. Hebert)

- With ruined finances and an iimpoverished people, the State of Louisiana cannot protect herself against her remorseless enemy, the Mississippi, at its annual high floods. The General Government *must come* to the rescue; otherwise, the fairest and most fertile portion of the Valley of the Mississippi must be abandoned and become depopulated. There is no illusion in this. It is a simple fact.

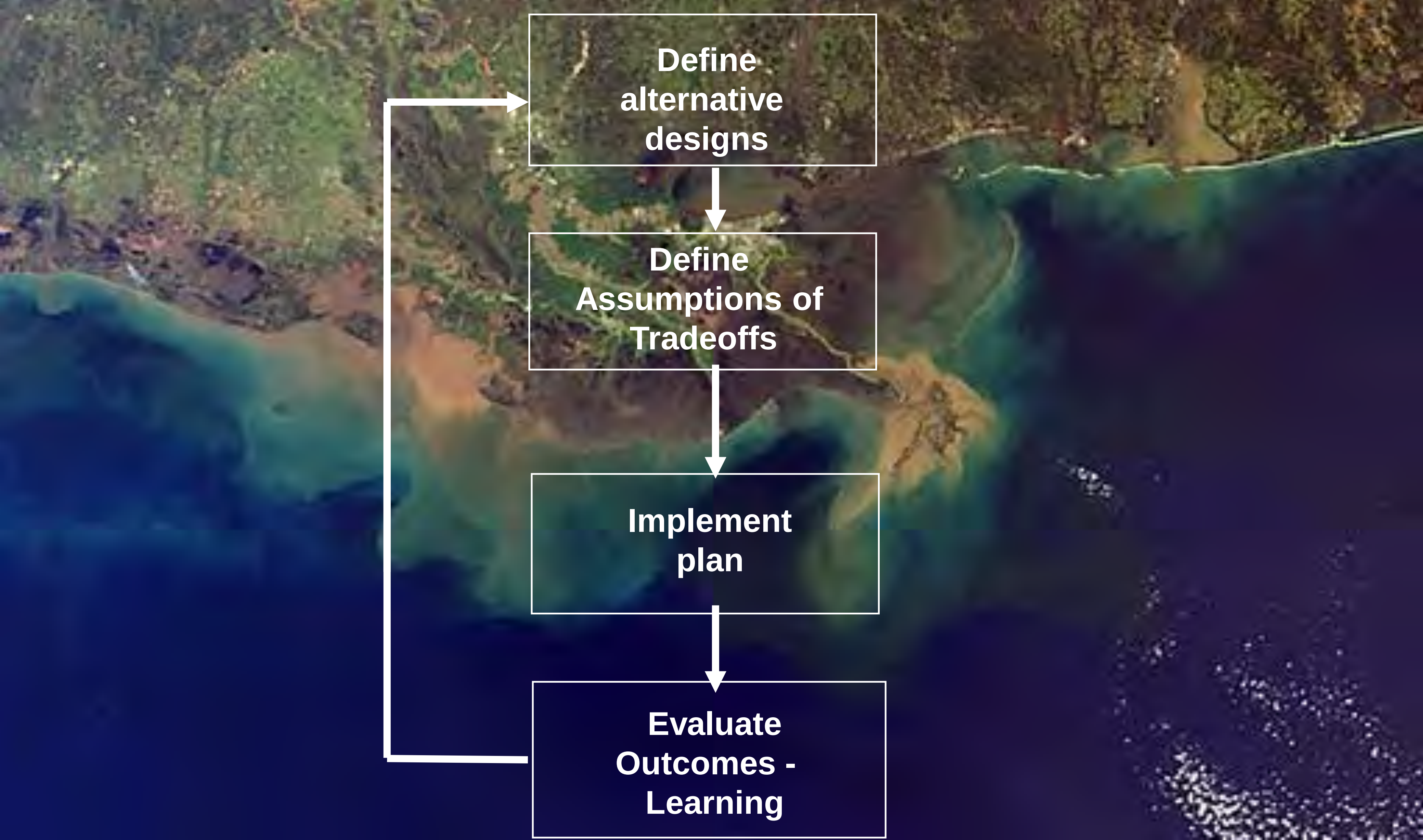
THIS WE HOPE TO RESTRAIN—

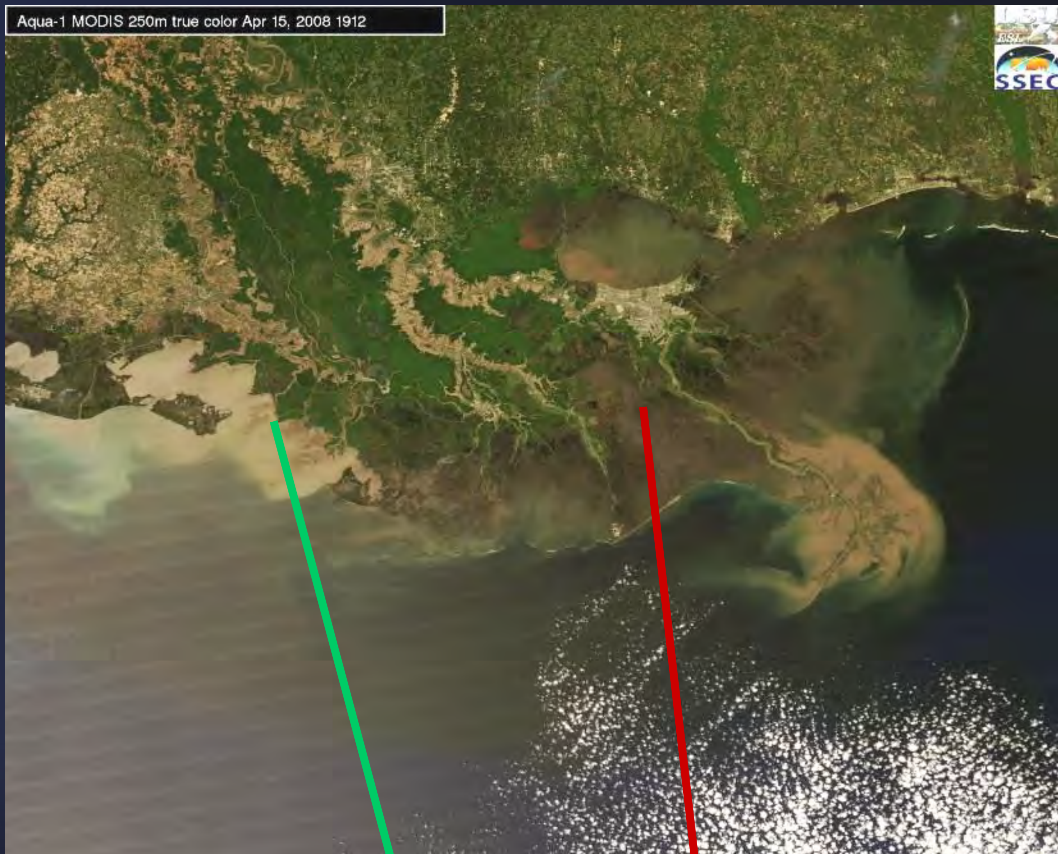


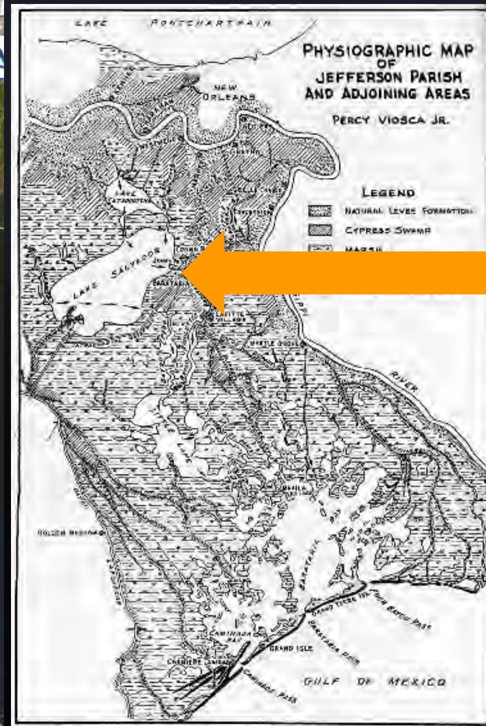
AND THIS WE HOPE TO SEE UNHAMPERED IN ITS ENTRANCE INTO THE GREAT MISSISSIPPI RIVER.

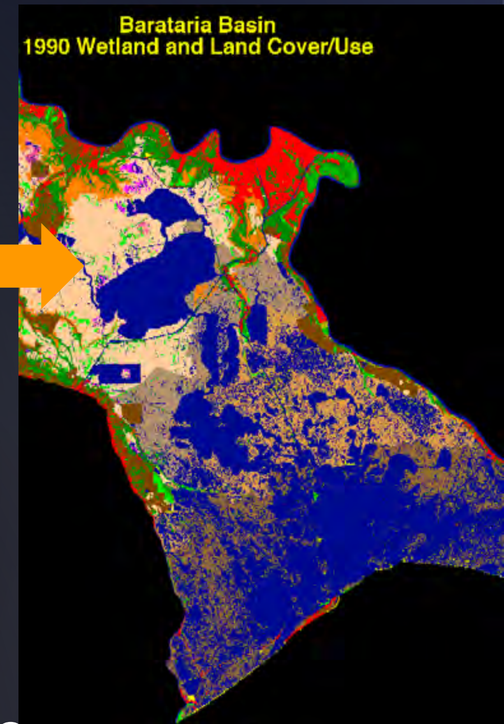


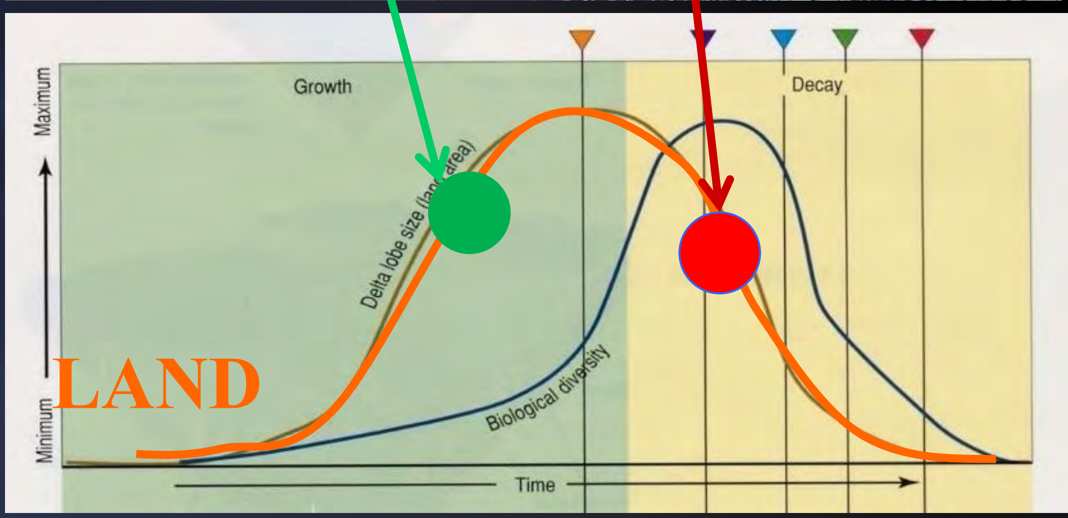
Passive adaptive management cycle – Engineering the Mississippi River for Flood Control and Navigation











River abandonment caused by levees along the Mississippi River, reducing sediment delivery to wetlands (see sediment plumes in satellite image), has caused a shift from prograding to transgressive processes to dominate along the deltaic coast.

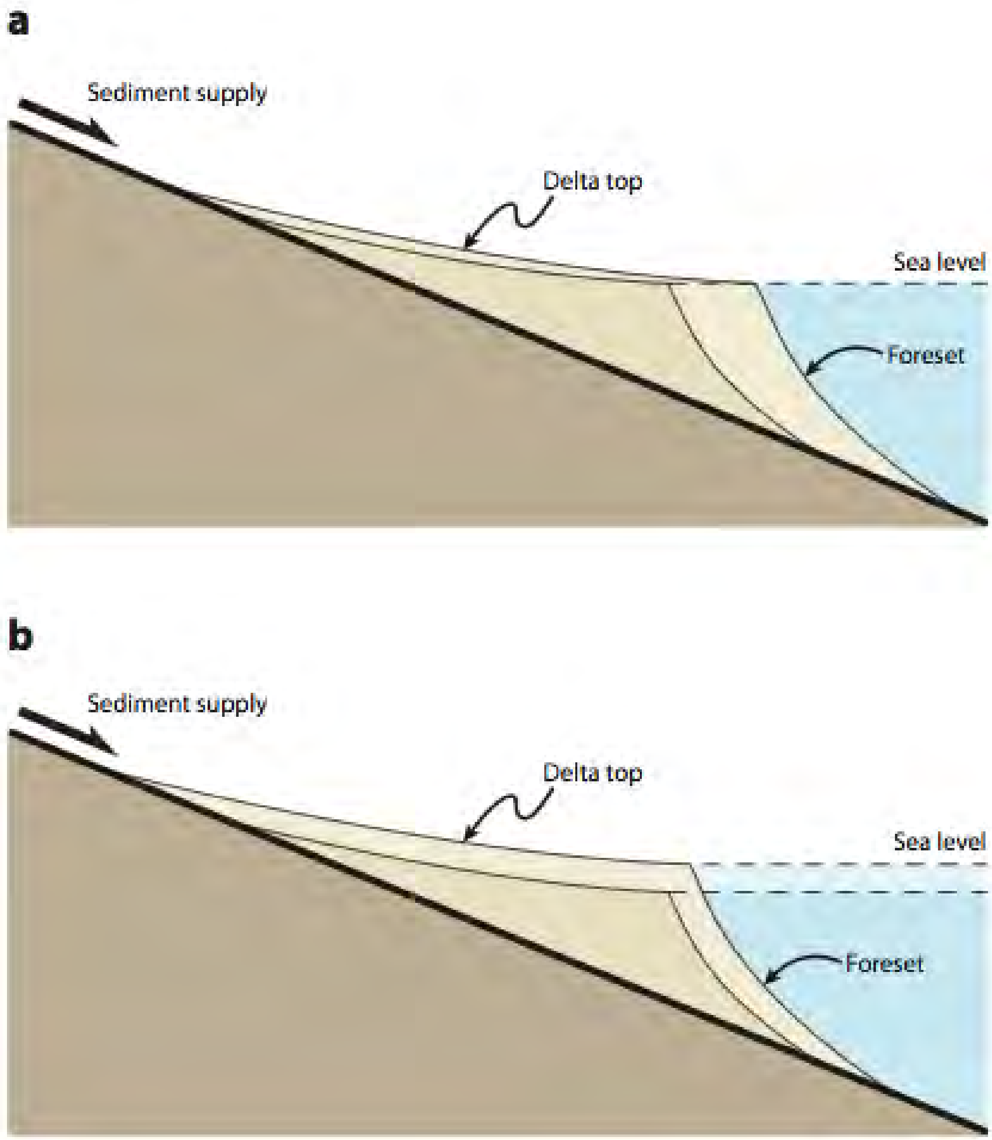


Figure 3

Sketches showing the longitudinal clinoform shape of a river delta. (*a*) A prograding delta with constant sea level. (*b*) A delta subject to a relative sea-level rise comparable to its overall surface relief; instead of passively drowning, the delta responds by depositing sediment to preserve its overall shape. The trajectory of the shoreline (transgression or regression) depends on the balance between relative sea-level rise rate and sediment supply.

* Mitigation through freshwater and sediment diversion (outlets)

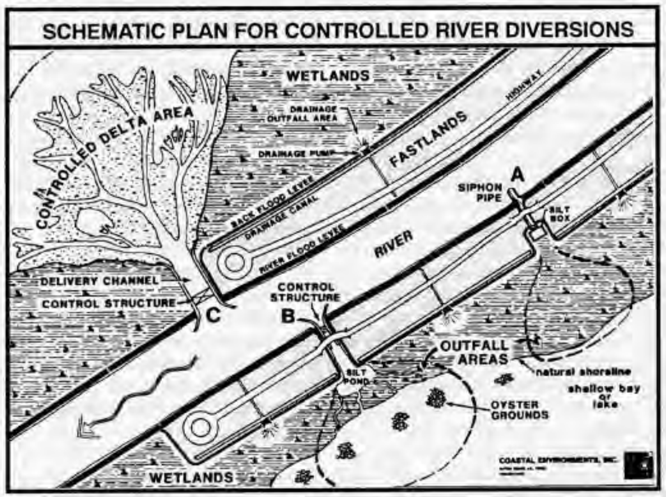
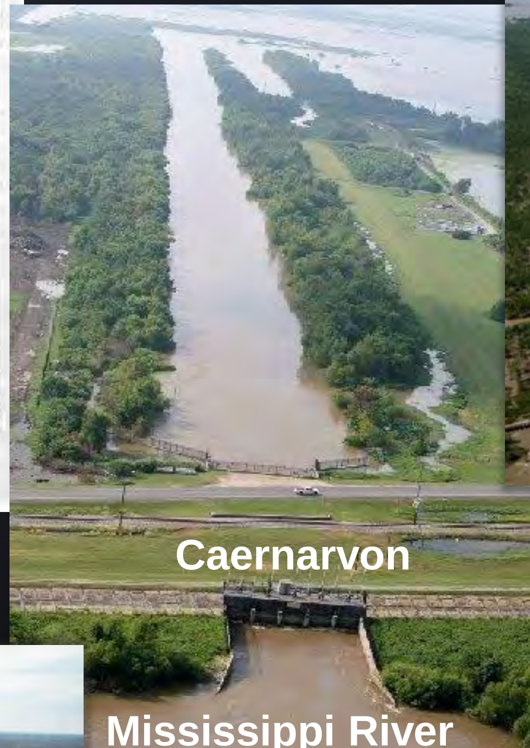
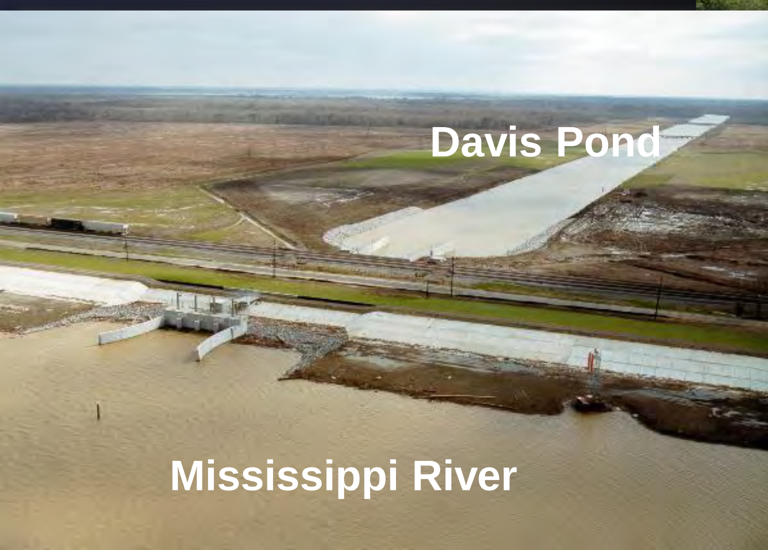


Figure 16. *Schematic of three basic types of controlled river diversions: A. siphon; B, gated diversion; and C, controlled subdelta. Published with the permission of S.M. Gagliano, (51).*





Wetland Loss vs Biological Productivity?

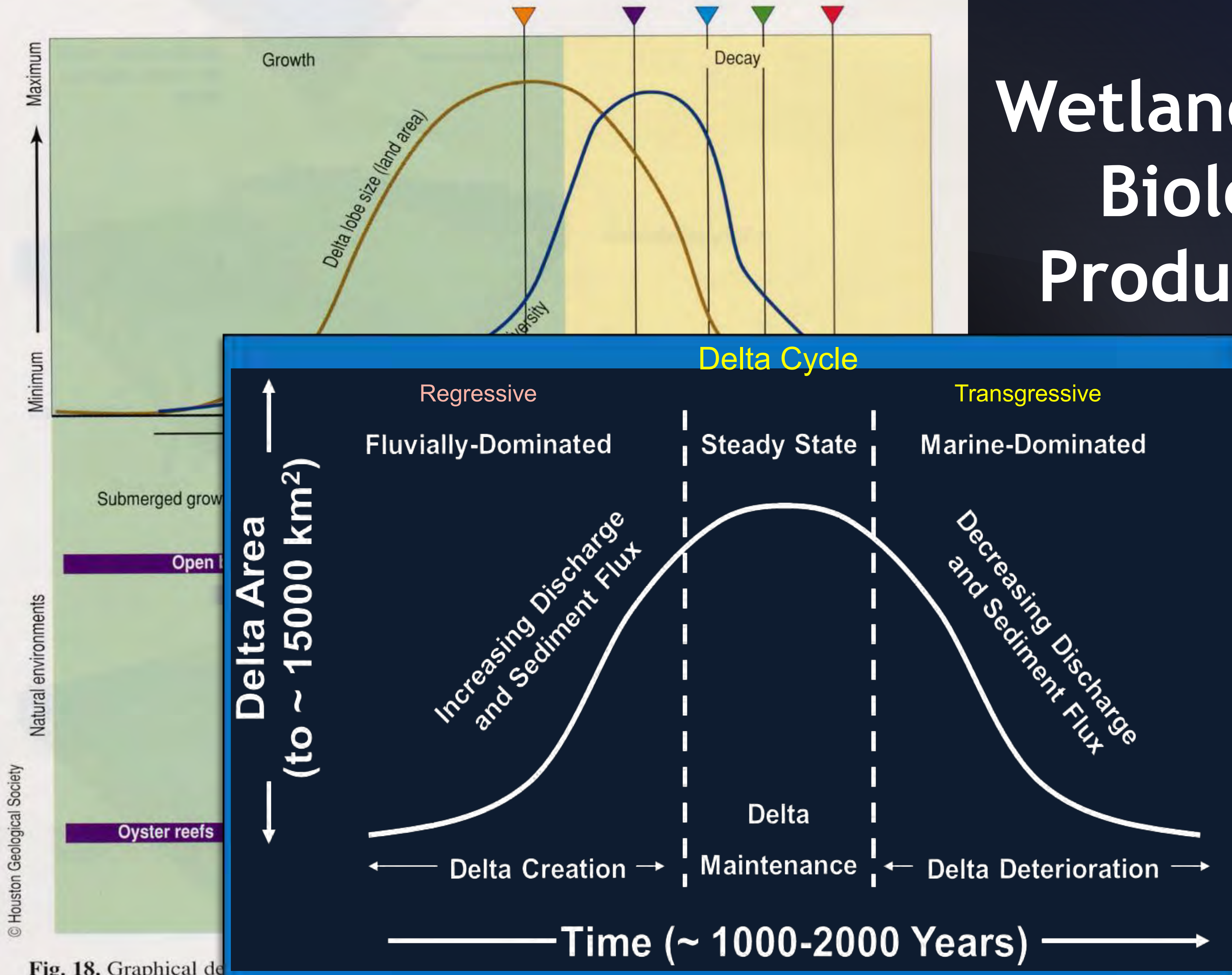


Fig. 18. Graphical de… Van Beek 1975; Neill and Deegan 1986). Habitat and biological diversity peak in the early to middle stage of the decay phase.

Sand - Silt – Salt - Nitrate
Tradeoffs of Rebuilding Deltaic Coasts

west by the natural levees of old distributaries and on the seaward edge by a barrier headland or island system. The interdistributary basin is

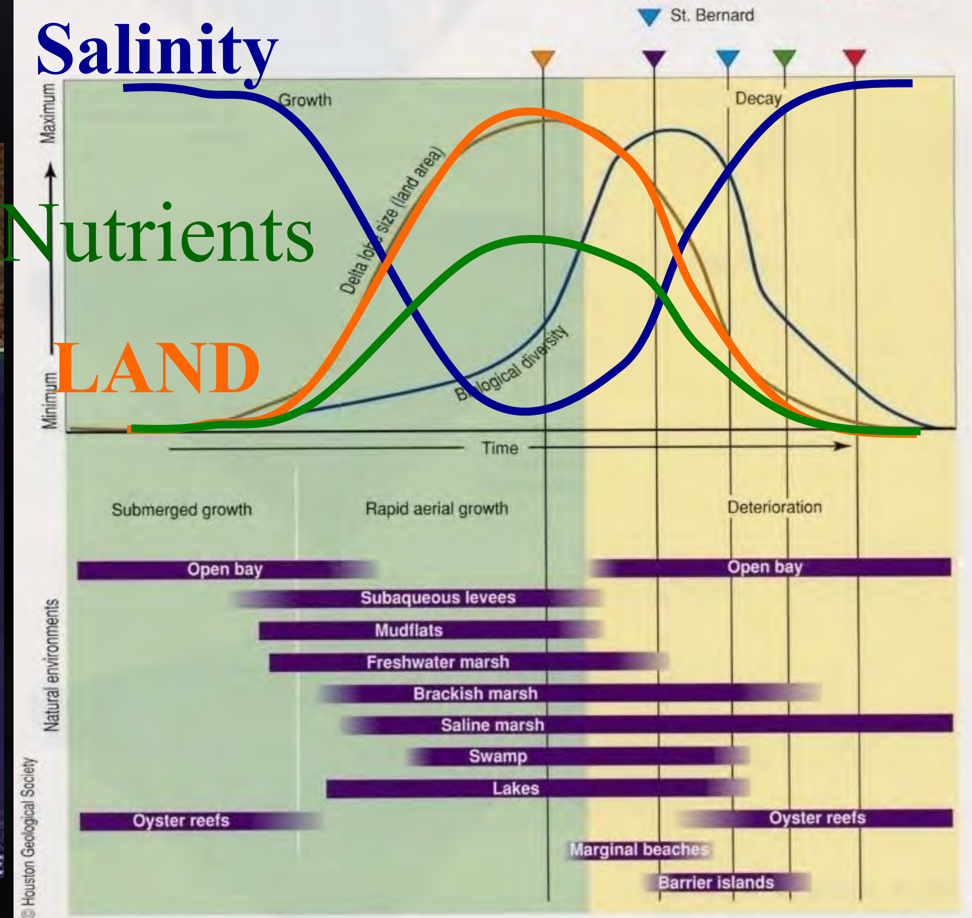


Fig. 18. Graphical depiction of the growth and decay of a delta lobe (adapted from Gagliano and Van Beek 1975; Neill and Deegan 1986). Habitat and biological diversity peak in the early to middle stage of the decay phase.

Calibrating Coastal Processes associated with Engineering Design relative to SCALE of Coastal Landscape Issues (constraint is normally $$$$) (Boesch et al. 1994)

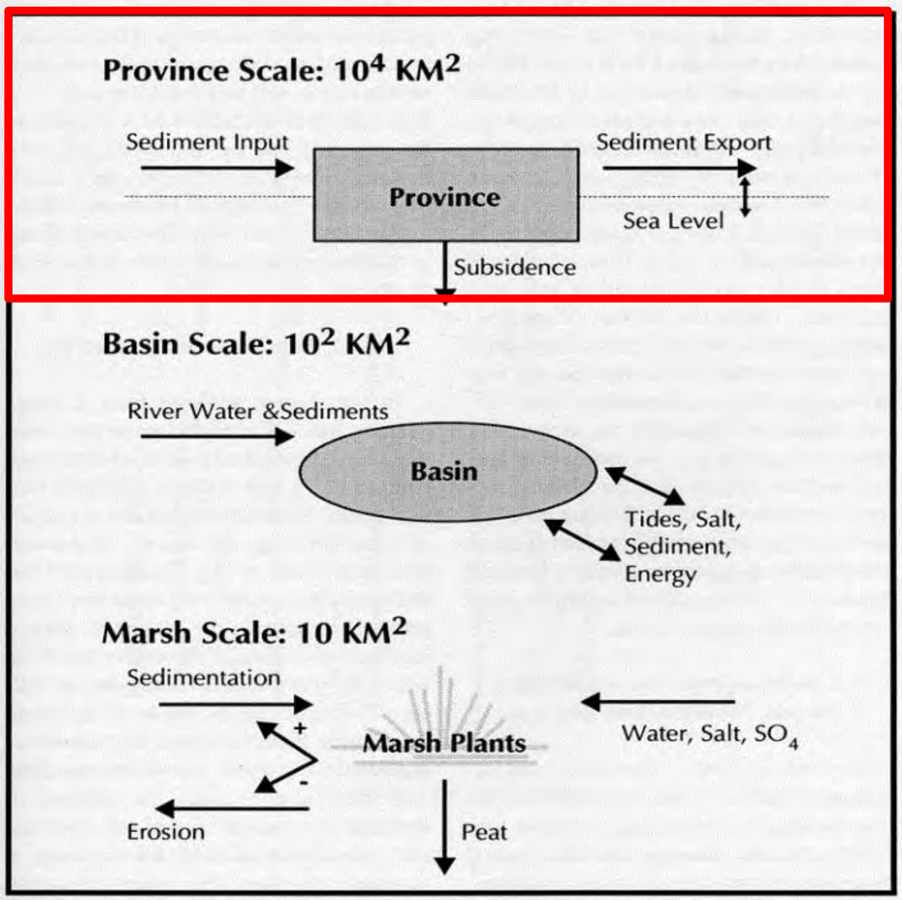


Figure 7. *Conceptual framework of dominant processes operable over three spatial scales in Louisiana's coastal wetlands.*

Table 4. *Water and sediment control strategies and the spatial scales on which they primarily operate (shaded).*

Parish – State -- Federal

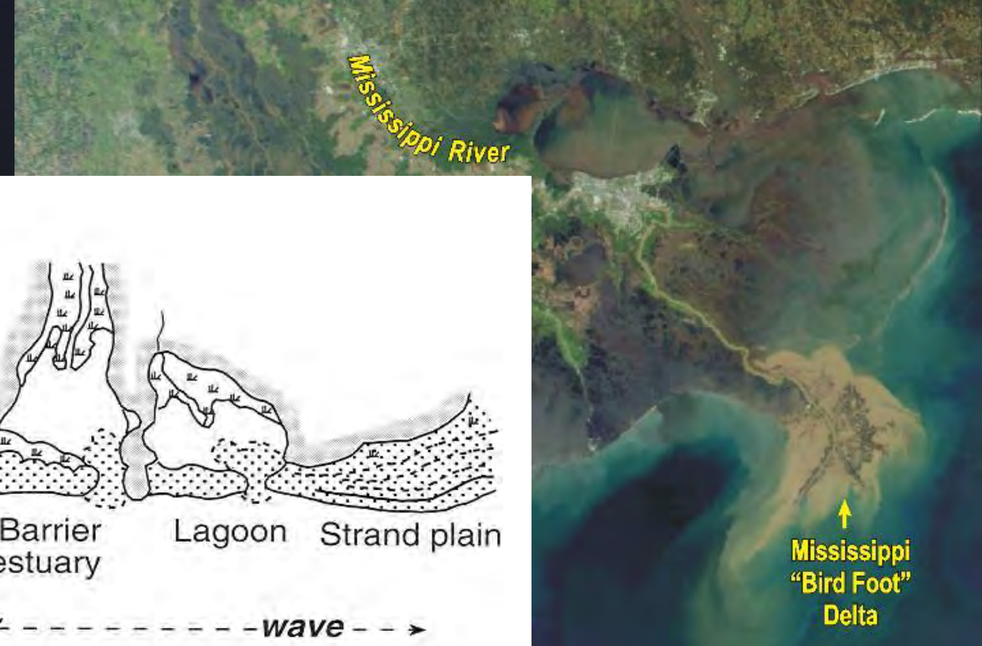
Strategies	Spatial Scale		
	Marsh	Hydrologic Basin	Province
1. Vegetation planting			
2. Shore fences/barriers			
3. Weirs/berms			
4. Terracing			
5. Marsh impoundments			
6. Hydrologic restoration			
7. Dredged material disposal			
8. Shoreline modification			
9. Herbivore control			
10. Sediment transport by pipelines			
11. Siphons			
12. Crevasse formation			
13. Major water/sediment diversion			
14. New channels			
15. Critical land bridges			
16. Reoccupation of existing channels			
17. Major river modifications			
18. Barrier island restoration			

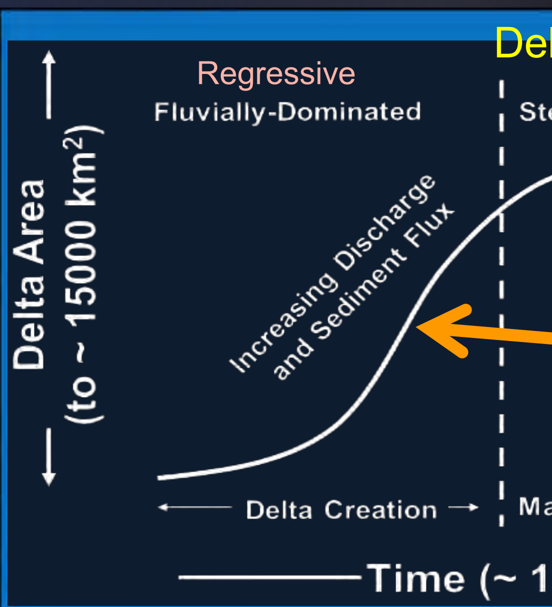
*Previous Modeling and Planning Efforts

Evolution of scaling solution to nature of the problem; degree of integrating wetland restoration and reducing risk to human settlement

Biogeochemistry of Coasta[l] ... Flood...

Capturing chro... delta dev...





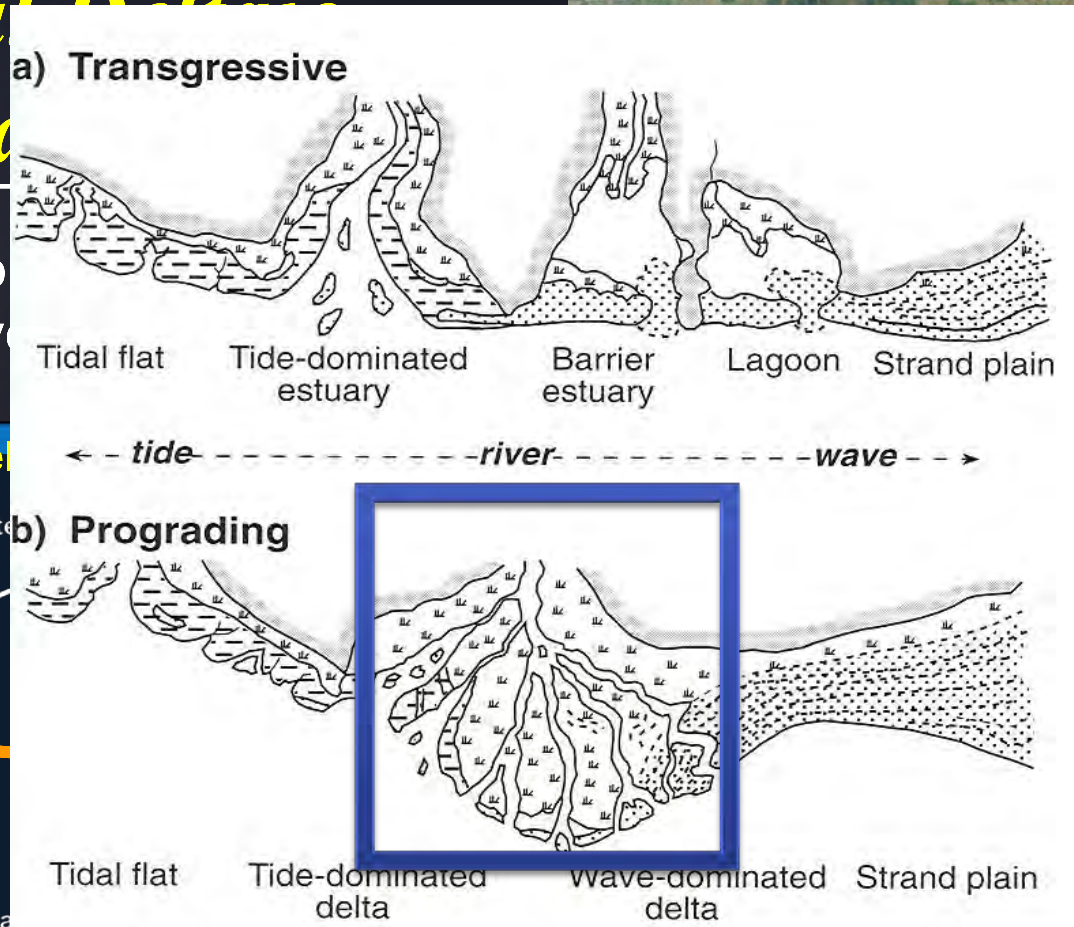
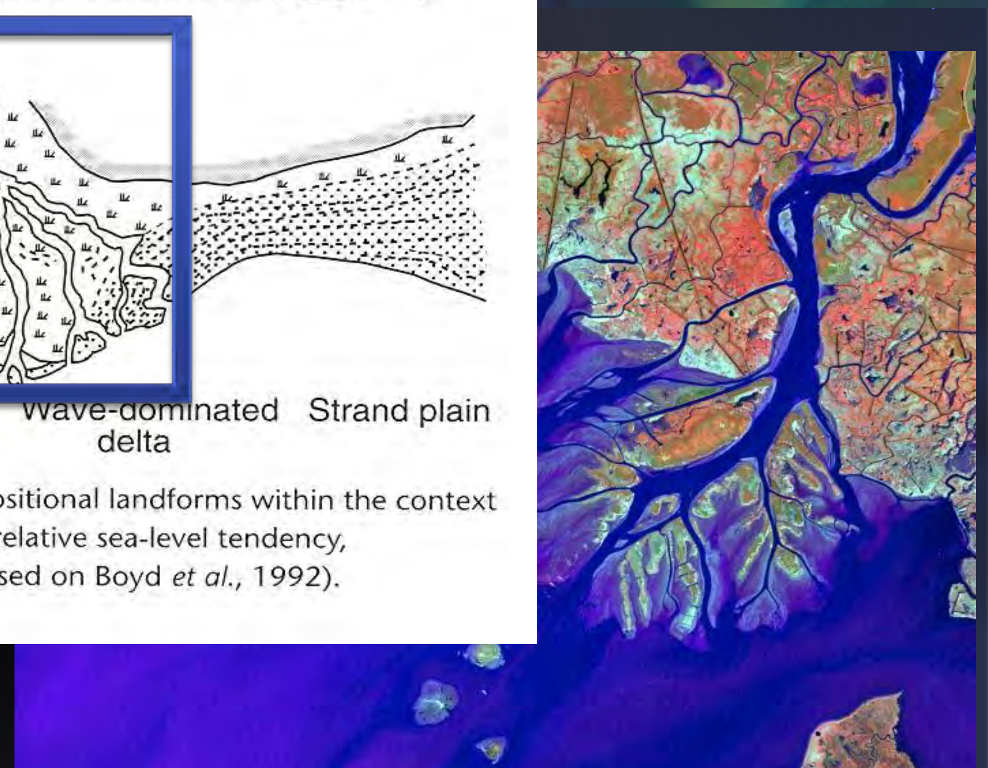


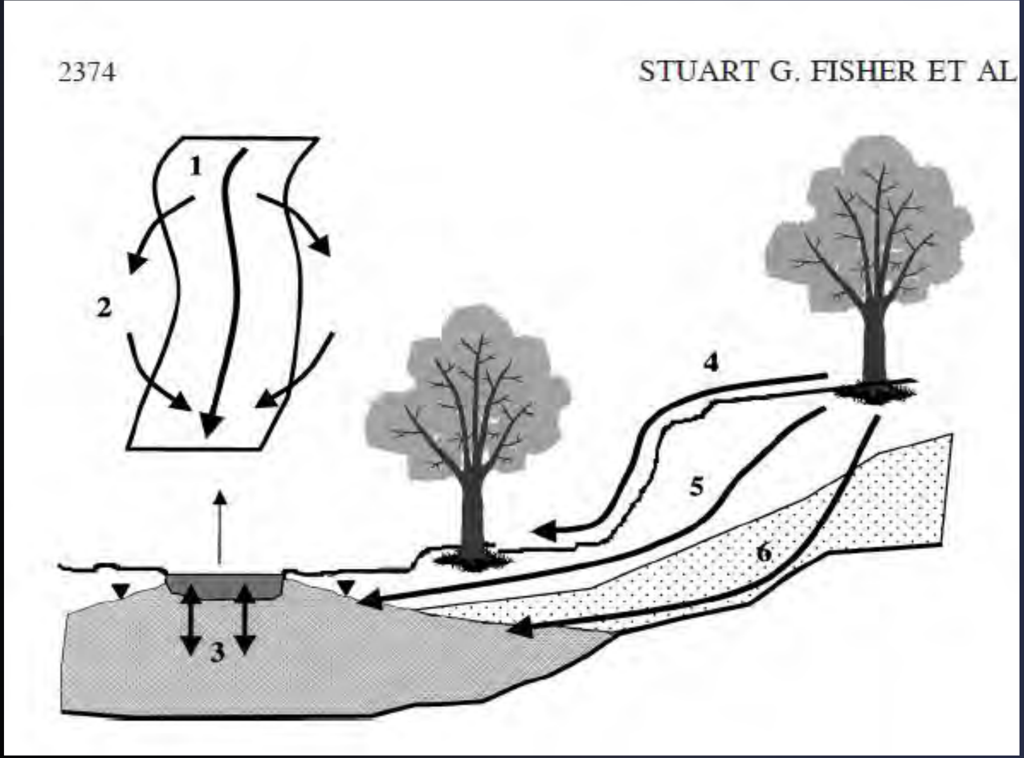
Figure 7.5. Classification of coastal depositional landforms within the context of river, wave and tide domination, and relative sea-level tendency, (a) transgressive, and (b) prograding (based on Boyd *et al.*, 1992).

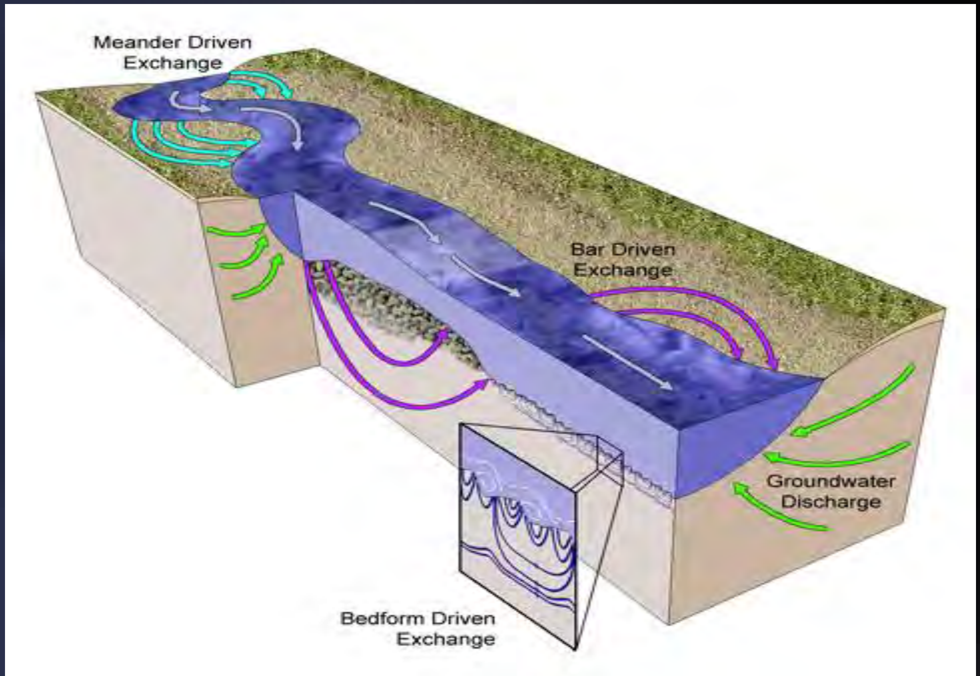


Biogeochemistry of Coastal Deltaic Floodplains

Compared to Concepts Developed for Alluvial Floodplains

1. Spatial pathways of hydrologic connectivity





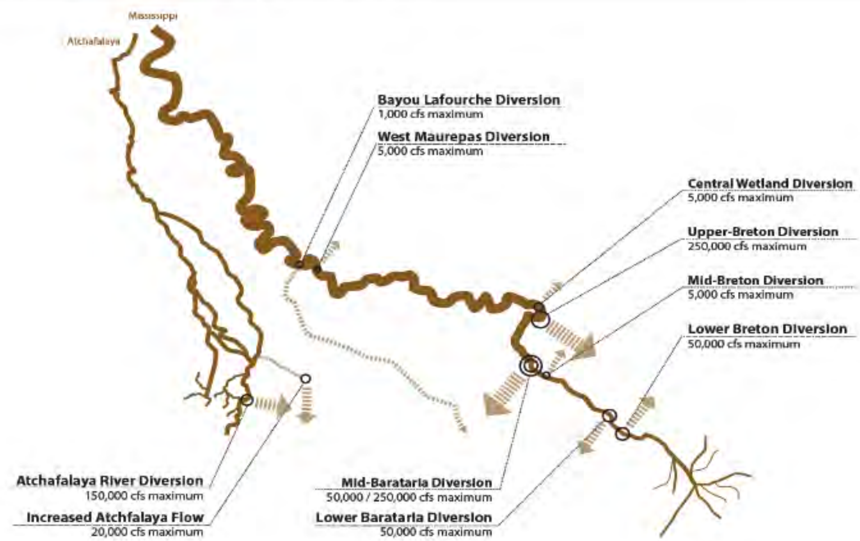
Louisiana's 2012 Coastal Master Plan

- Sediment capture diversions for land building

- 10 diversions on Mississippi and Atchafalaya Rivers

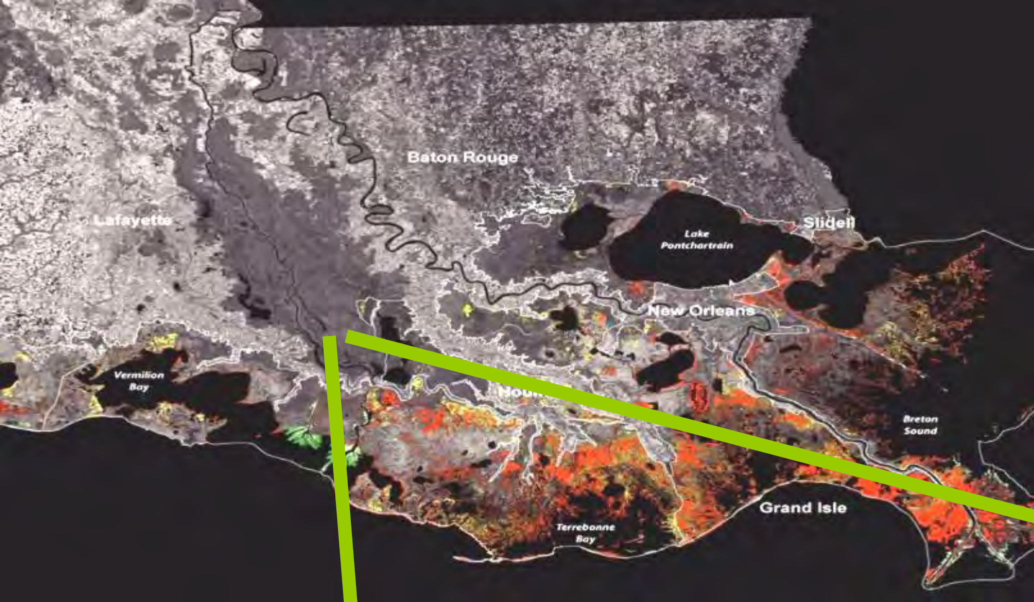
- Wax Lake Outlet: 900 to 8800 $m^3 s^{-1}$
- Maximum discharge size categories:
    - 141.6 $m^3 s^{-1}$ (5,000 cfs)
    - 1416 $m^3 s^{-1}$ (50,000 cfs)
    - 7080 $m^3 s^{-1}$ (250,000 cfs)

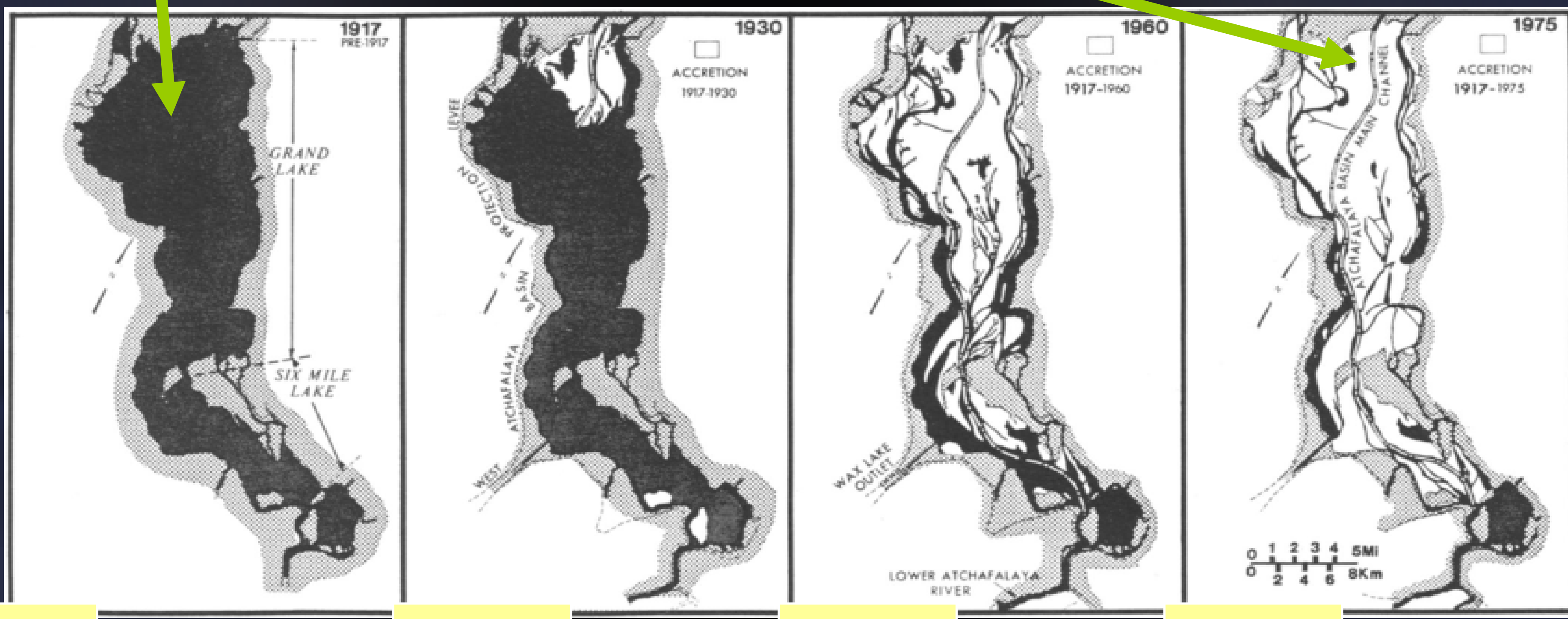
Sediment Diversions in the Master Plan



▲ Figure 5.15
Sediment diversions depicted in the map above would be operated in coordination with high river events and seasonal flows. Operation at maximum capacity would occur only at targeted intervals for a fraction of time each year.

1: The Atchafalaya Floodway represents major section of flood control system

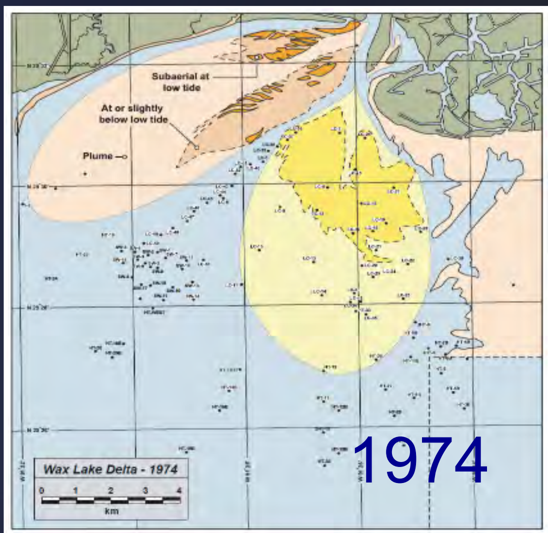


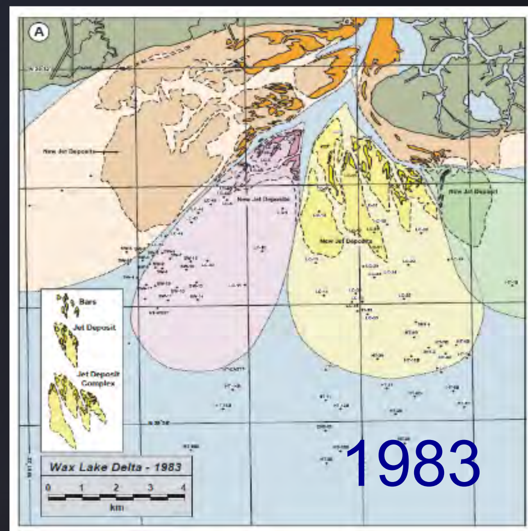


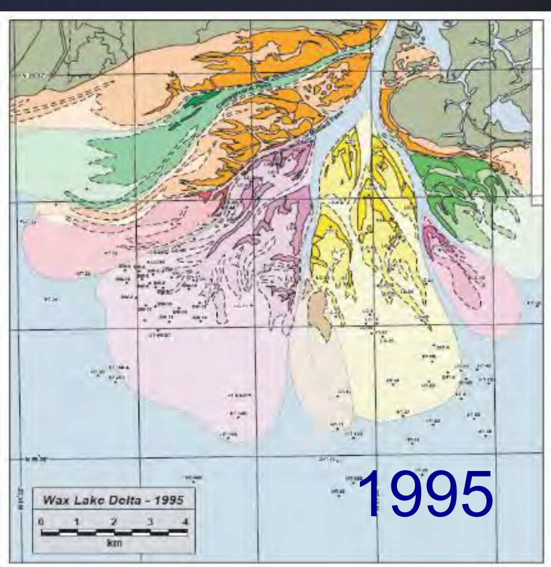
1912 1930 1960 1975

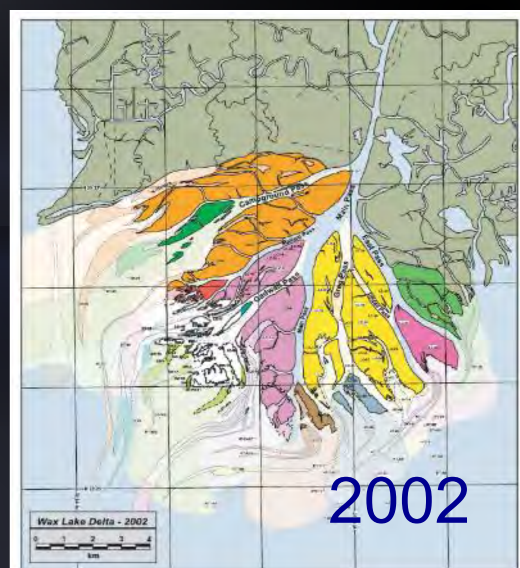
Roberts et al. 1997

Coastal Deltaic Floodplain









Forecasting Deltaic Processes: (Ecosystem Forecasting)
(1) Linking Physical Processes (the River and the Shelf);
(2) Geomorphic Features:
(3) Ecological Succession (habitat utilization):

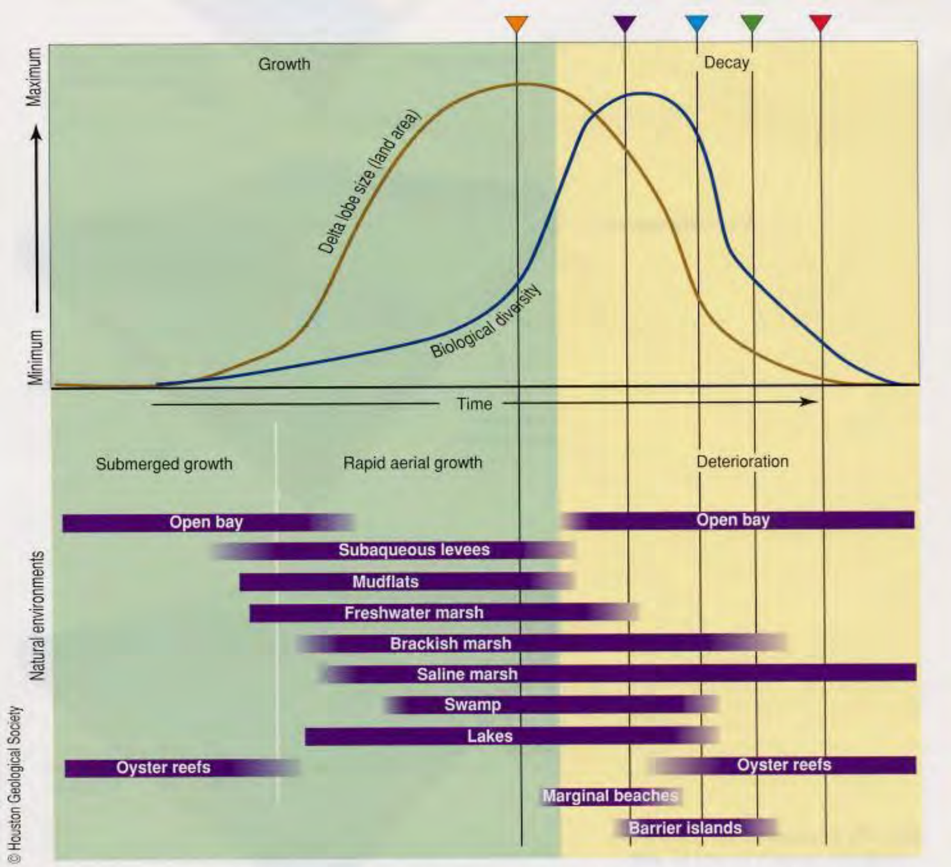
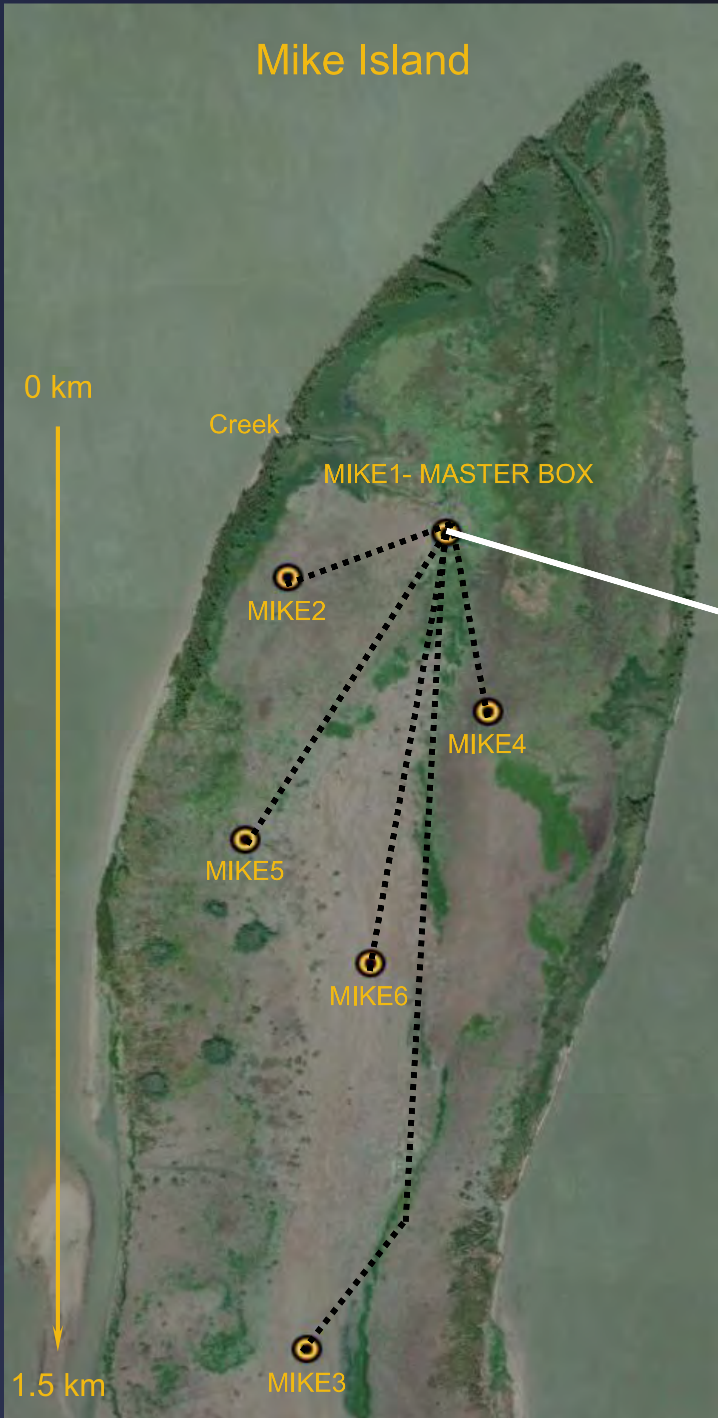


Fig. 18. Graphical depiction of the growth and decay of a delta lobe (adapted from Gagliano and Van Beek 1975; Neill and Deegan 1986). Habitat and biological diversity peak in the early to middle stage of the decay phase.

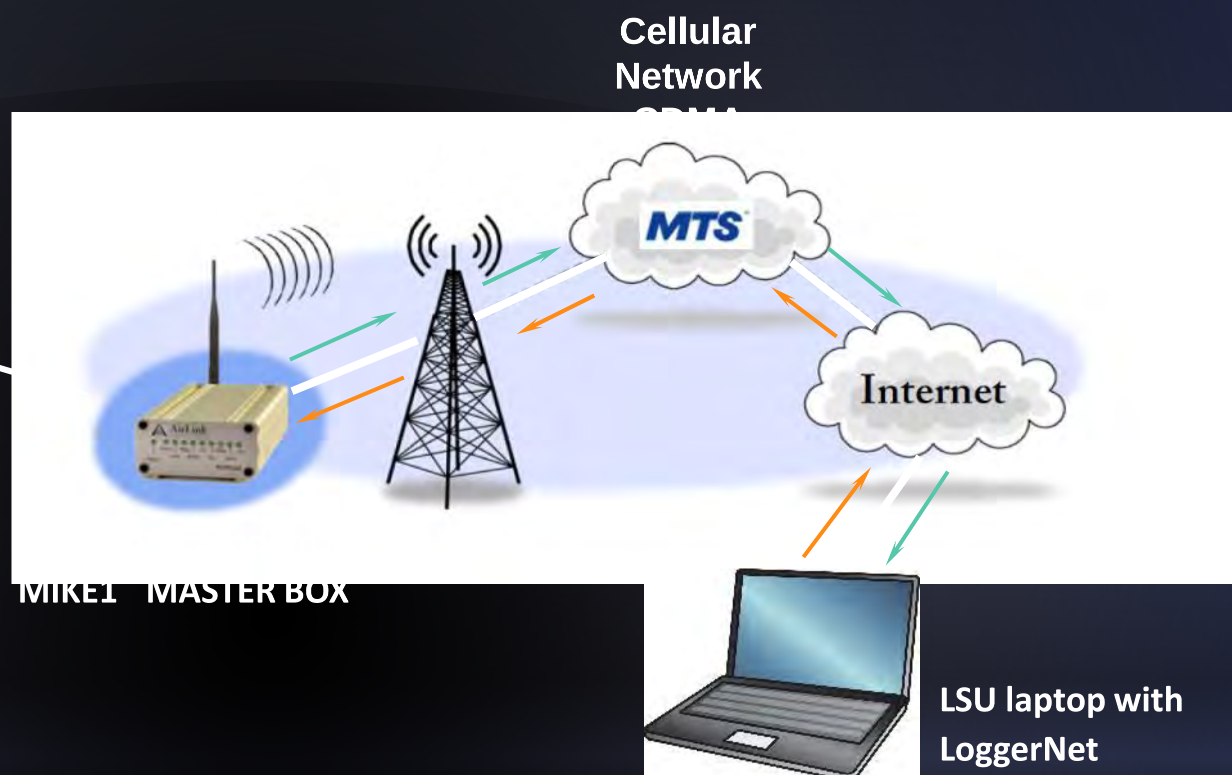
Fig. 37. Commercial shrimp catch.

Fig. 39. Commercial catch of blue crabs.



Telemetry System - WLD

Telemetry: tele = remote; metron = measure



***CDMA** (Code Division Multiple Access) is a radio network technology used by many cellular providers across the globe*

Instrumentation set up

OBS-500
Turbidity

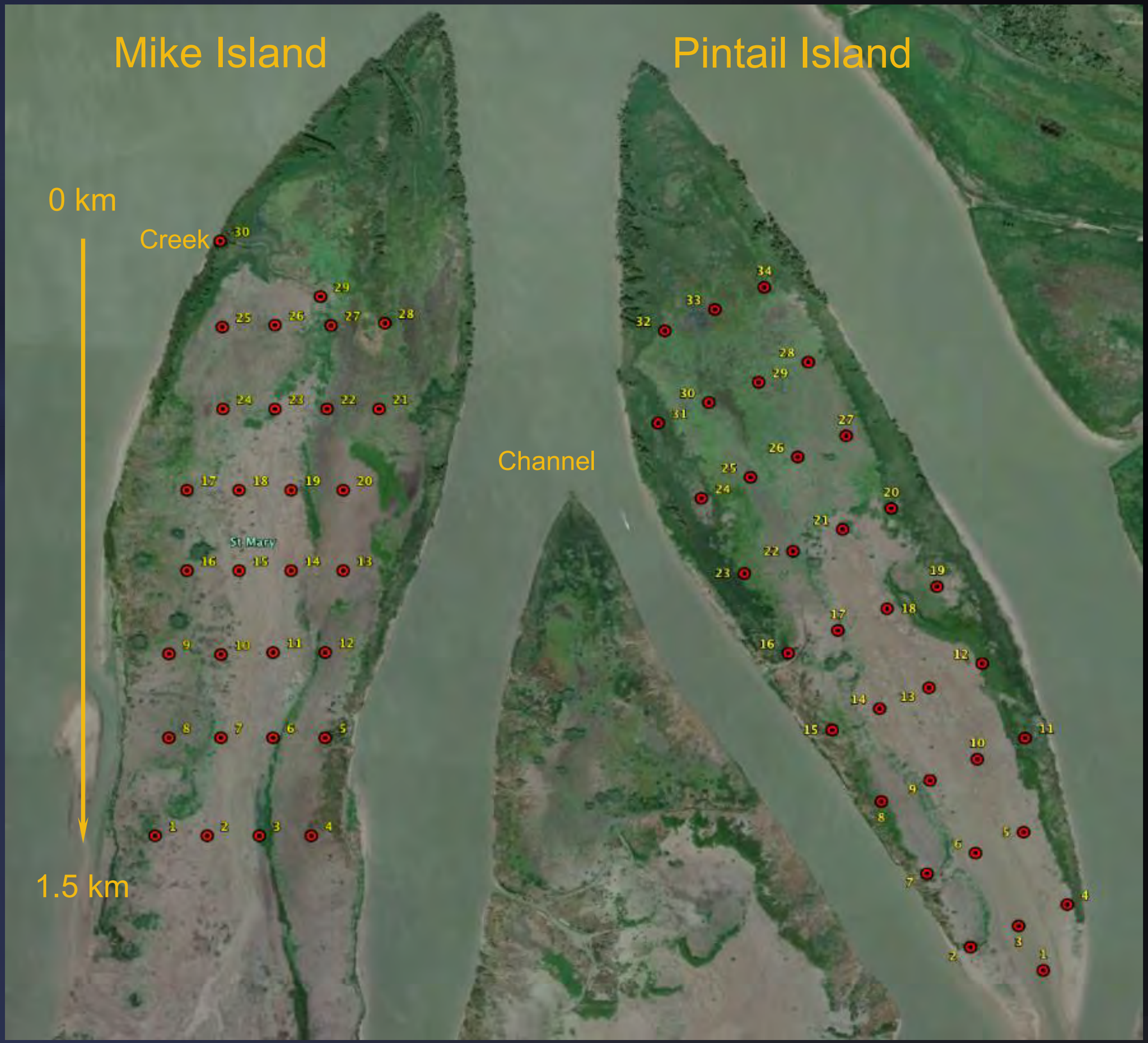
Pressure
transducer

Temperature/
Conductivity

SUNA-V2
Nitrate sensor

Argonaut-ADV
2D side-looking
probe

Water Quality Survey - Mike and Pintail Islands



- Intensive grid (150 x 250 m) sampling in the upper section of Mike Island and whole Pintail Island (30 and 34 stations, respectively).

- Monthly sampling from March to August 2013 to capture variability during peak spring-summer flood season.

- Variables: water column TN, TP, inorganic nutrients, temp, salinity, conductivity, water velocity and direction.

Funding Sources and Collaborations

NSF

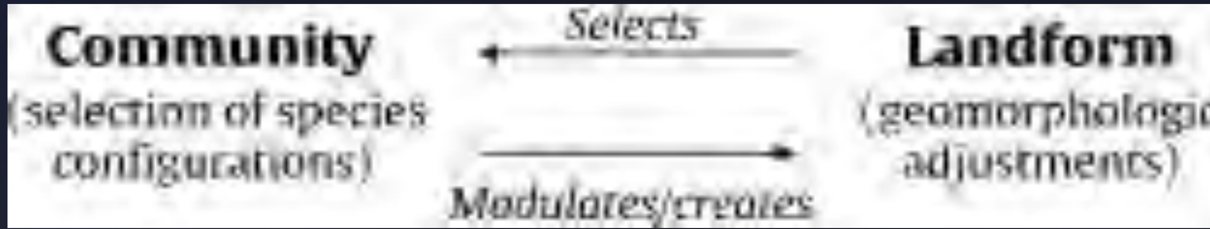
Louisiana Board of Regents

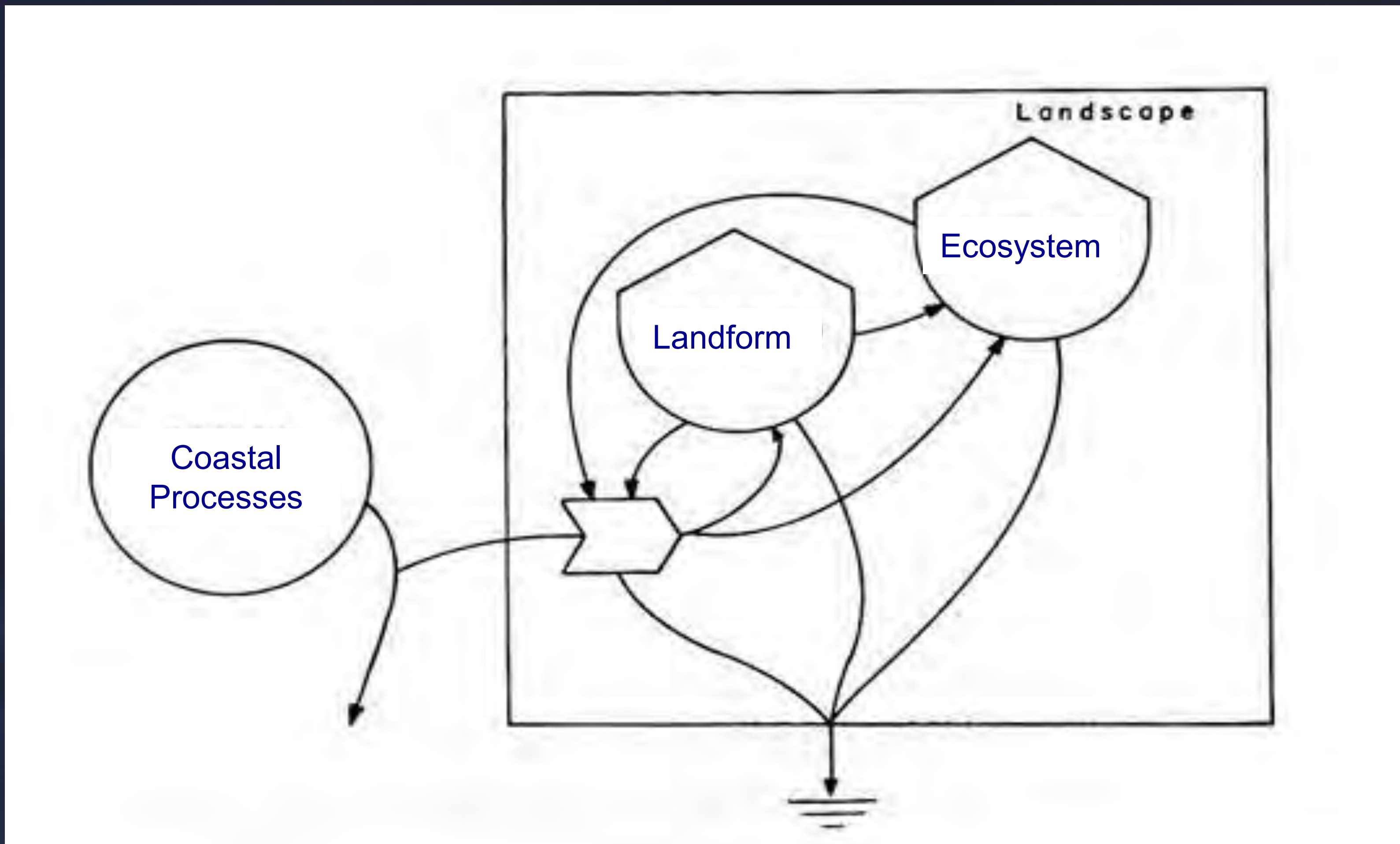
Sea Grant Louisiana

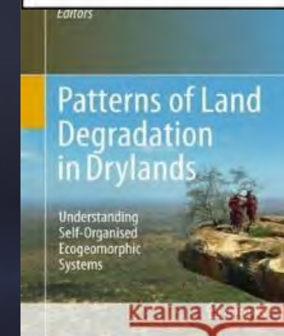
Kelly Henry, Ph.D., **2012**. Linking nitrogen biogeochemistry to different stages of wetland soil development in the Mississippi River delta, Louisiana

Henry and Twilley 2013. Ecosystems DOI: 10.1007/s10021-013-9727-3

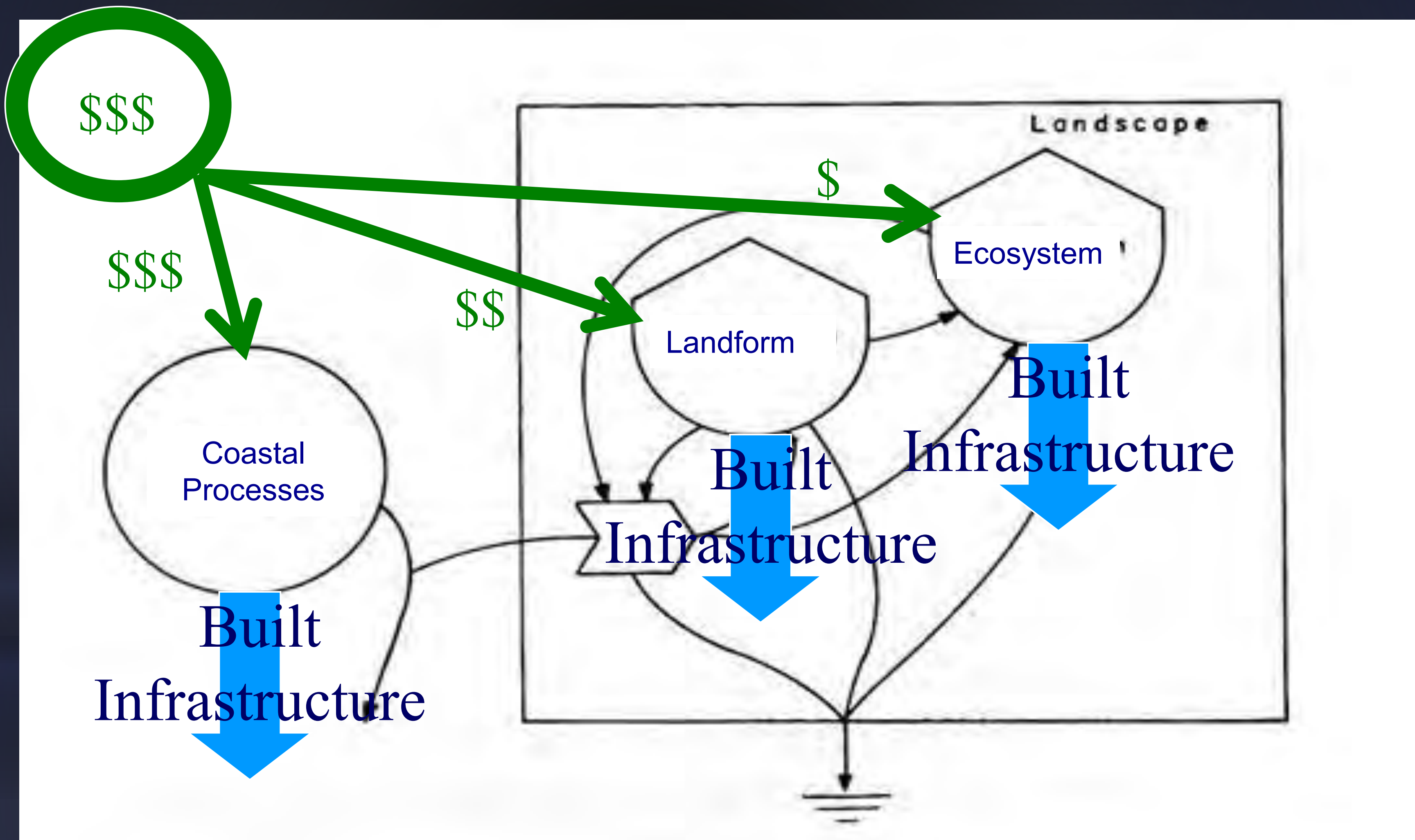
Ben Branoff, M.S., **2012**. Nitrogen biogeochemistry in a restored Mississippi River delta: A modeling approach.







Ecogeomorphology



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Landscape
Ecosystem
Landform
Coastal Processes
Built Infrastructure
Built Infrastructure
Built Infrastructure

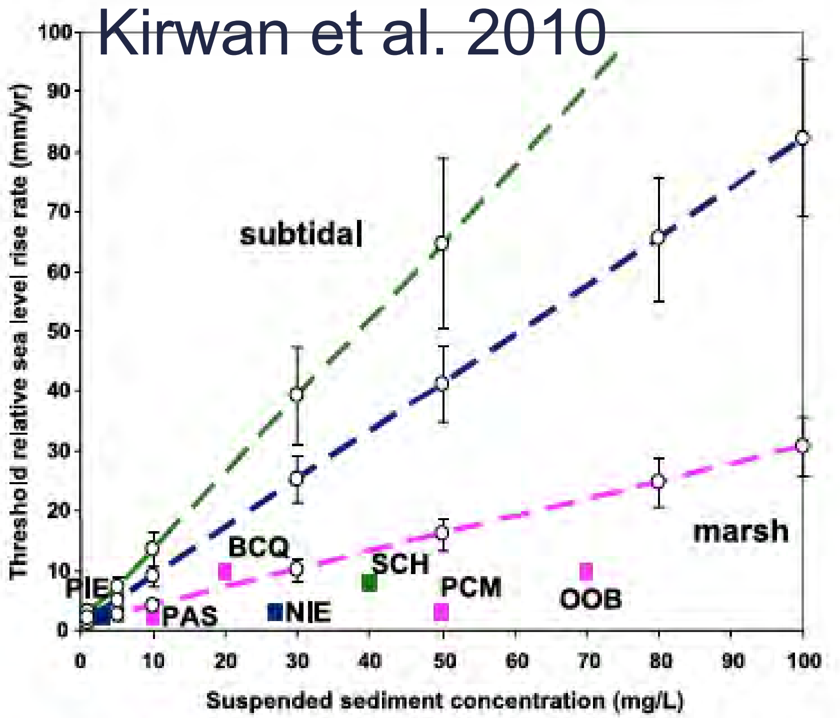
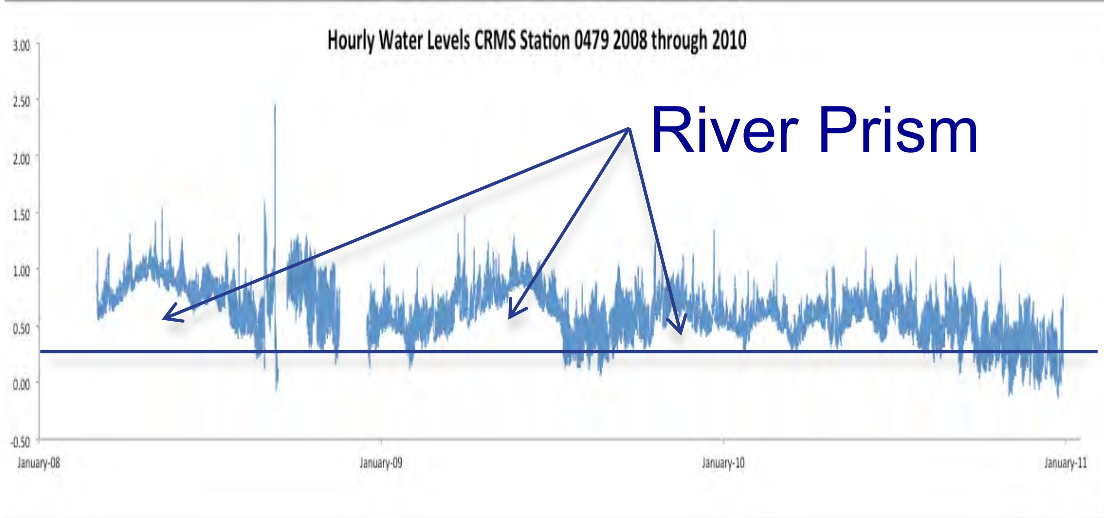
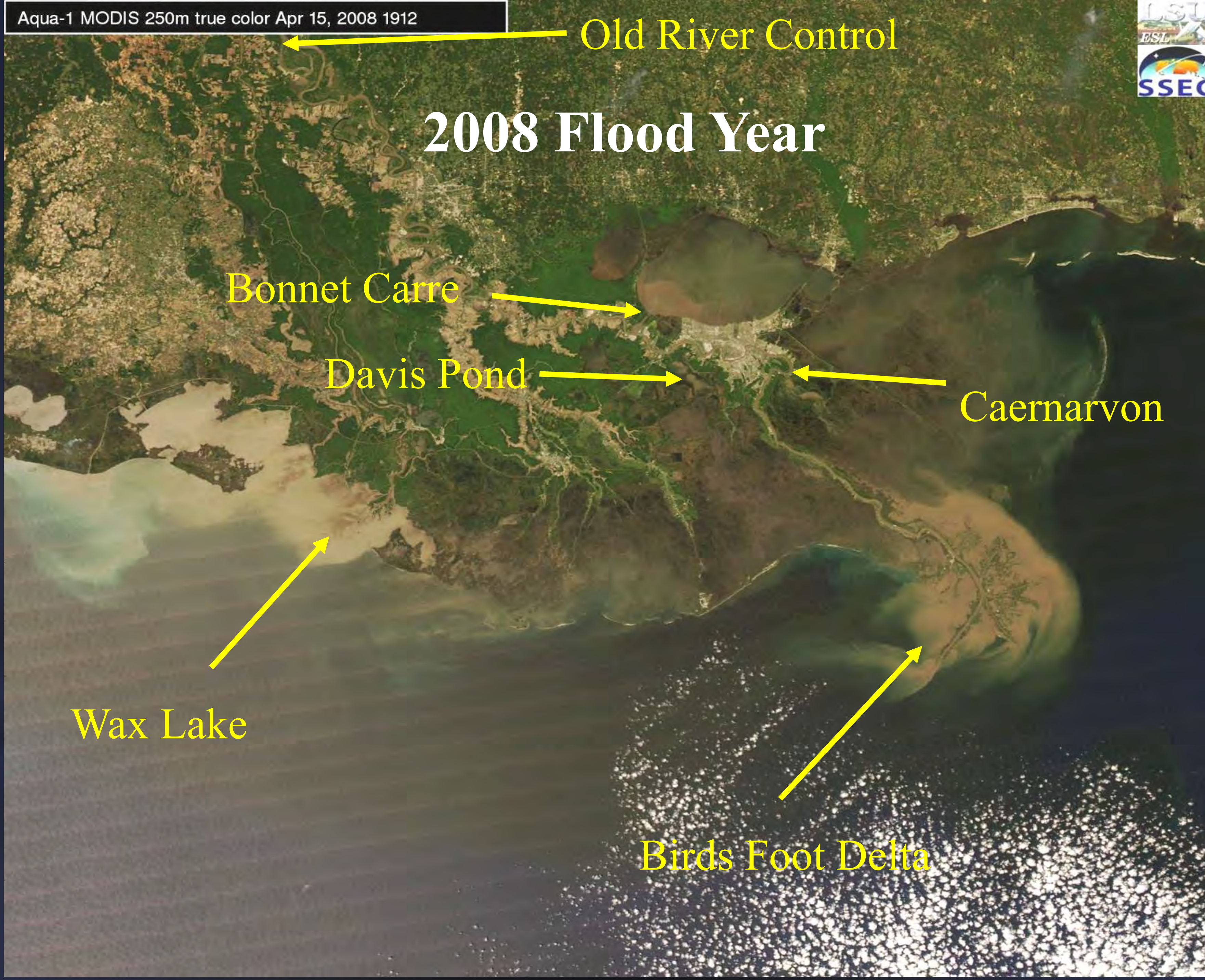


Figure 3. Predicted threshold rates of sea-level rise, above which marshes are replaced by subtidal environments as the stable ecosystem. Each line represents the mean threshold rate (±1 SE) predicted by 5 models as a function of suspended sediment concentration and spring tidal range. Pink line denotes thresholds for marshes modeled under a 1m tidal range, blue line denotes 3 m tidal range, and green line denotes 5 m tidal range. For reference, we have included examples (denoted with square markers) of marshes worldwide in estuaries with different rates of historical sea-level rise, sediment concentration, and tidal range. (Abbreviations: PIE = Plum Island Estuary, Massachusetts; PAS = Pamlico Sound, North Carolina; BCQ = Bayou Chitique, Louisiana; NIE = North Inlet Estuary, South Carolina; SCH = Scheldte Estuary, Netherlands; PCM = Phillips Creek Marsh, Virginia; OOB = Old Oyster Bayou, Louisiana).




Aqua-1 MODIS 250m true color Apr 15, 2008 1912
Old River Control
2008 Flood Year
Bonnet Carre
Davis Pond
Caernarvon
Wax Lake
Birds Foot Delta
LSU ESL
SSEC