Long-term Change in Lavaca and Matagorda Bays Related to Freshwater Inflow Change

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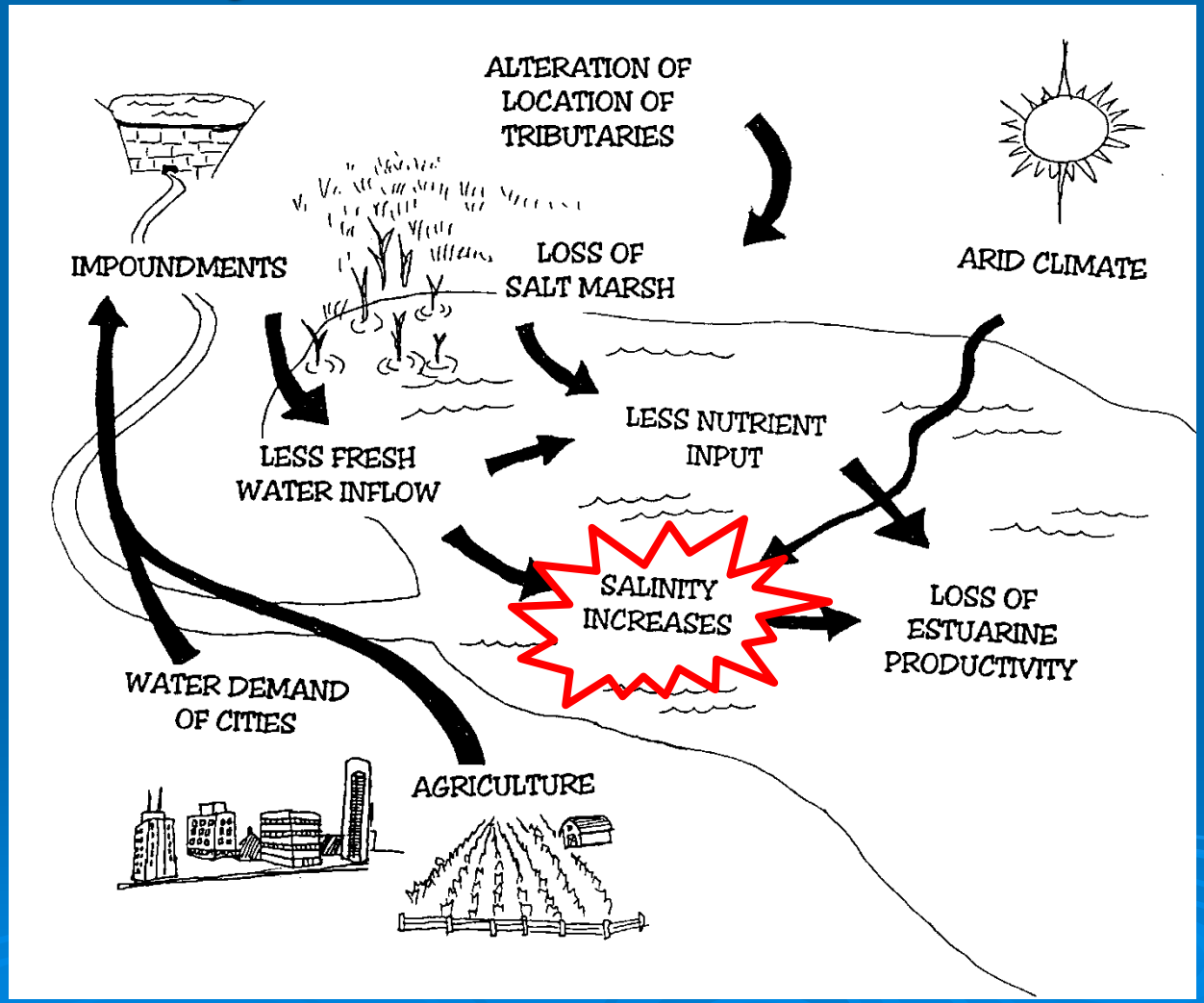
Altered Freshwater Inflow Changes Coastal Bays & Estuaries

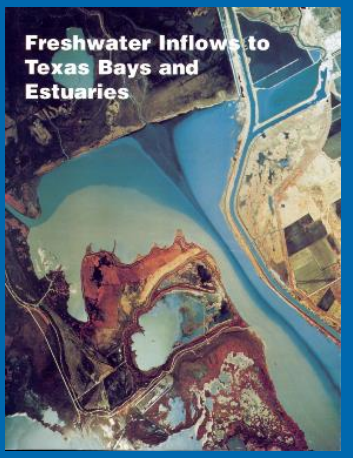
- Changes:
  - Hydrology
  - Nutrients
  - Sediments
  - Salinity
- Loses:
  - Habitat
  - Biodiversity
  - Productivity
  - Ecosystem Services



Source: Montagna et al. 1996, CCBNEP #8
http://cbbep.org/publications/virtuallibrary/ccbnep08.pdf

History of Inflow Legislation in Texas

- 1985: House Bill 2
  - Established data collection programs necessary to "support a sound ecological environment"
    - Protected 7 species: White shrimp, brown shrimp, blue crab, oyster, red drum, spotted seatrout, black drum
  - 1994: *Freshwater Inflow to Texas Bays and Estuaries*



- 2007: Senate Bill 3
  - Required environmental flow regime standards for geographic segments state-wide
  - Standard must be "adequate to support a sound ecological environment and to maintain the productivity, extent, and persistence of key aquatic habitats . . ."

Difference in Instream vs. Inflow Approaches

- Freshwater systems: Flow defines habitat


Rapid


Riffle


Run

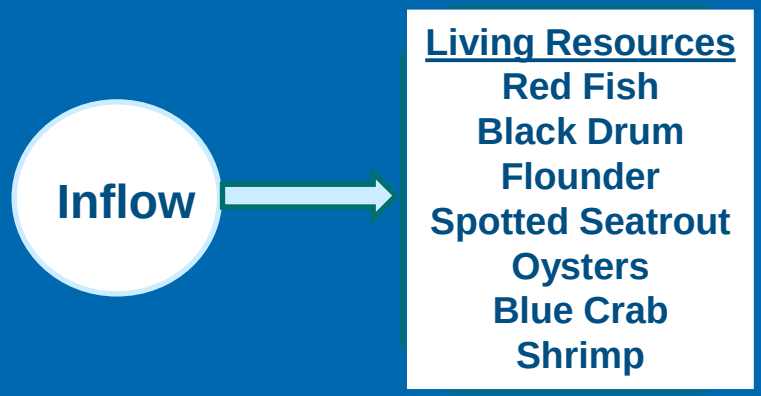

Pool

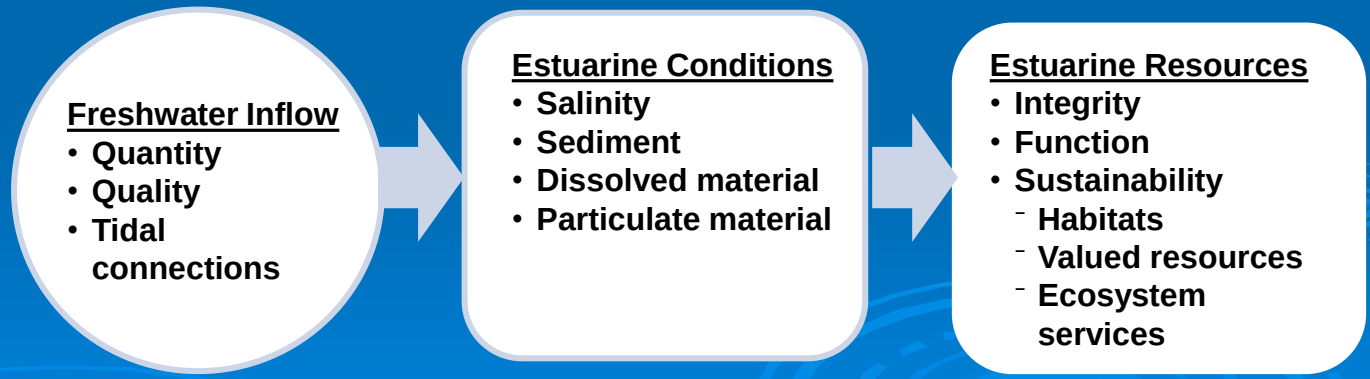
- Coastal waters: Flow defines conditions and conditions create habitat

Lavaca and Matagorda Bays After a Flood

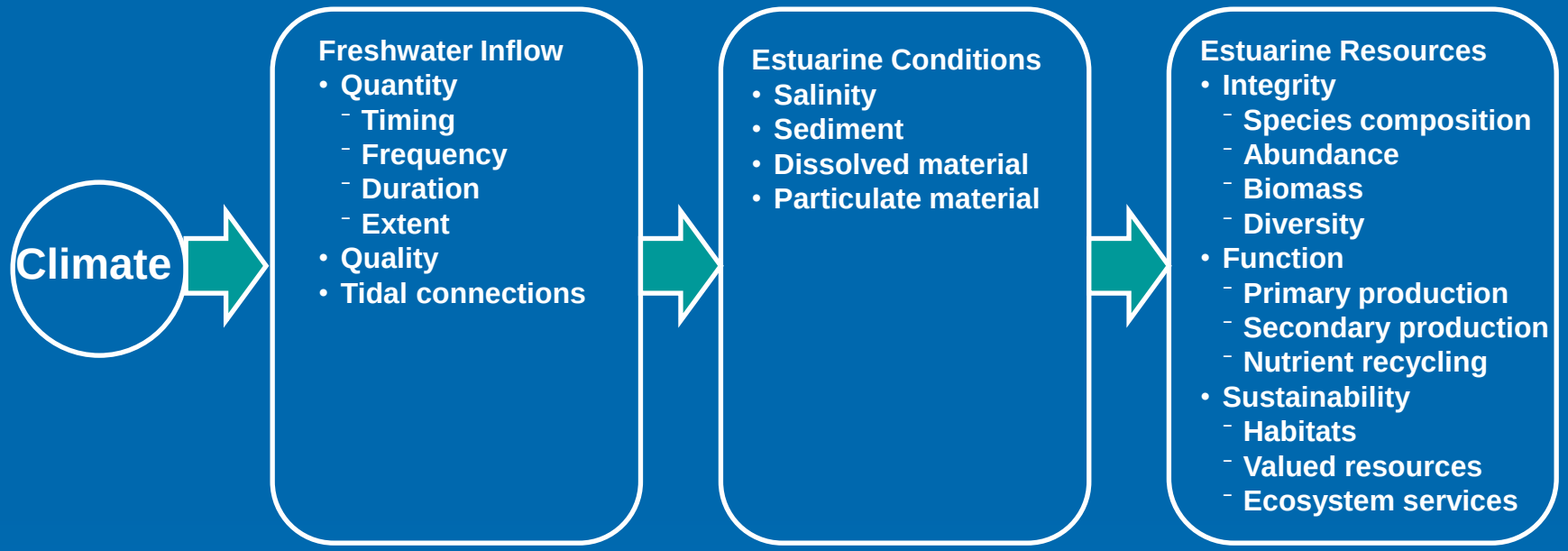
Inflow Science in Texas

- Reflects two major eras:
  - 1985 HB2
    - Influenced by riverine studies
    - Species-based approach
  - 2007 SB3
    - Evolving science
    - Ecosystem-based approach





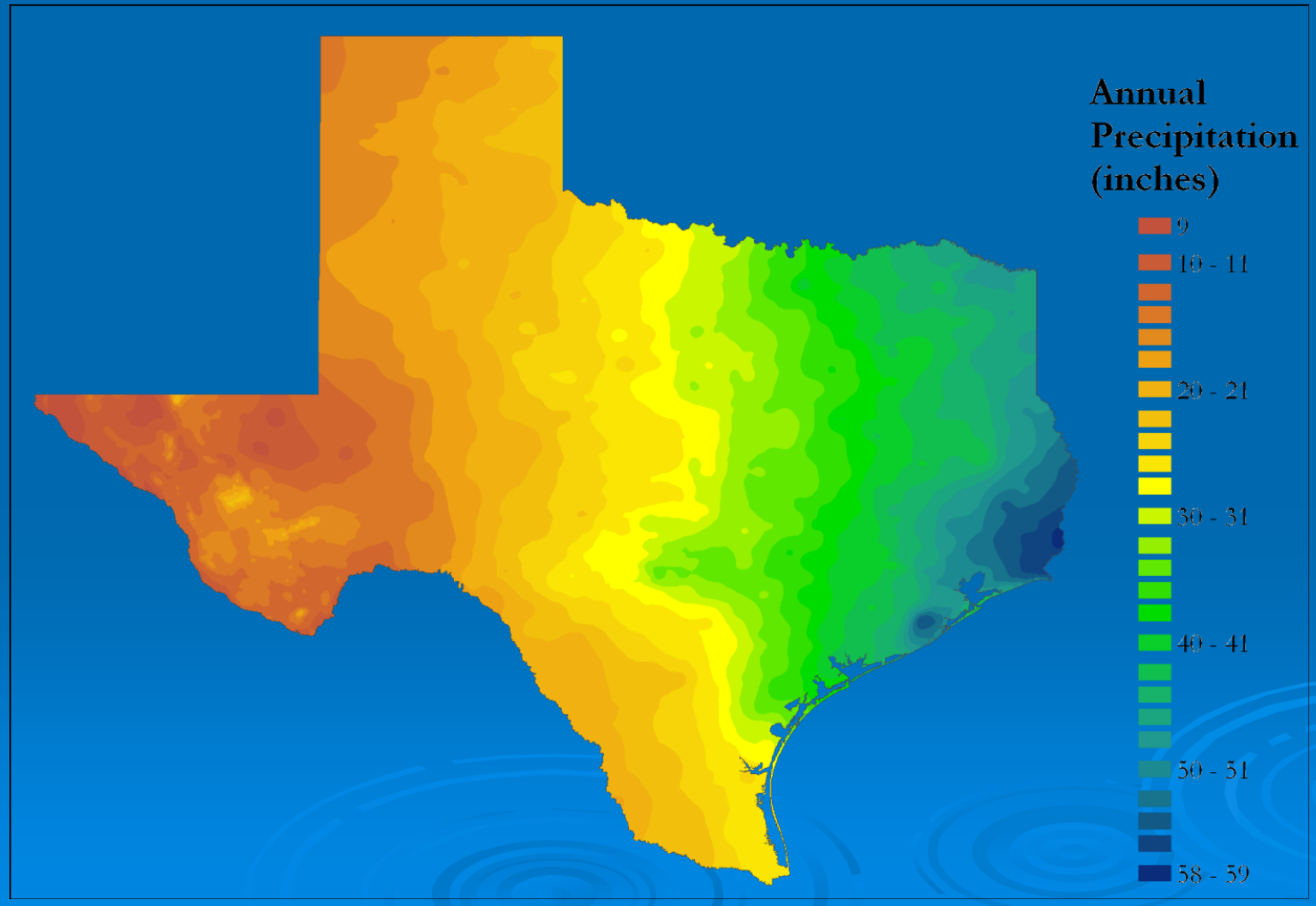
Inflow Has Indirect Effects on Biological Resources: "Domino Theory"



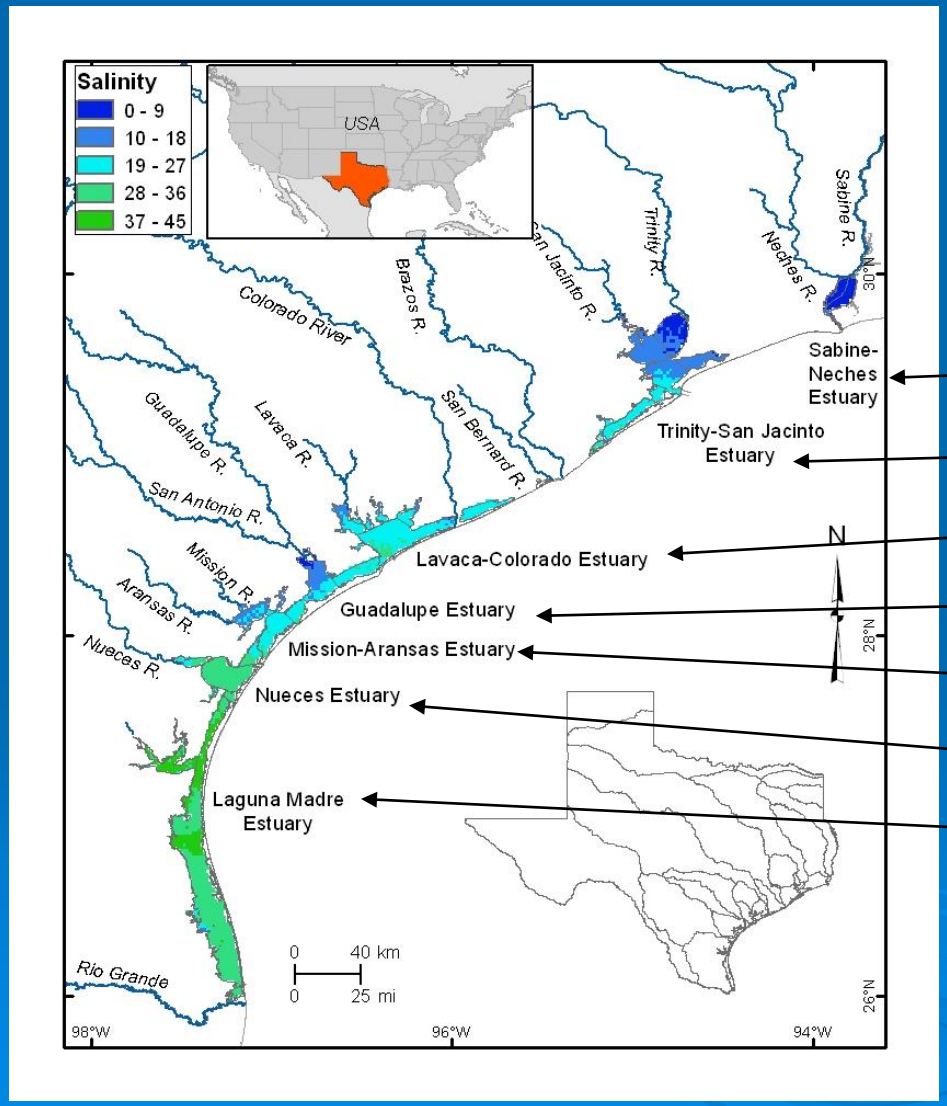
Evolution of the idea:

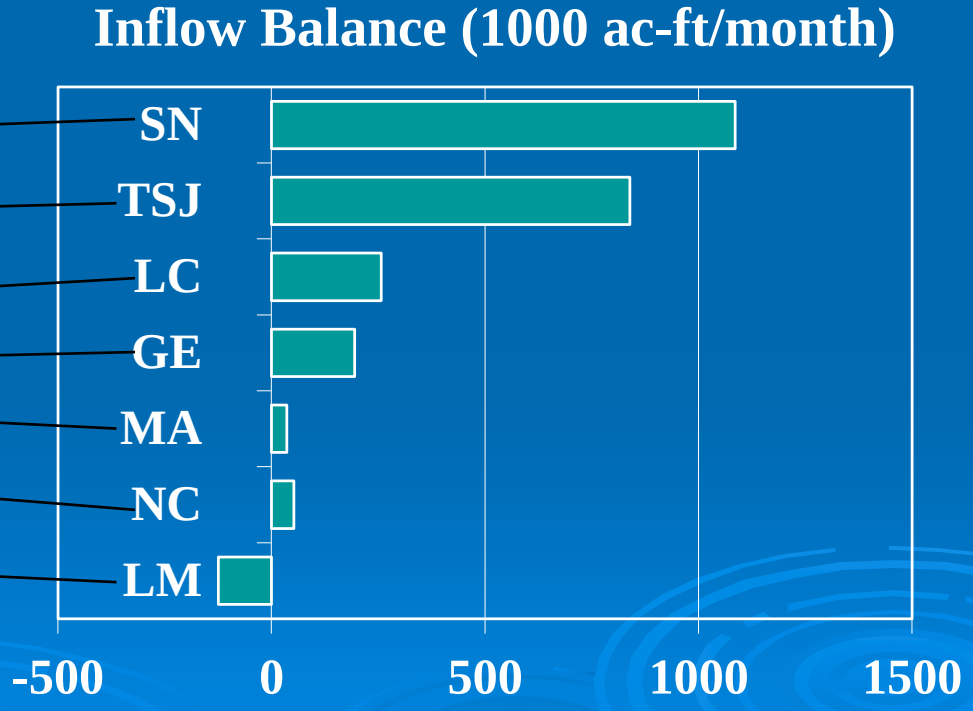
- Alber, *Estuaries* (2002) https://doi.org/10.1007/BF02692222
- Science Advisory Committee, *Methodologies for Establishing a Freshwater Inflow Regime* (2009)
- Palmer et al., *Hydrobiologia* 667:49-67 (2011) https://doi.org/10.1007/s10750-011-0637-0
- Montagna et al., *Hydrological Change and Estuarine Dynamics* (2013)
- Montagna, *Gulf and Caribbean Research* 32:14 pp (2021) https://doi.org/10.18785/gcr.3201.04

There is a Rainfall Gradient From East to West in Texas



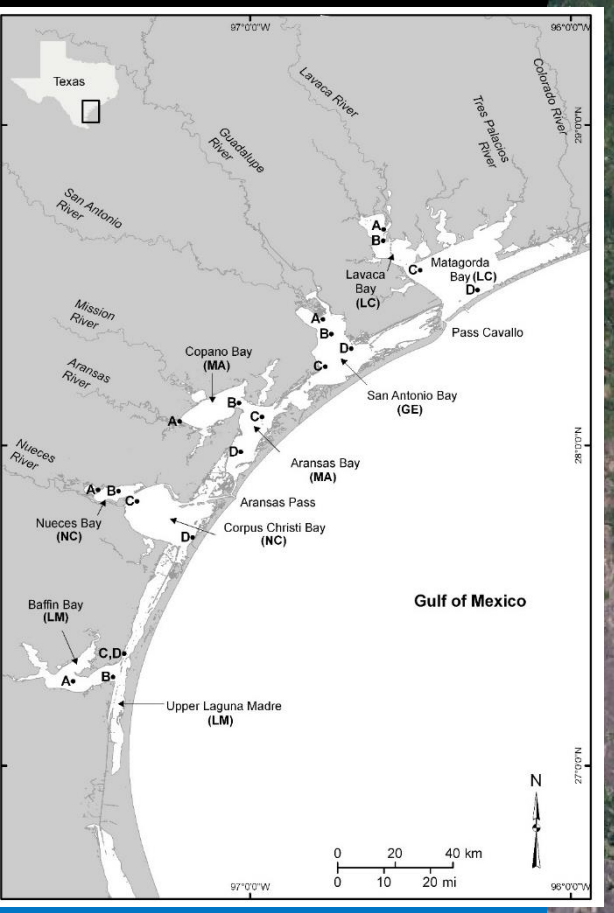
Texas Coast-Wide Inflow Gradient Provides a Perfect Natural Experiment





Inflow (TWDB): 1941-2009
Salinity (TPWD): 1977-2015

HRI Long-Term Studies



Gradient in turbidity during a flooding event indicates inflow differences

Lavaca-Colorado

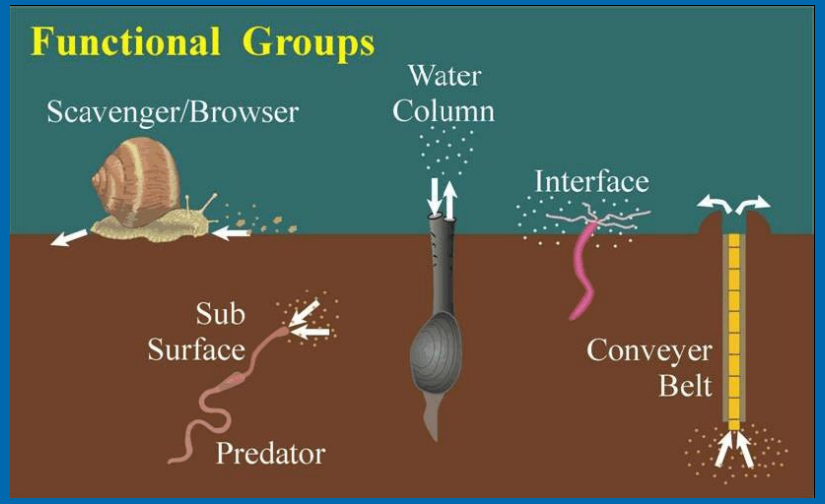
Guadalupe

Nueces

Water and sediment quality measured from 1987 to 2019

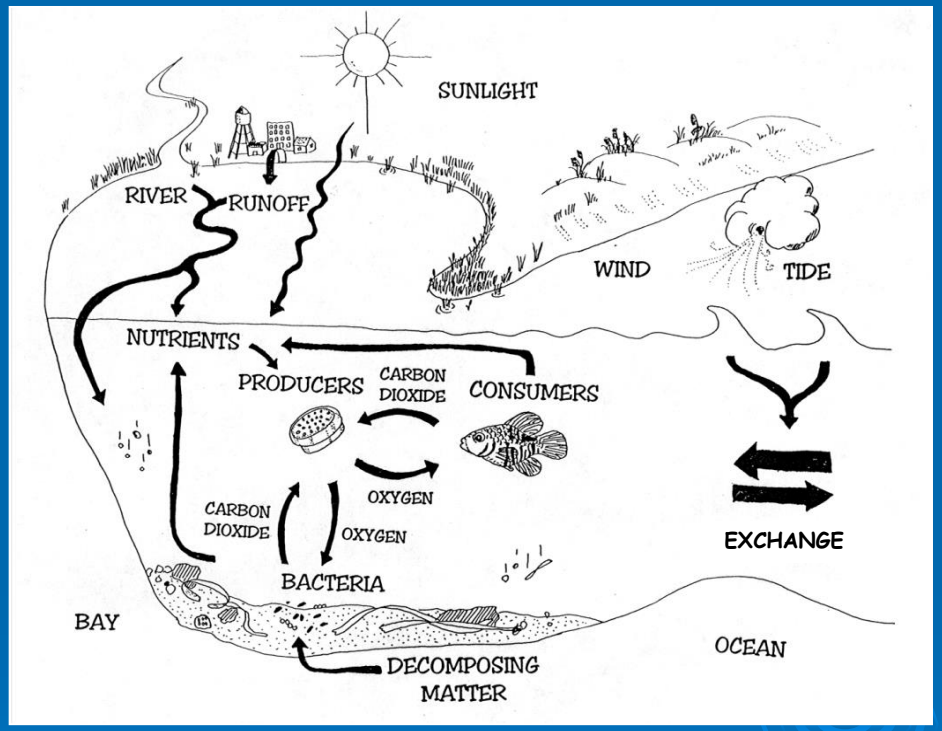
11.6.2002

Benthos are Indicators and Integrators



Source: Tenore, K.R. et al. (2006) *Journal of Experimental Marine Biology and Ecology* 300:392-402

- Sediments are the memory of the ecosystem
- Benthos are sampling water column 24/7/365
- Thus, benthos are integrators
  - overlying water column is dynamic
  - benthos sample and integrate ephemeral events over long times scales

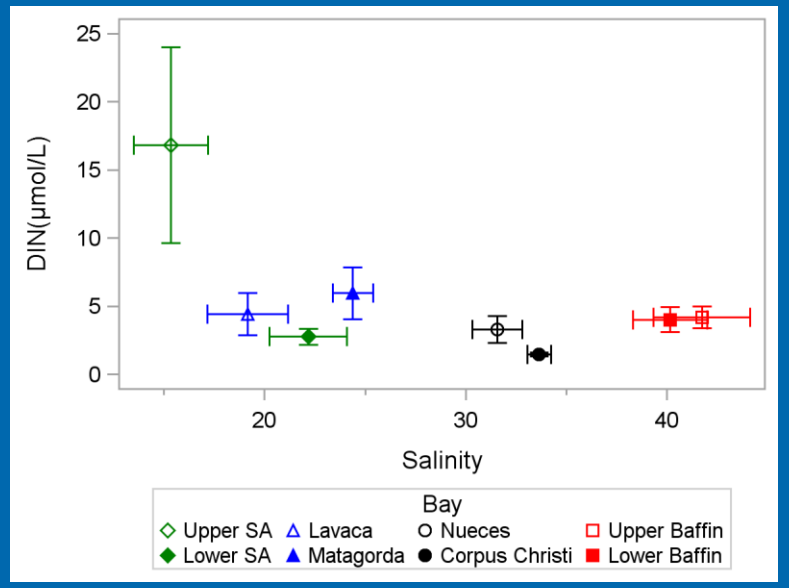


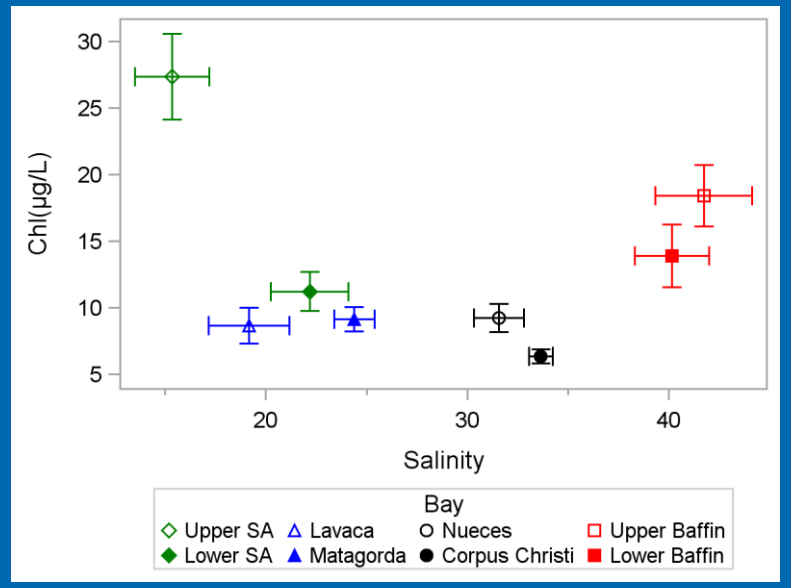
Source: Montagna et al. (1996) CCBNEP #8 http://cbbep.org/publications/virtuallibrary/ccbnep08.pdf

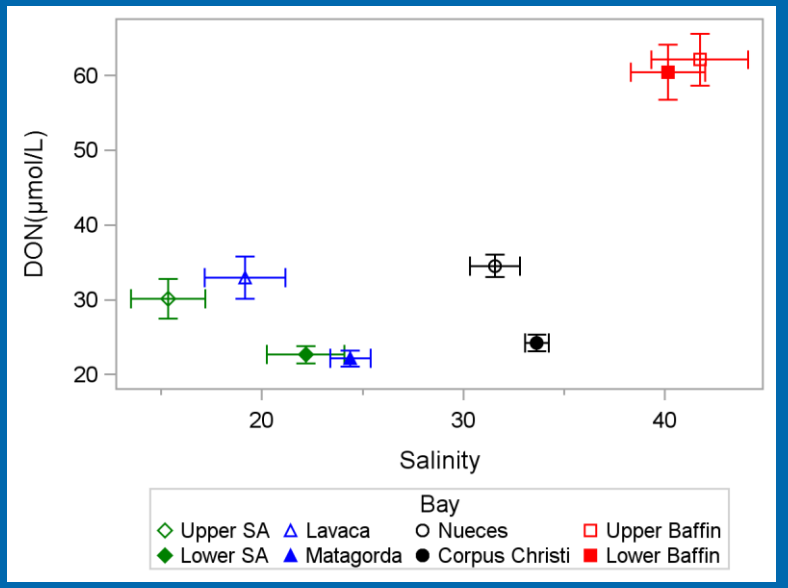
Benthos are Preferred Bioindicators by BBEST's

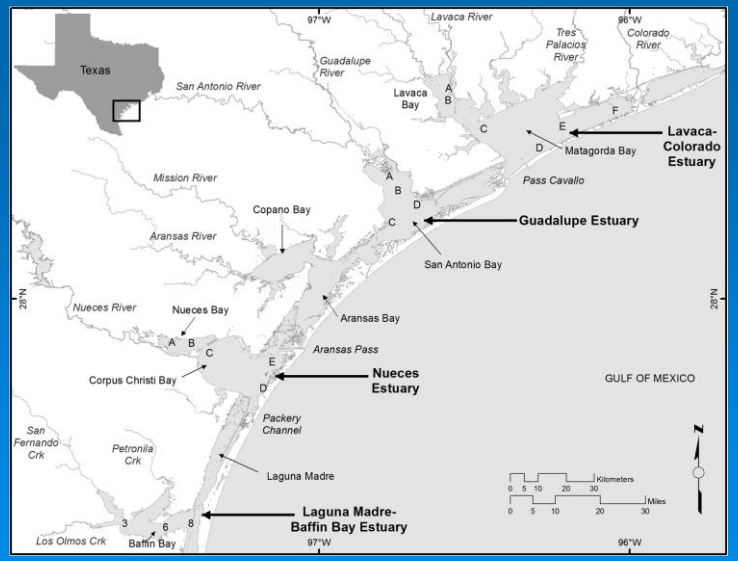
Bay System	Indicator Species
Sabine Lake, 2009	Eastern oyster, Atlantic rangia, Blue crab juveniles, Olney bulrush, Intermediate marsh, Brackish marsh
Galveston Bay, 2009	Eastern oyster, Atlantic rangia, Dermo, Oyster drill, Wild celery, Gulf menhaden, blue catfish, Mantis shrimp, Pinfish
Brazos River, 2012	Salinity, Nutrients, Sediment supply
Lavaca and Matagorda Bays, 2011	Eastern oyster, Dermo, Oyster drill, brown shrimp, white shrimp, blue crab, Gulf menhaden and Atlantic croaker, Benthic infauna
Mission, Copano, Aransas, and San Antonio Bays, 2011	Eastern oyster, Atlantic rangia, brown rangia, white shrimp, Blue crab
Nueces, Corpus Christi, and Baffin Bays, 2011	Eastern oyster, Atlantic rangia, Smooth cordgrass, benthic infauna, blue crab, Atlantic croaker, nutrient cycling, sediment loading
Lower Laguna Madre, 2012	Seagrasses

Key Findings Over 30 Years Nutrients



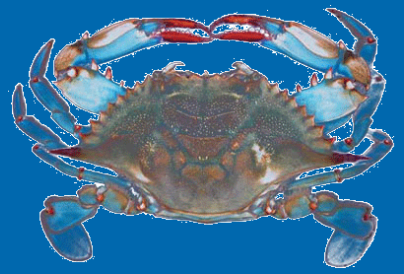






Nutrients and chlorophyll patterns illustrate an emerging paradigm where phytoplankton biomass in positive estuaries is supported by "new" nitrogen from riverine input, while high concentrations of reduced nitrogen (organic, ammonium) allowed for high chlorophyll in the negative estuary. (Limnol. Oceanogr., 2018, 63: 2465–2478)

Key Findings Over 30 Years
Effects of Droughts on Texas Bays



Blue Crabs

- Abundance ↓
- Size (width) ↑
- Juvenile Abundance ↓
- Juvenile % ↔

Shrimp

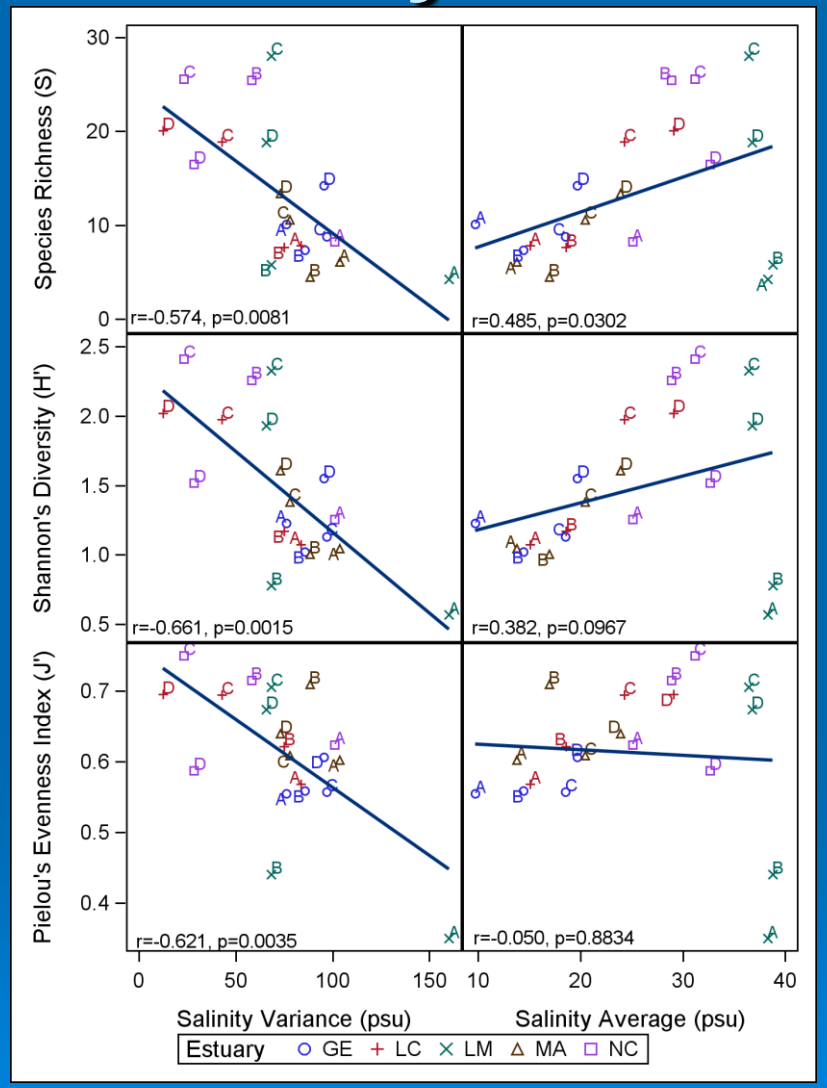
- Abundance ↓
- Size (length) ↑
- Juvenile Abundance ↓
- Juvenile % ↓

Water Quality

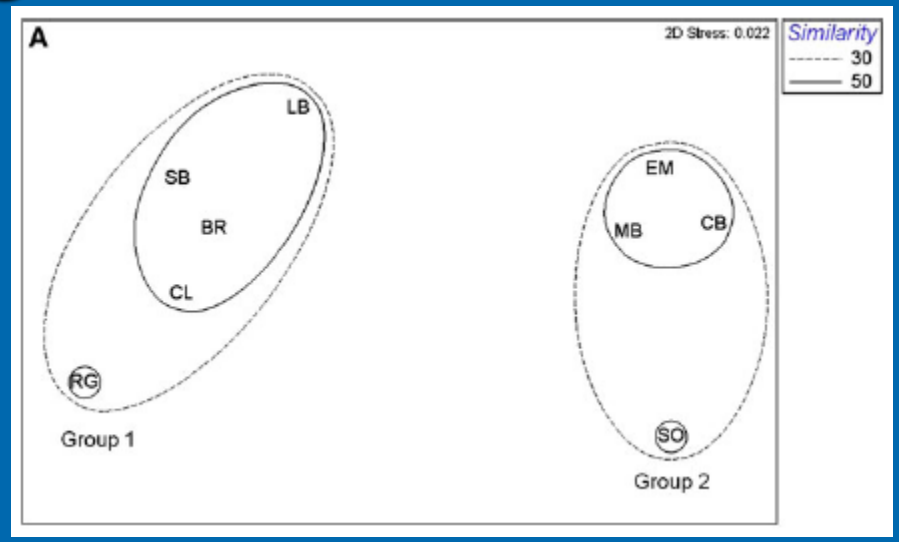
- Nitrate + Nitrite ↓
  Reduced loading
- Chlorophyll ↓
  Reduced nutrients
- pH ↓
  Reduced photosynthesis

Hydrobiologia, 2015, 753: 111-129

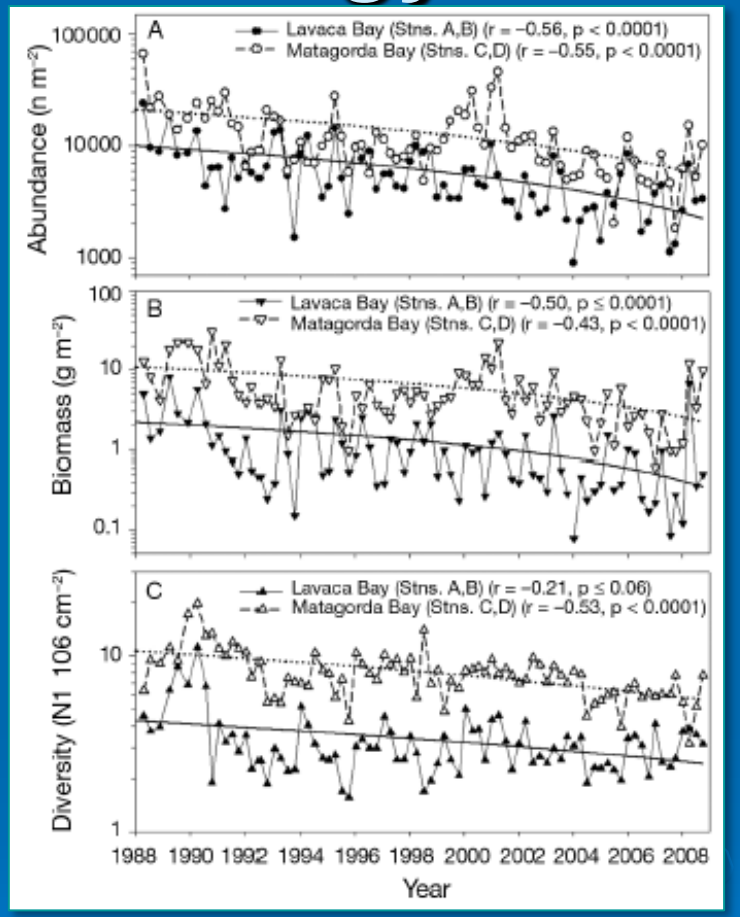
Key Findings Over 30 Years - Biology



Salinity variability drive diversity (Estuaries and Coasts, 2016, 39:967-980)



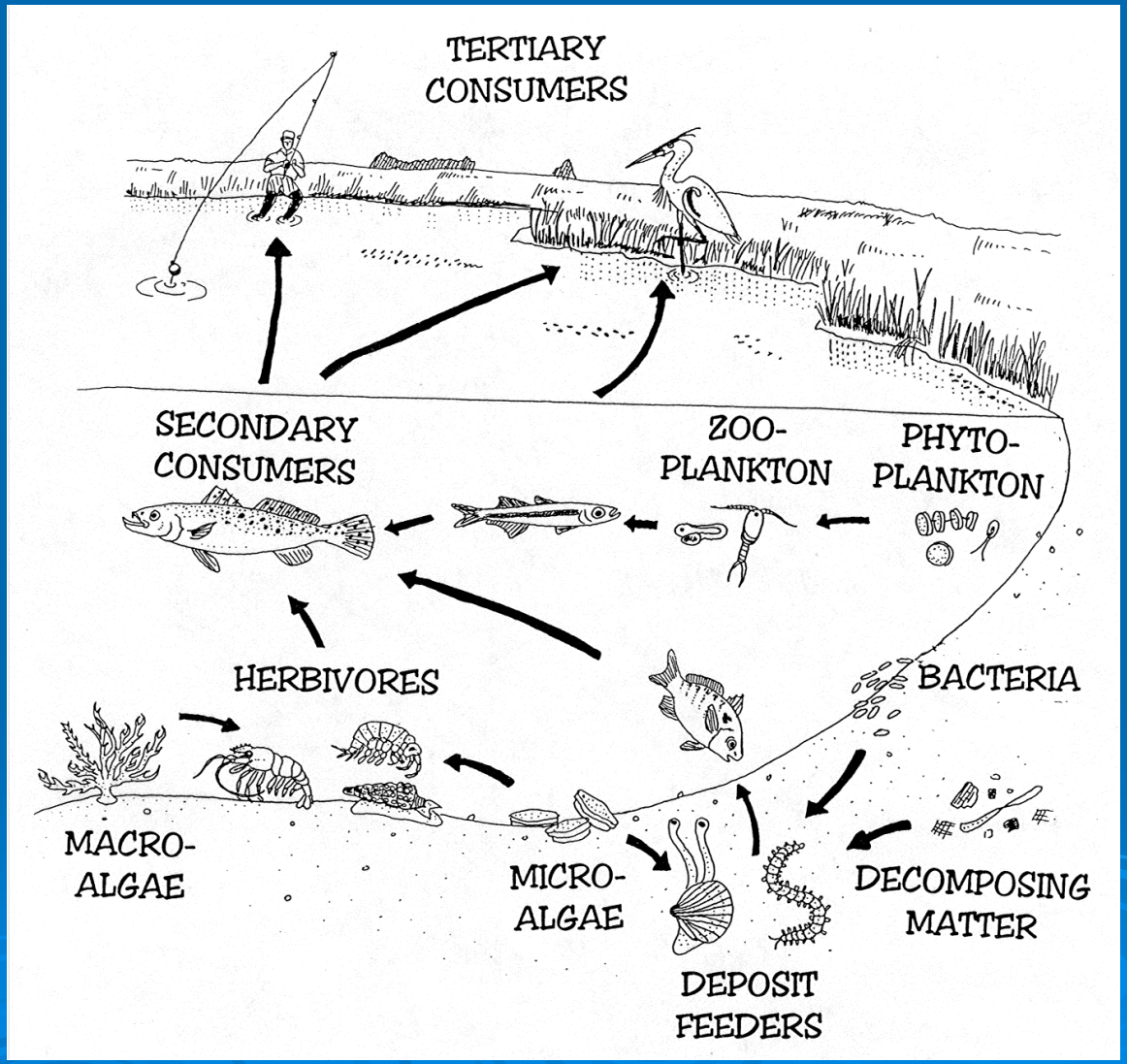
Primary bays near GOM (Group 2) have different community structure than secondary bays near rivers (Group 1) (Hydrobiologia (2011) 667:49–67)



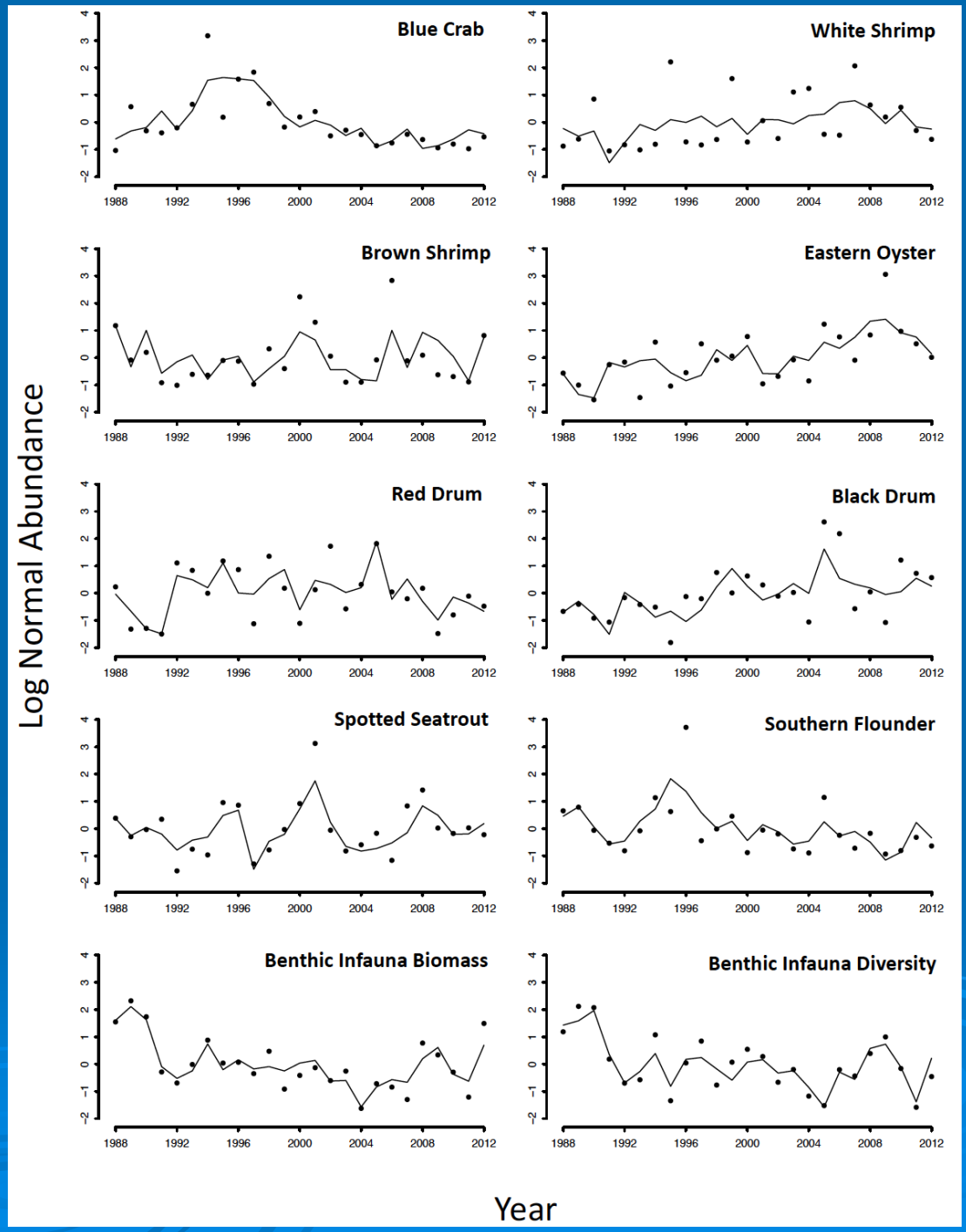
Benthos are declining dramatically in the Lavaca-Colorado Estuary, Texas (Mar Ecol Prog Ser, 2011, 436:67-80) and other estuaries

Should We Care if Mud Bugs are Disappearing?

- Benthos are key food sources for fish

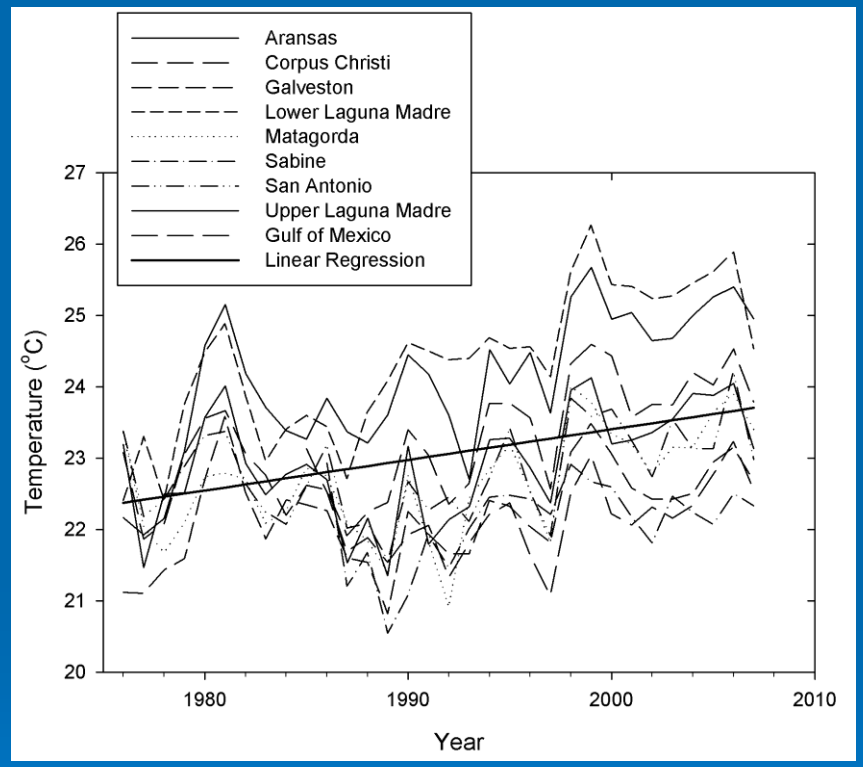


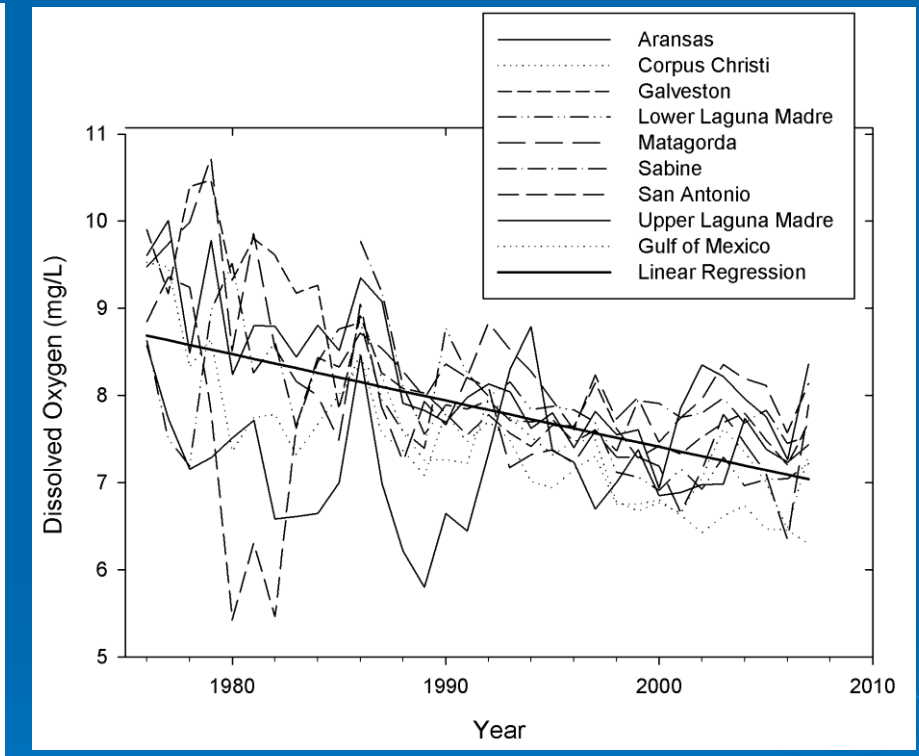
Blue Crab and Flounder also declining, but Black Drum increasing



Climate Change?

- From 1980 to 2008, sea water temperatures increased and dissolved oxygen is decreased coast-wide





The Impact of Global Warming on Texas

Second edition

Edited by Jurgen Schmandt, Gerald R. North, and Judith Clark

University of Texas Press, Austin

2011

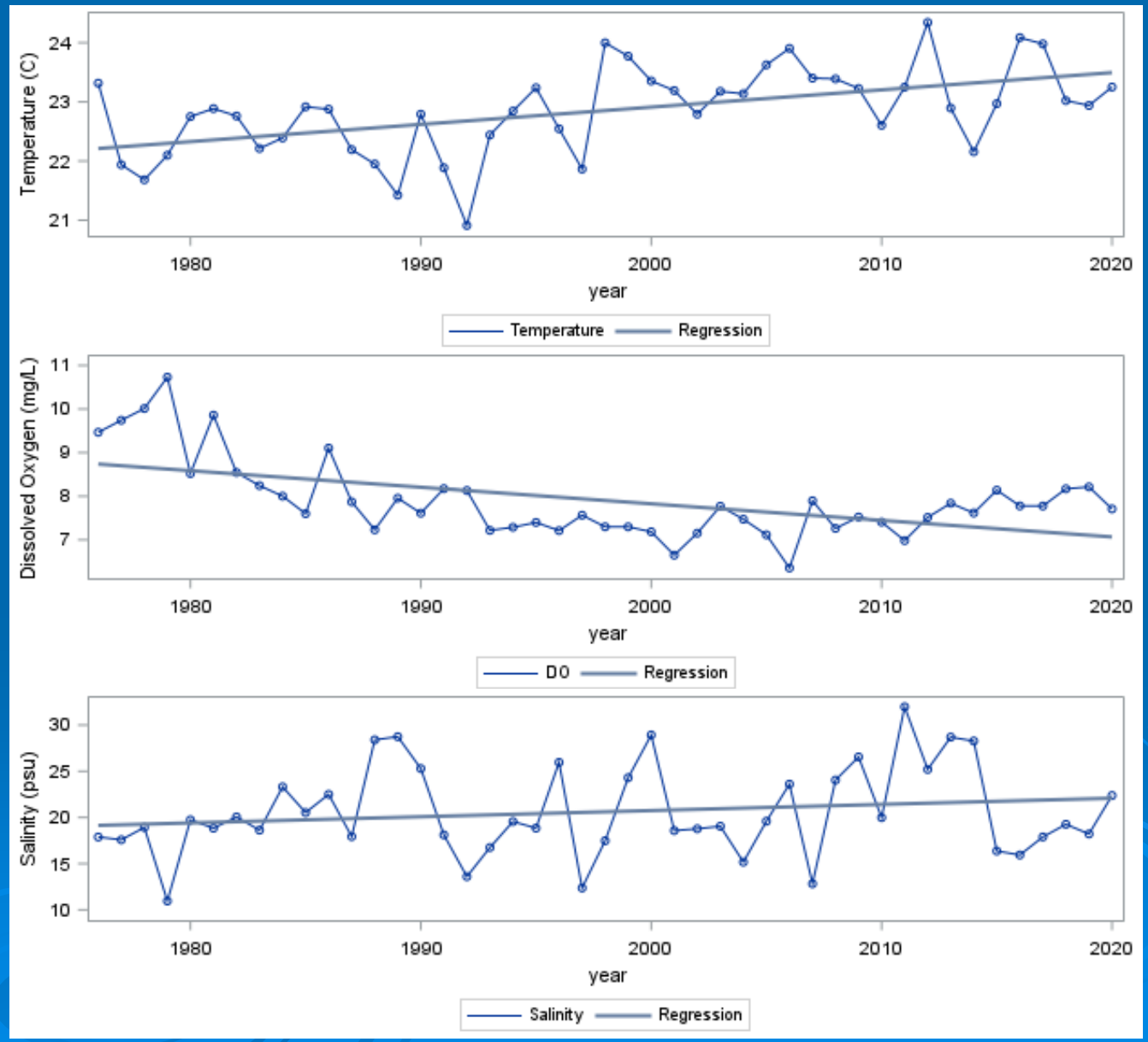
Chapter 4

Coastal Impacts

Paul A. Montagna, Jorge Brenner, James Gibeaut, Sally Morehead

Change is Acute in Matagorda Bay System

- Sea water temperature is rising
- Dissolved oxygen is decreasing
- Salinity is not changing

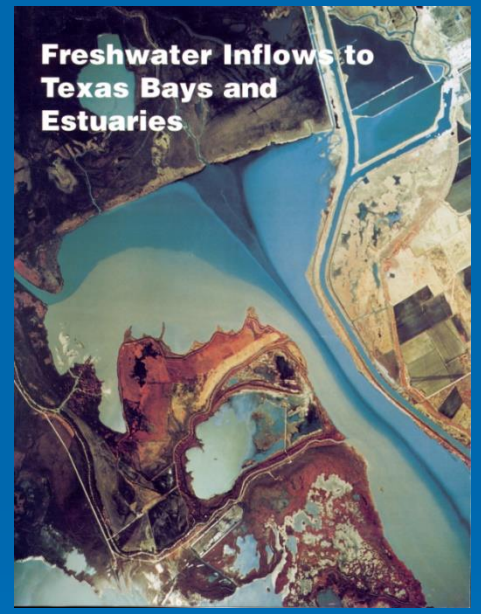


So, What's Going On

- Evidence of climate change effects
- Jasmine provided evidence of non-point source pollution
- Need to change the curve!

Next Steps – Better Outputs

- Publish a second edition of “Freshwater Inflow to Texas Bays and Estuaries”
  - Legal framework is SB3, not HB2
  - Management goal now different
  - Methodology now different
  - 30 years of new data
  - “Must Need” for adaptive management
  - New goal: not how much FWI needed for whole bay, but how much is needed to maintain natural hatcheries (i.e., refugia)



- Team 10 Co-PI’s + many other people

With Help From Many (over many years)

- Sponsors (past and present)
  - Local
    - City of Corpus Christi
    - Coastal Bend Bays & Estuaries Program
    - Lower Colorado River Authority
    - Matagorda Bay Mitigation Trust (Today)
  - State
    - TX Water Development Board
    - TX General Land Office (Today)
    - TX Sea Grant (Today)
  - Federal
    - National Aeronautics and Space Administration
    - National Oceanic Atmospheric Administration (Today)
    - National Science Foundation
    - US Army Corps of Engineers
    - US Bureau of Reclamation
  - Foundations
    - Harte RF, CF
    - Tinker
    - Hershey (Today)
    - Mitchell
    - National Fish and Wildlife Foundation
- Staff
  - Rick Kalke
  - Larry Hyde
  - +16 others
- 44 Students
- 15 Postdocs