Restored oyster reefs enhance estuarine ecosystem services by altering nearshore salinity

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UF|IFAS UNIVERSITY *of* FLORIDA

Sea Grant Florida

Globally: "Most Threatened" Marine Habitat

Beck et al. 2011

Globally: "Most Threatened" Marine Habitat

- Overharvest
- Oil spills
- Flow Reductions

- Development/pollution
- Changing climate (temp, SLR, rain)
- Erosion (boats & storms)

- Disease

Beck et al. 2011

Reef condition

Bay	Ecoregion	
●	Good	
◐	Fair	
◉	Poor	
○	Functionally extinct	

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Reef condition

Bay — Ecoregion
- ● — Good
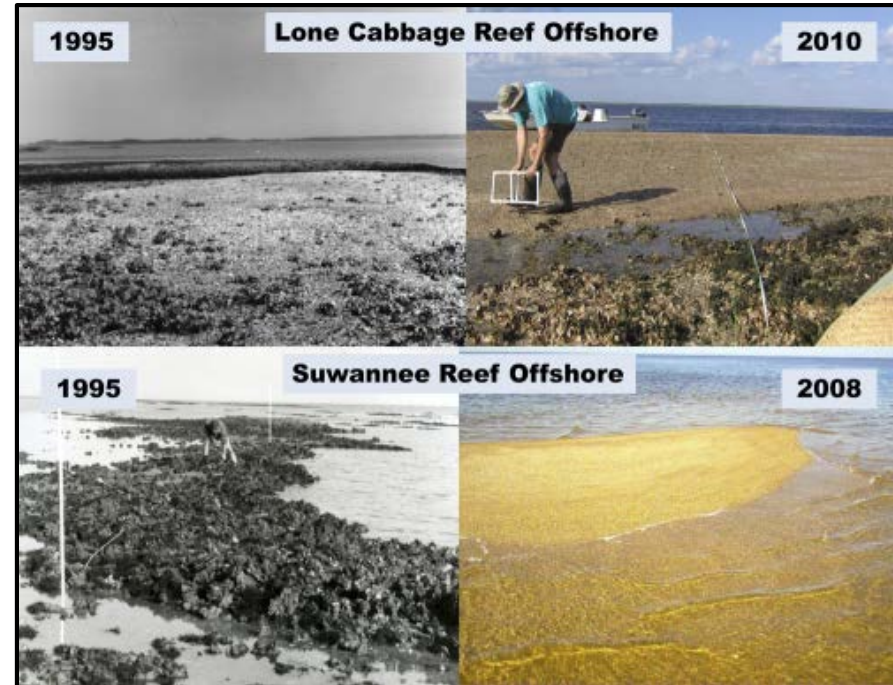- ◐ — Fair
- ◉ — Poor
- ○ — Functionally extinct
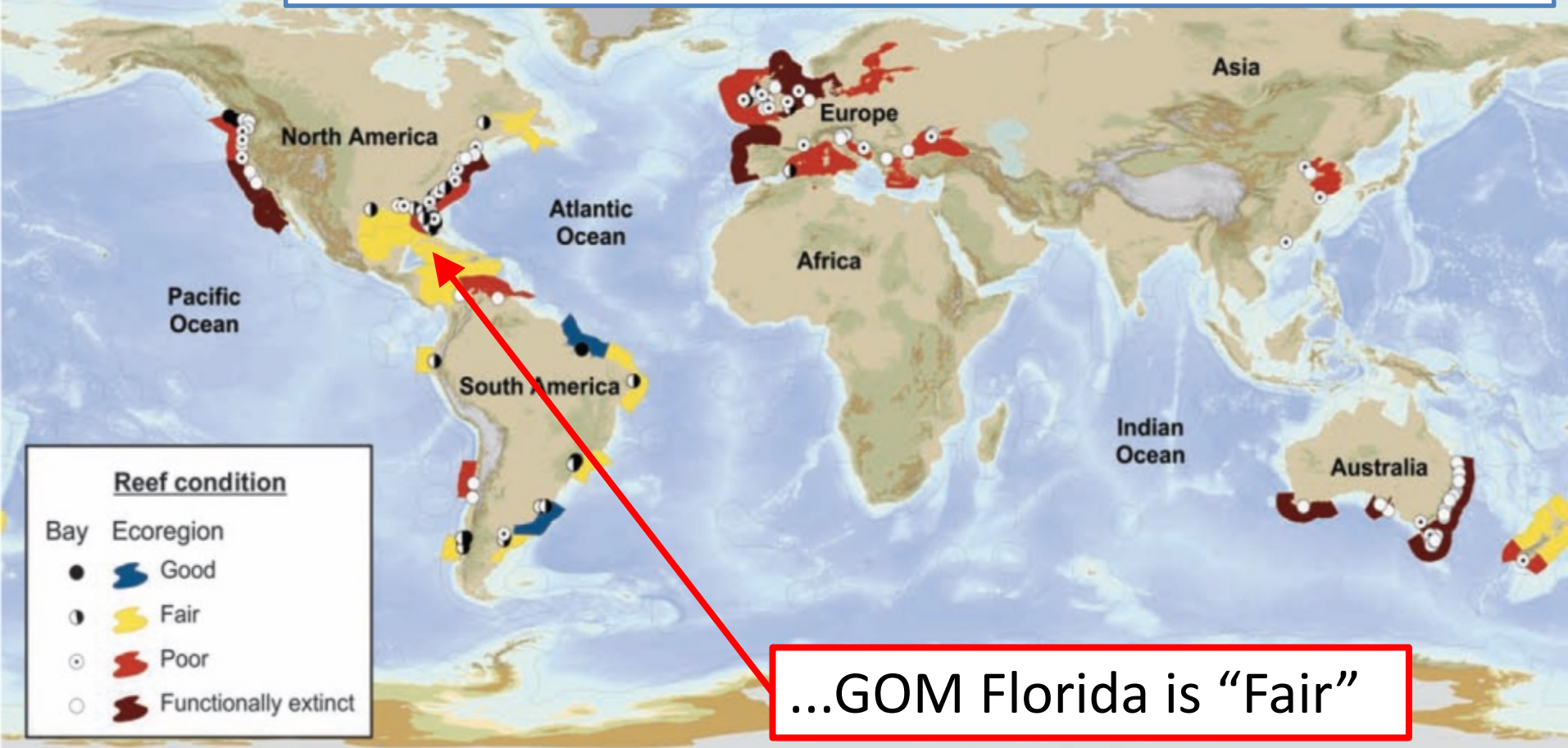
...GOM Florida is "Fair"

Florida Big Bend: *Critical* Losses

Seavey et al. 2011

1995 — Lone Cabbage Reef Offshore — 2010
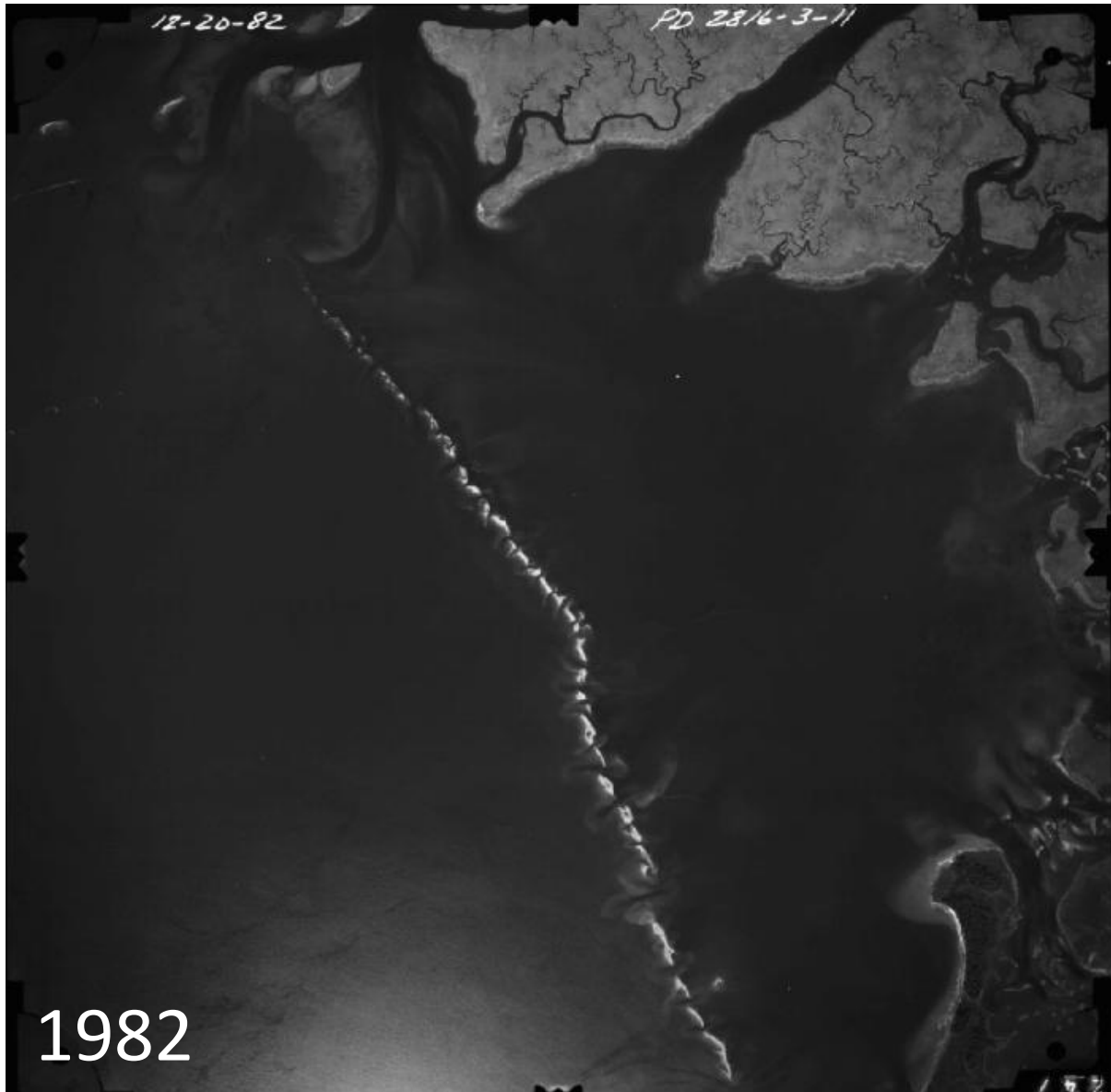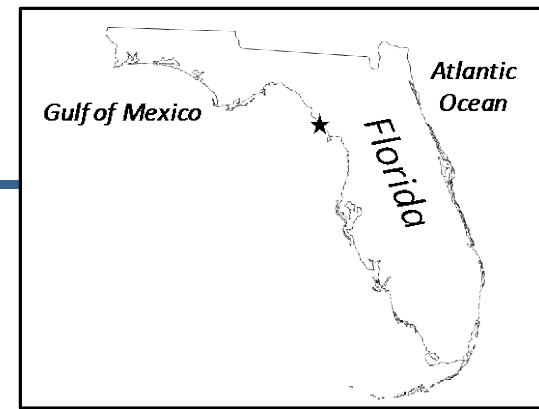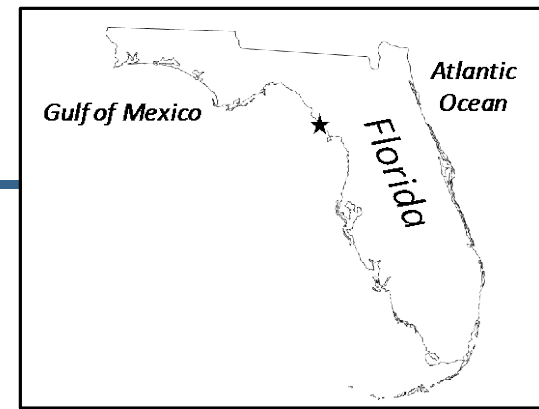
1995 — Suwannee Reef Offshore — 2008
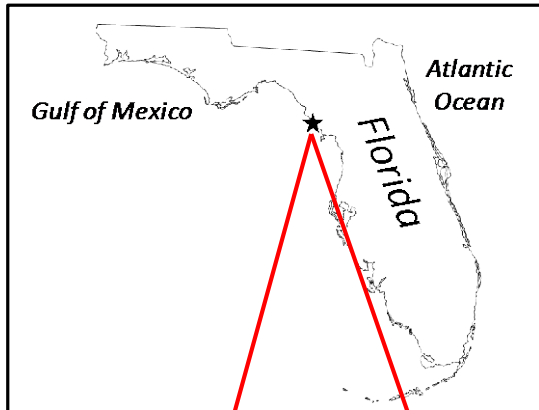
Big Bend Reef Losses:
- 88% offshore
- 61% nearshore
- 50% inshore
- Net Loss: 66% in ~30 Years

Collapse of an Oyster Reef

1982

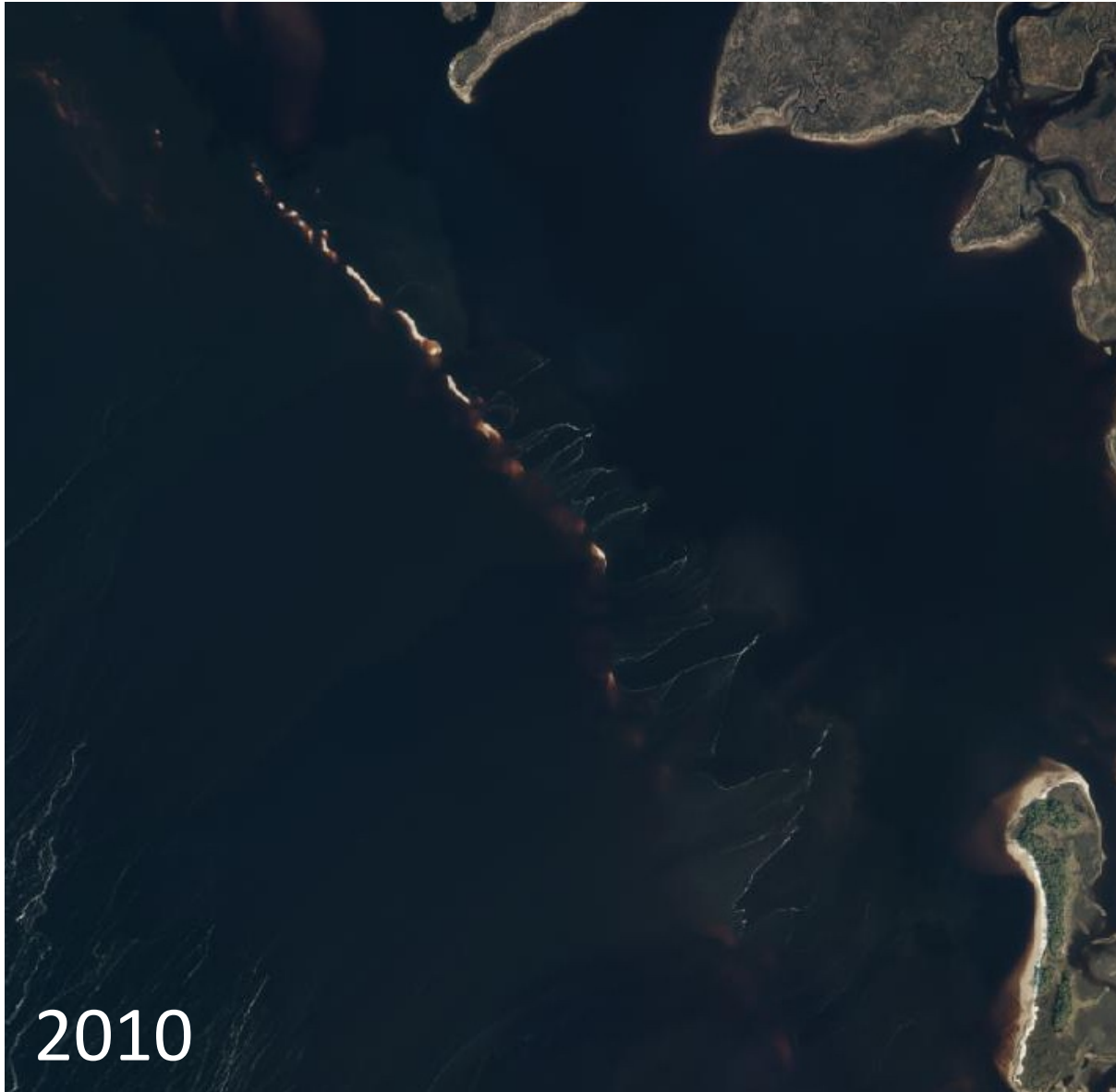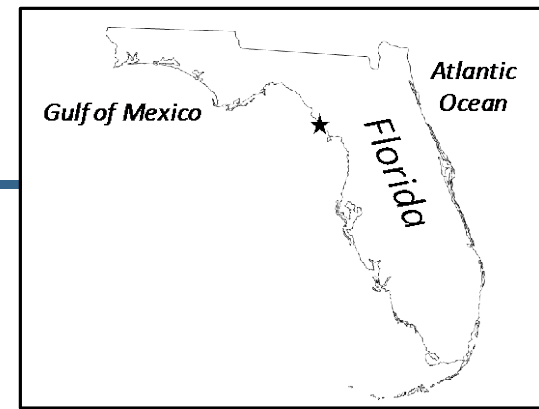# Collapse of an Oyster Reef
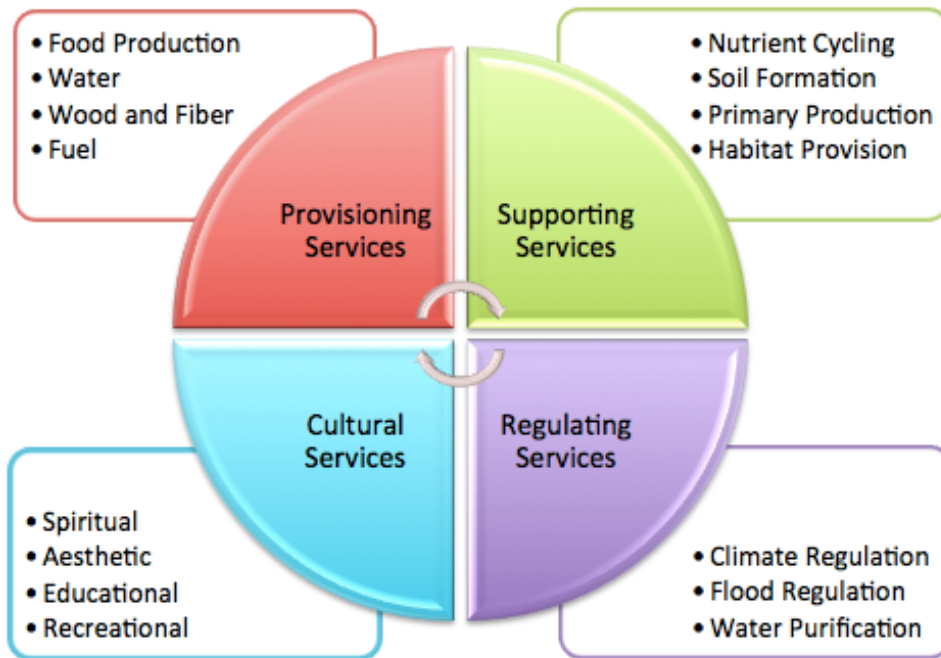

3-10-95   1"=2083'   PD 4309-3-11

1995

Collapse of an Oyster Reef

2010

...WHY?!

Oysters and Ecosystem Services

- Fisheries Support
- Biodiversity
- WQ Enhancement
- Storm Surge Protection...

FL State Archives

- Food Production
- Water
- Wood and Fiber
- Fuel

Provisioning Services

- Nutrient Cycling
- Soil Formation
- Primary Production
- Habitat Provision

Supporting Services

Cultural Services

- Spiritual
- Aesthetic
- Educational
- Recreational

Regulating Services

- Climate Regulation
- Flood Regulation
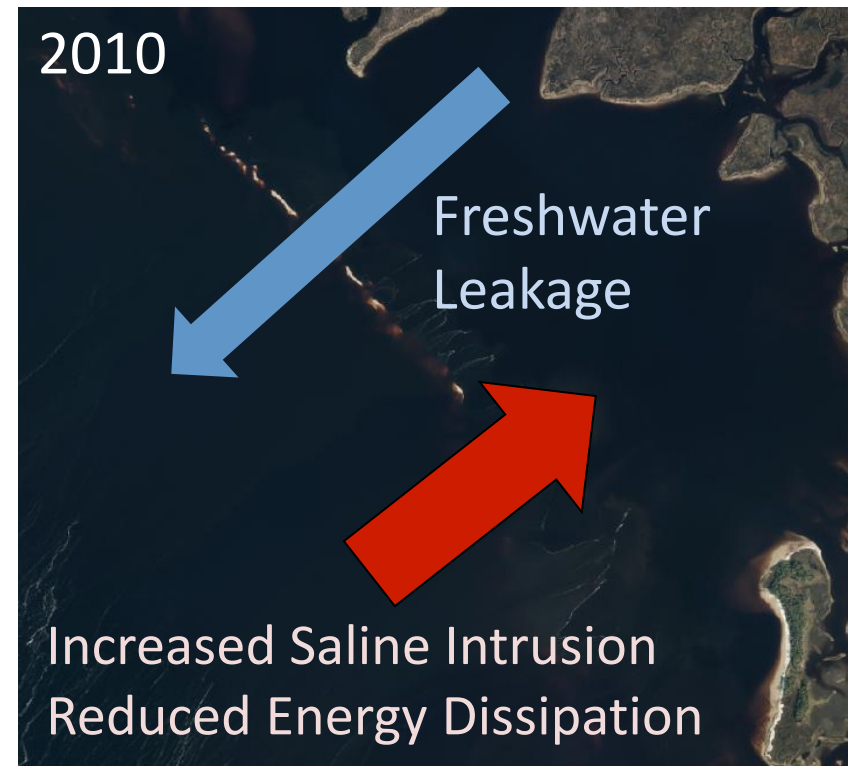- Water Purification

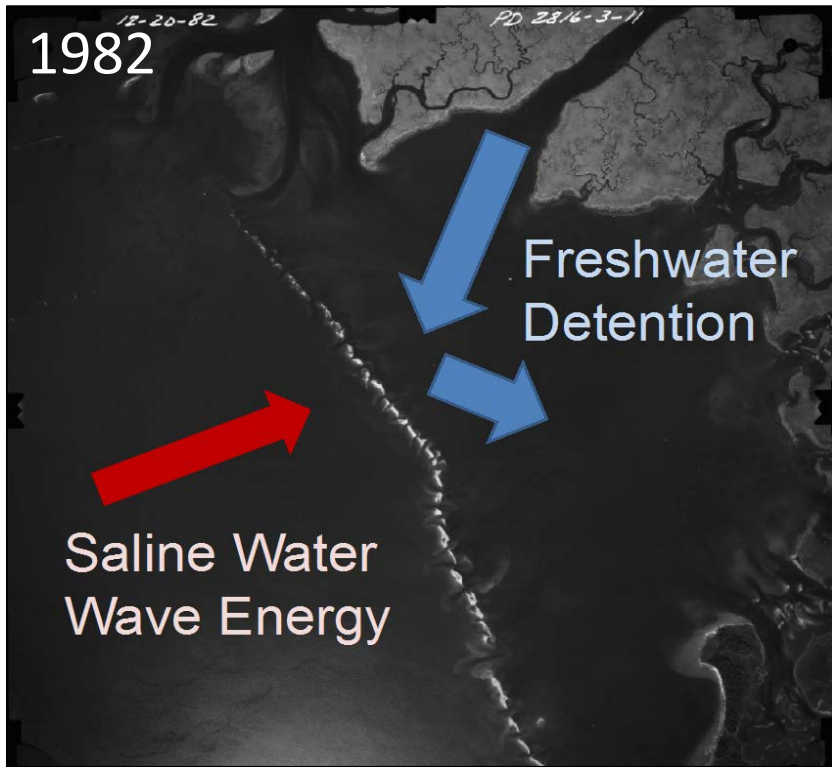Source: Millenium Ecosystem Assessment, 2005.

Susan Stocker/Sun Sentinel/MCT
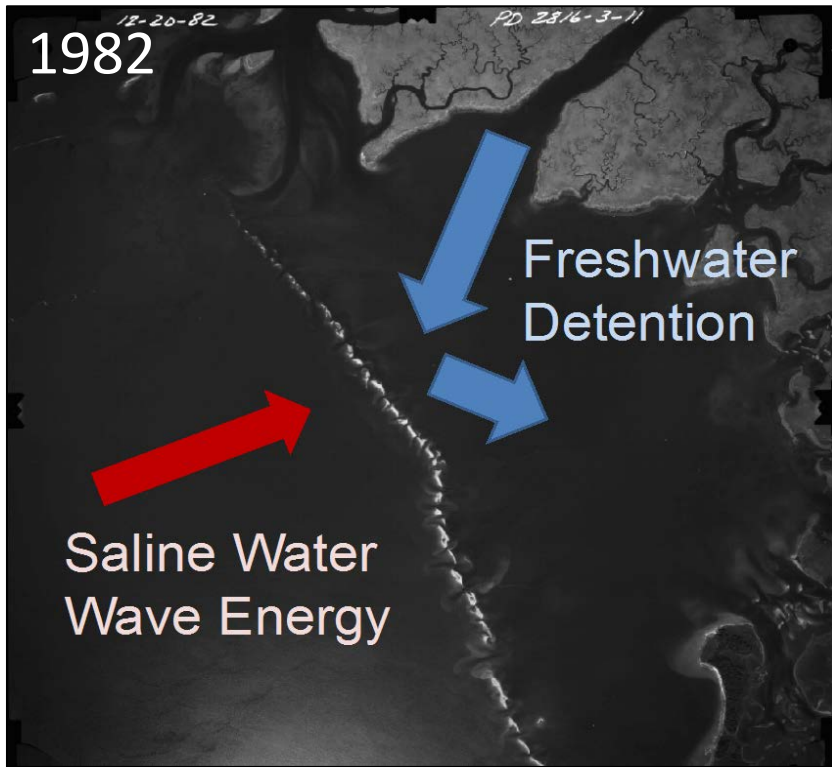
Freshwater Detention: A *Keystone* Service?

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1982
Freshwater Detention
Saline Water Wave Energy

2010
Freshwater Leakage
Increased Saline Intrusion Reduced Energy Dissipation

Freshwater Detention: A *Keystone* Service?

1982 — Freshwater Detention / Saline Water Wave Energy

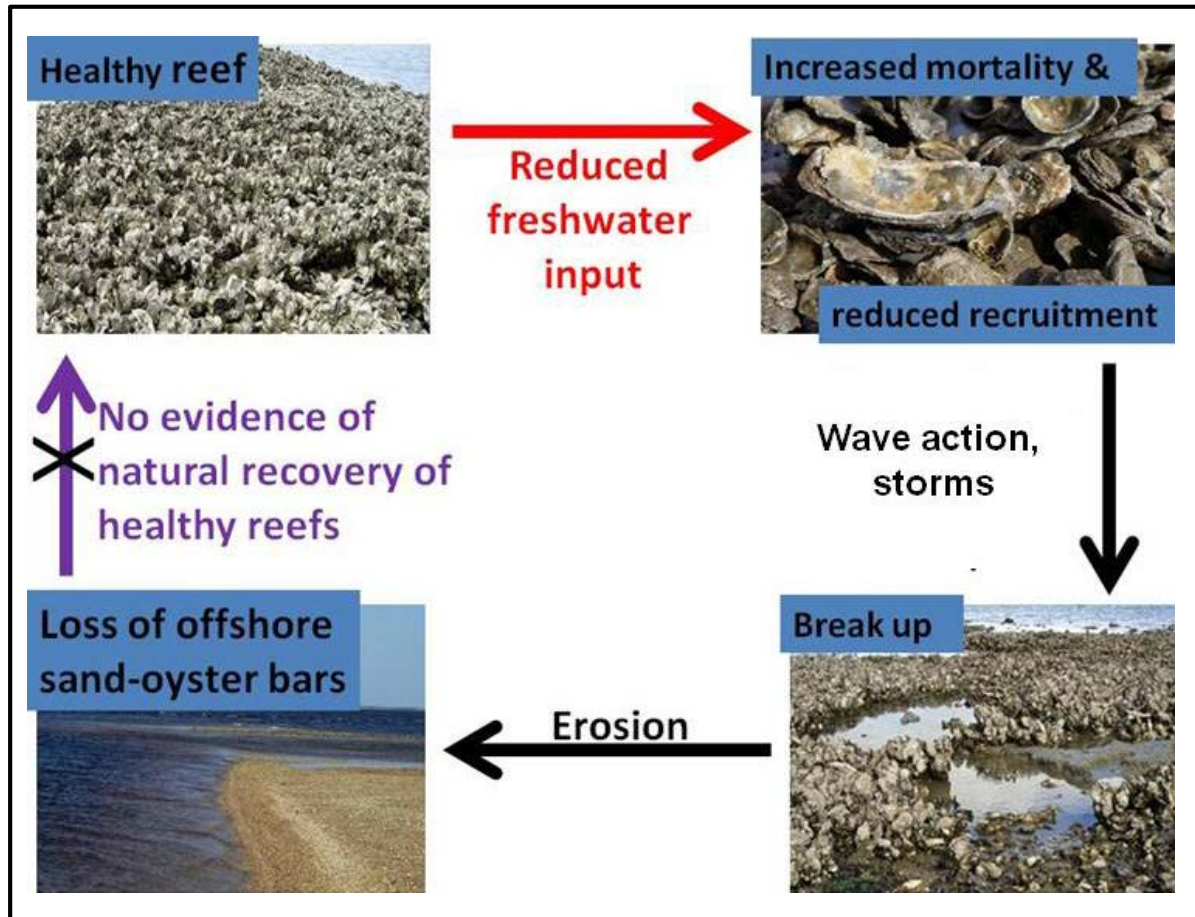2010 — Freshwater Leakage / Increased Saline Intrusion, Reduced Energy Dissipation
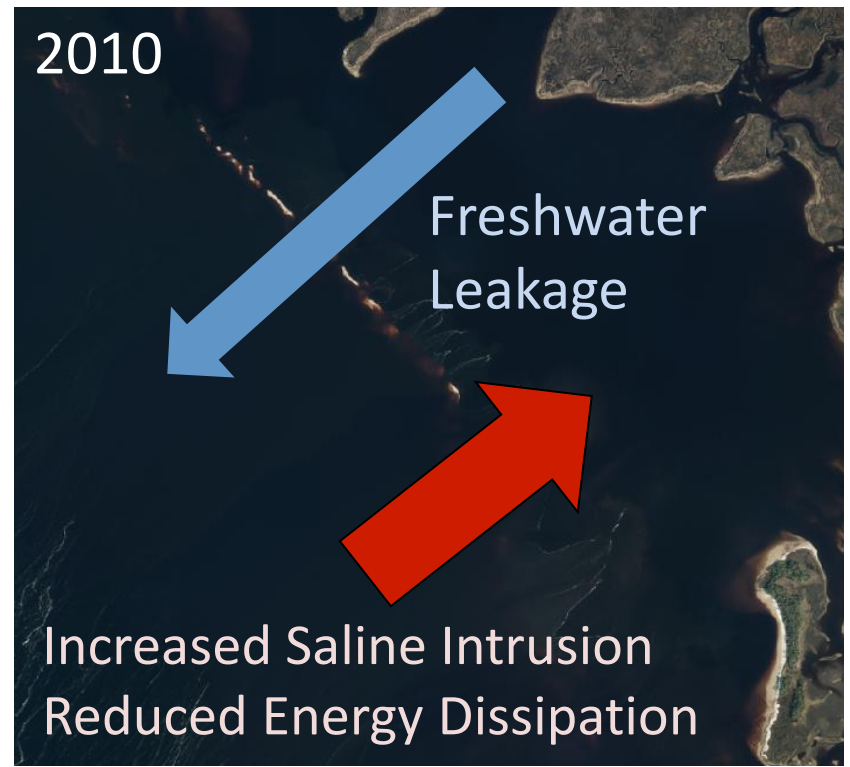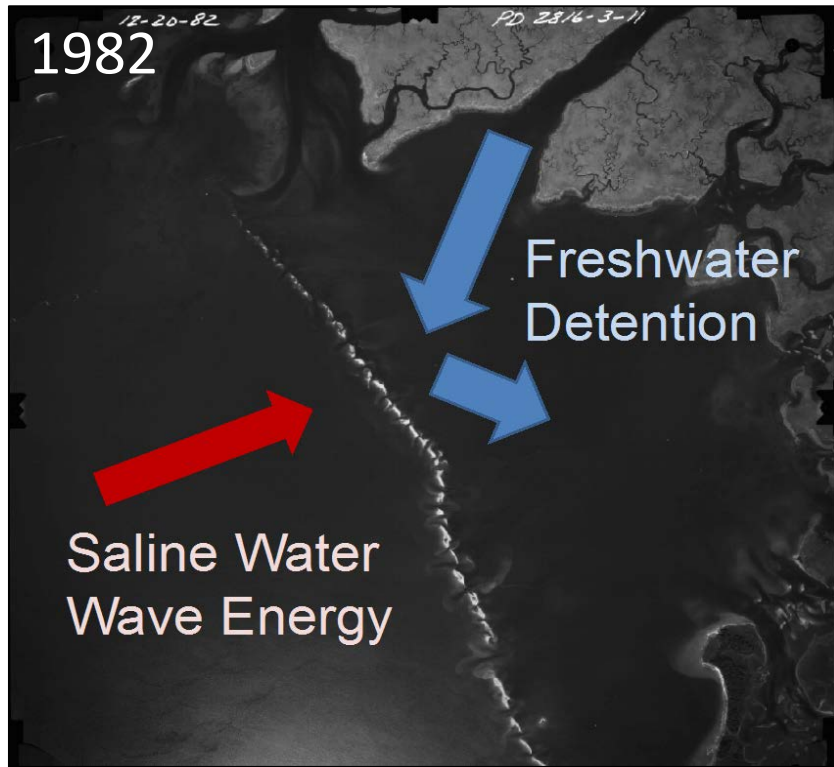
Hypothesis: *Healthy* shore-parallel reefs detain fresh water, influencing salinity over extensive areas and serving as a "keystone" ecosystem service.
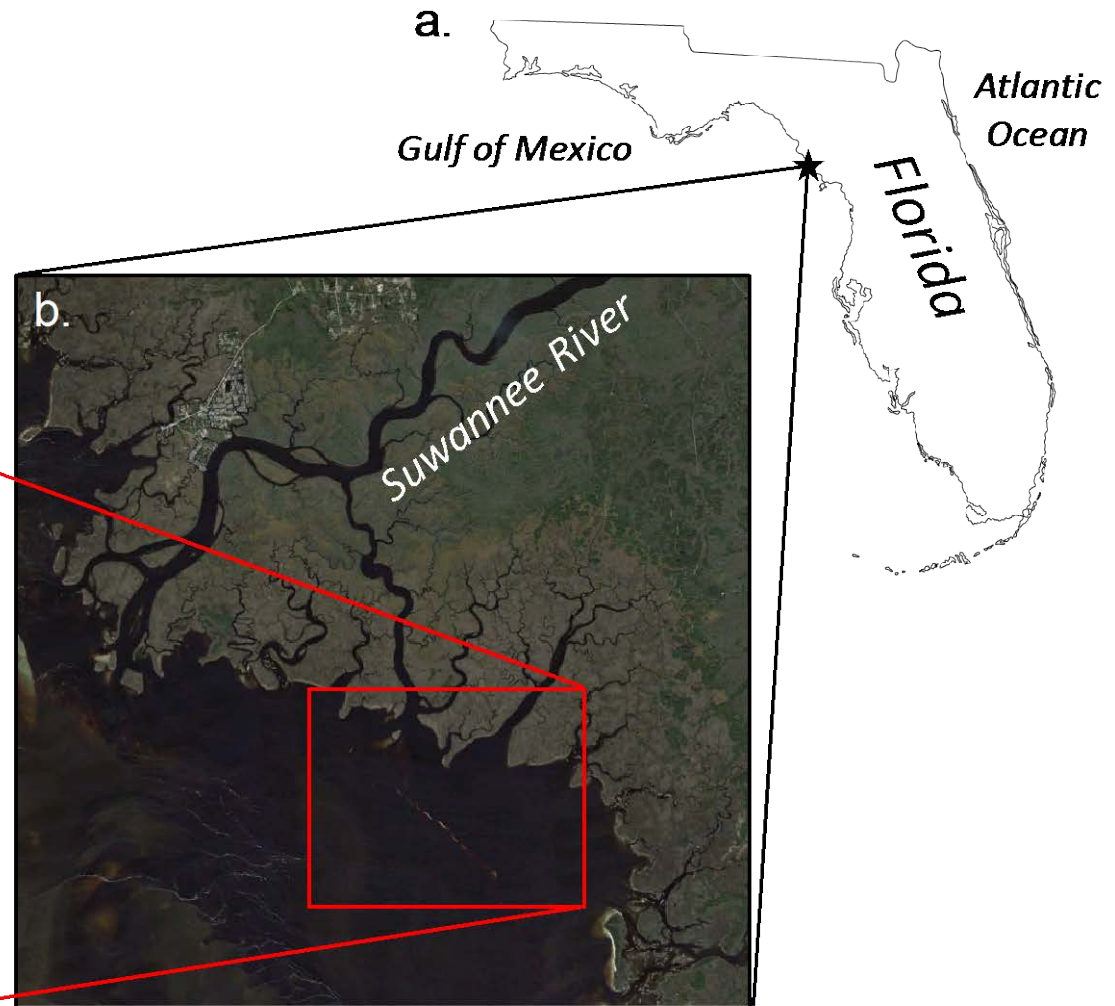
Where reefs are *degraded,* this service is lost or reduced…
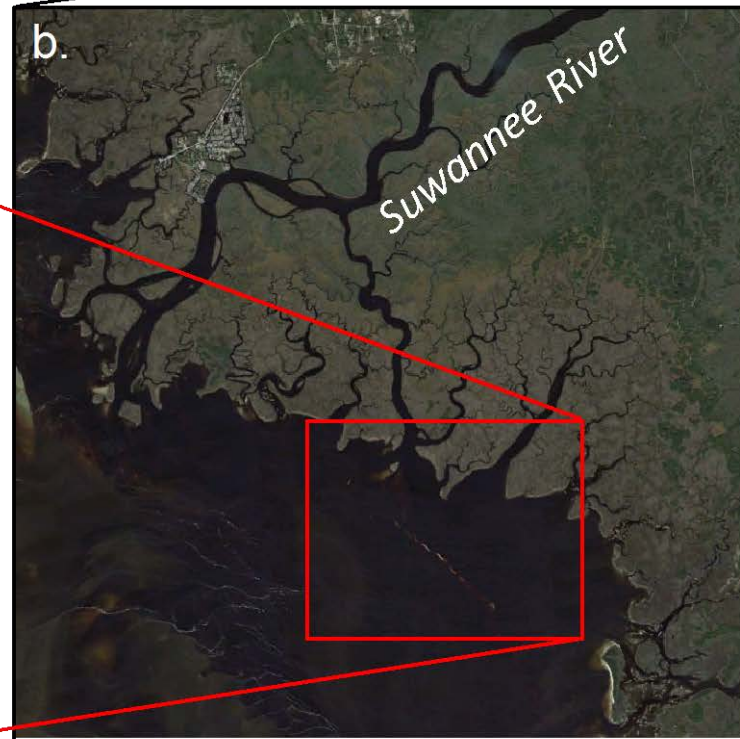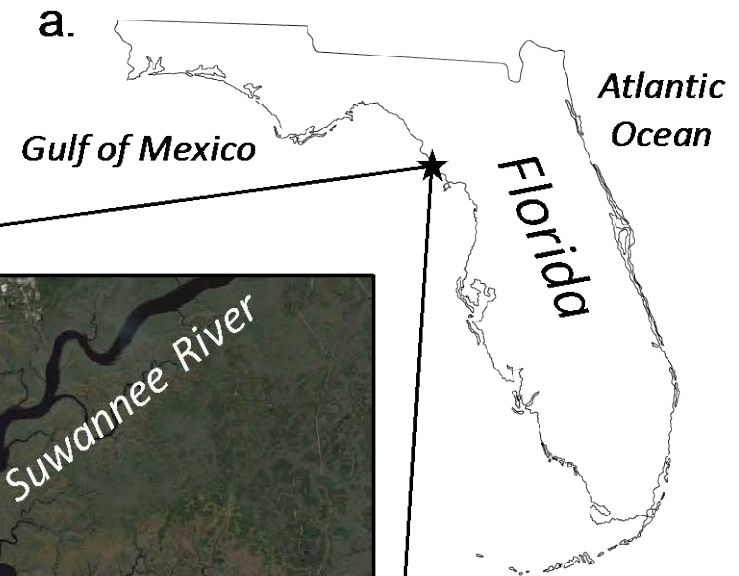
Freshwater Detention: A *Keystone* Service?

Reef degradation → decreased FW detention → higher salinities → increased predation → high oyster mortality → **reef collapse?!**
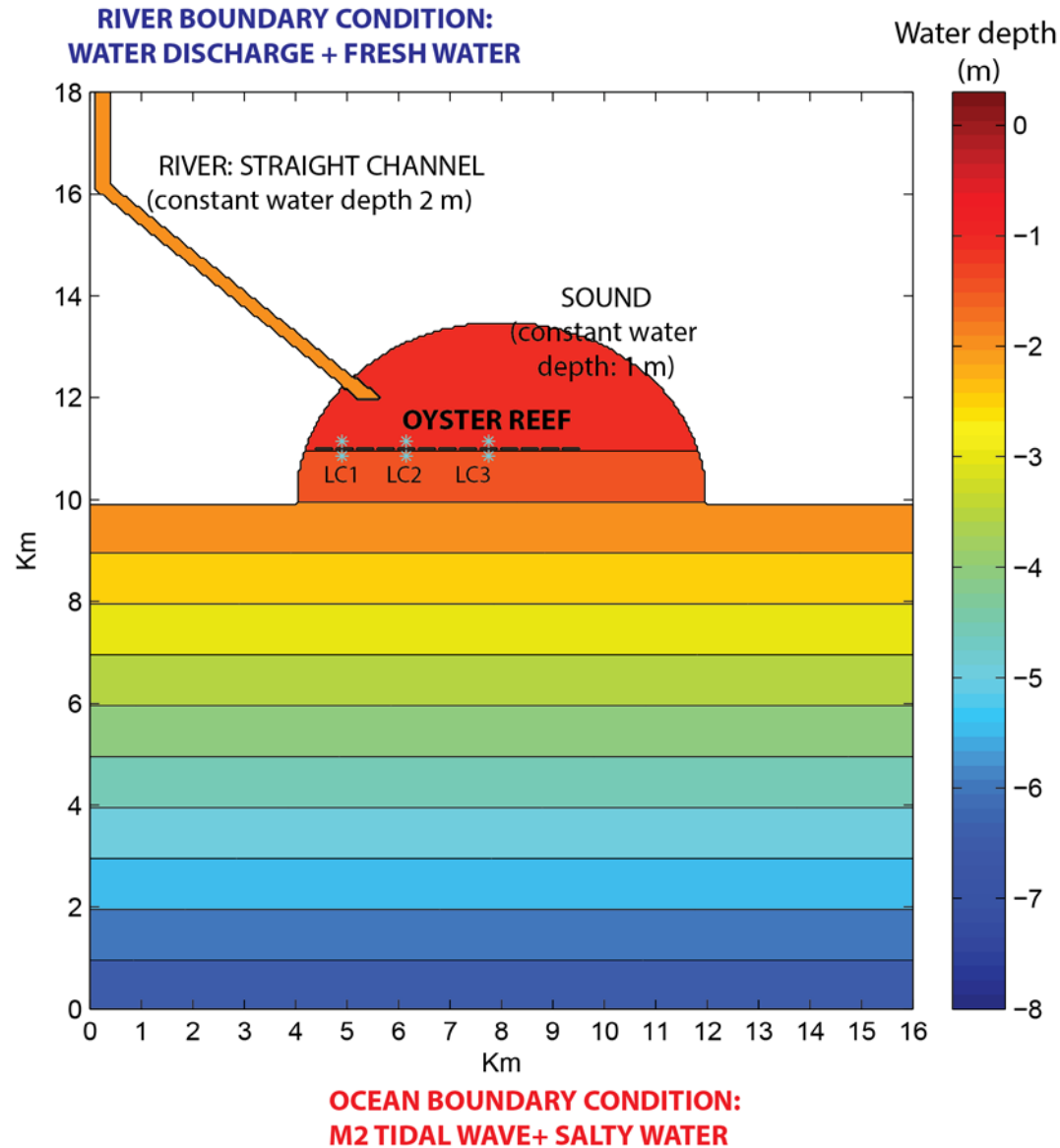

Frederick et al. 2014

Materials and Methods = **Field** + Models

a.

Gulf of Mexico

Atlantic Ocean

Florida

b.

Suwannee River

c.

Lone Cabbage Reef

LC1-LAND

LC1-SEA

LC2-LAND

LC2-SEA

LC3-LAND

LC3-SEA

Materials and Methods = **Field** + Models

a.

b.

c. Lone Cabbage Reef

LC1-LAND
LC1-SEA
LC2-LAND
LC2-SEA
LC3-LAND
LC3-SEA

Gulf of Mexico

Atlantic Ocean

Florida

Suwannee River

Materials and Methods = Field + **Models**

- 3-D Regional Ocean Modeling System

- "Idealized" Suwannee Sound bathymetry

- **Freshwater** flow from Suwannee River: 5, 10, and 20 m^3 s^{-1}

- **Salinity** = 25 PSU at tidal boundary

- M2+S2+K1+O1 tidal constituents

RIVER BOUNDARY CONDITION:
WATER DISCHARGE + FRESH WATER

RIVER: STRAIGHT CHANNEL
(constant water depth 2 m)

SOUND
(constant water depth: 1 m)

OYSTER REEF

LC1   LC2   LC3

Water depth (m)

OCEAN BOUNDARY CONDITION:
M2 TIDAL WAVE+ SALTY WATER

Materials and Methods = Field + **Models**

R1 = No reef

R2 = 50 m wide, MWL, 50 m inlets

R3 = 50 m wide, MWL-0.25, 50 m inlets

R4 = 50 m wide, MWL-0.12, 50 m inlets
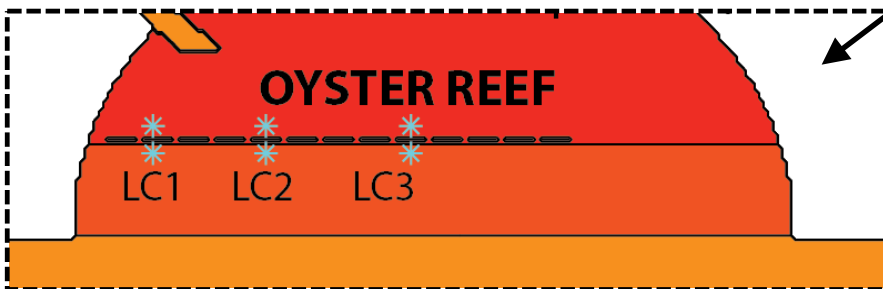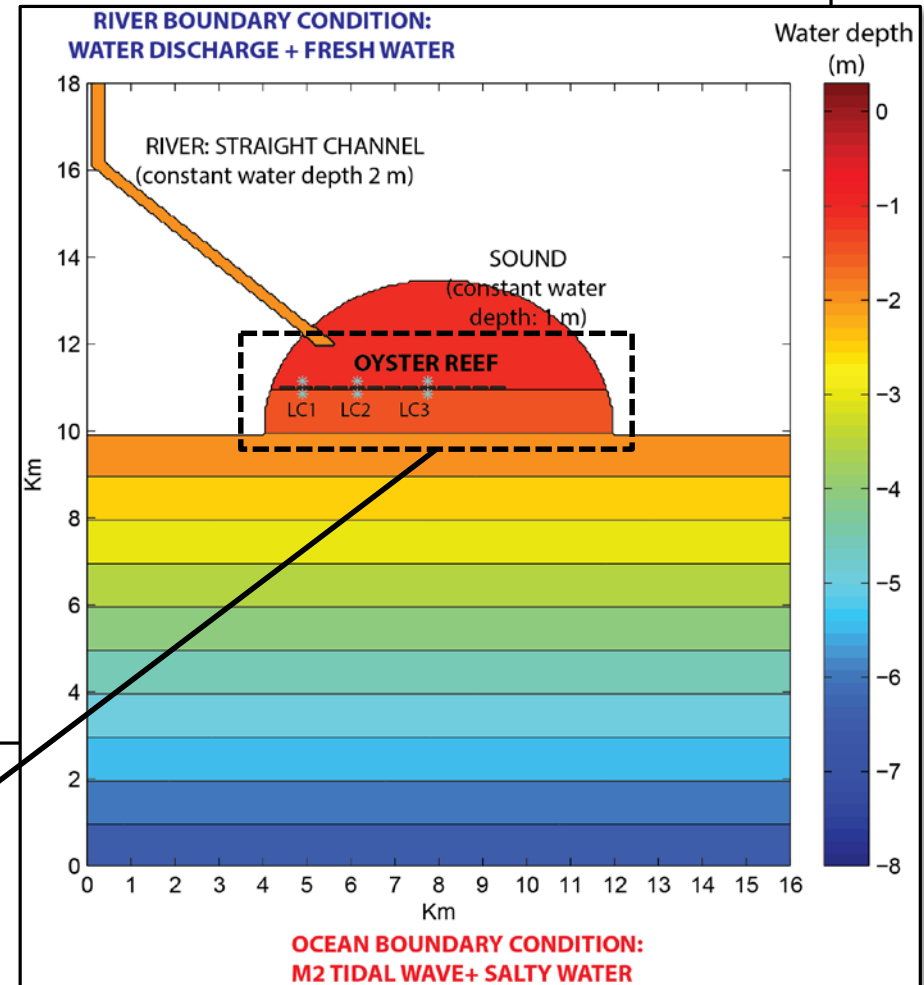
R5 = 50 m wide, MWL, 100 m inlets

R6 = 50 m wide, MWL, 150 m inlets

R7 = 100 m wide, MWL, 50 m inlets

R8 = 150 m wide, MWL, 50 m inlets

R9 = 50 m wide, MWL, no inlets

R10 = 50 m wide, MWL, 50 m inlets,
    reef extends across domain

RIVER BOUNDARY CONDITION:
WATER DISCHARGE + FRESH WATER

Water depth (m)

RIVER: STRAIGHT CHANNEL
(constant water depth 2 m)

SOUND
(constant water depth: 1 m)

OYSTER REEF

LC1 LC2 LC3

Km

Km

OCEAN BOUNDARY CONDITION:
M2 TIDAL WAVE+ SALTY WATER

OYSTER REEF

LC1   LC2   LC3

Results: **Field** + Models

Results: **Field** + Models

1:1 line

y = 1.36x
R^2 = 0.70

LC1-LAND
LC1-SEA
LC2-LAND
LC2-SEA
LC3-LAND
LC3-SEA

Results: **Field** + Models

C2

1:1 line

y = 1.36x
R² = 0.70

y = 1.22x
R² = 0.73

Results: **Field** + Models

1:1 line

C2

y = 1.36x
R² = 0.70

y = 1.22x
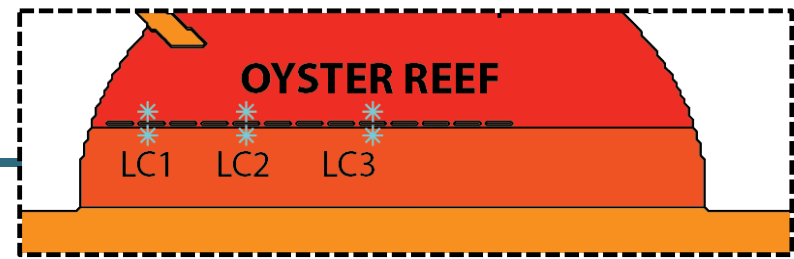R² = 0.73

d. LC3

y = 1.00x
R² = 0.92
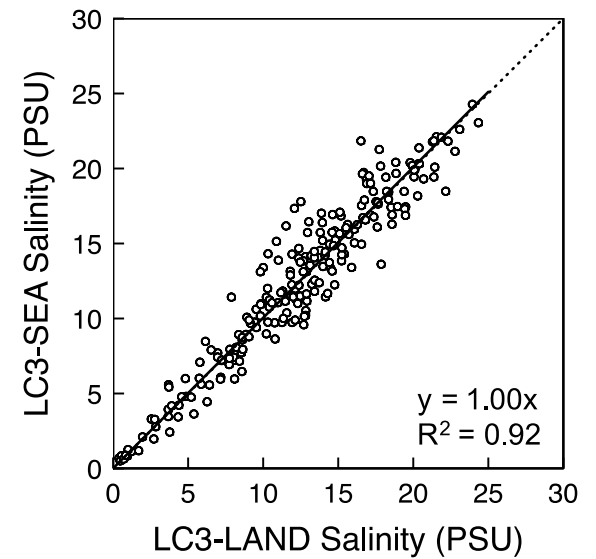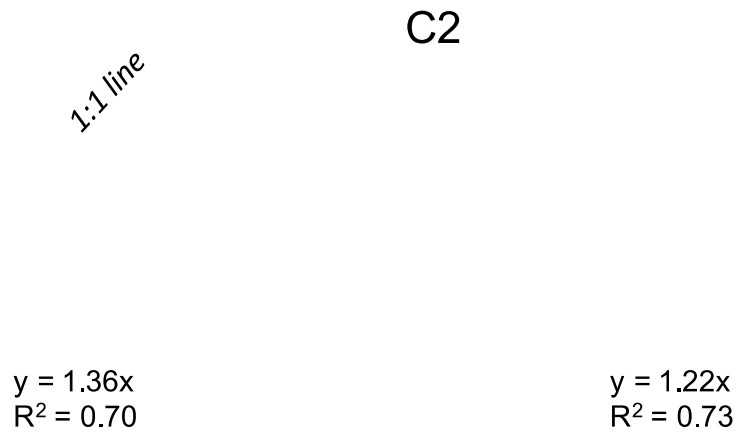
Results: **Field** + Models

Mean (Max) Daily Sal. Reduction (In vs. Out)
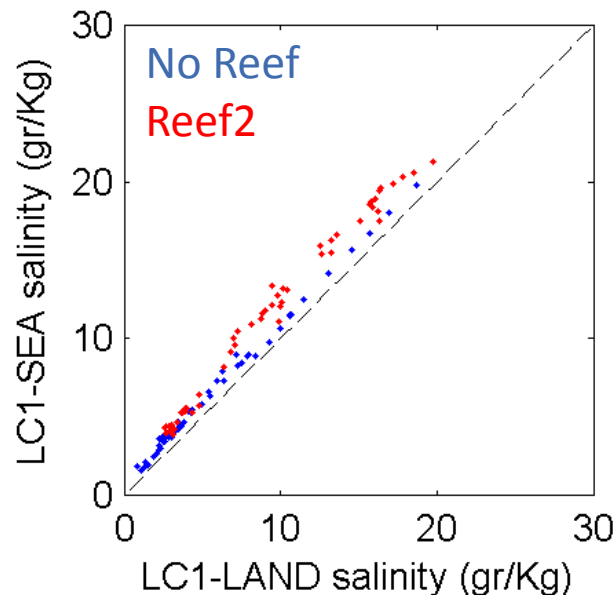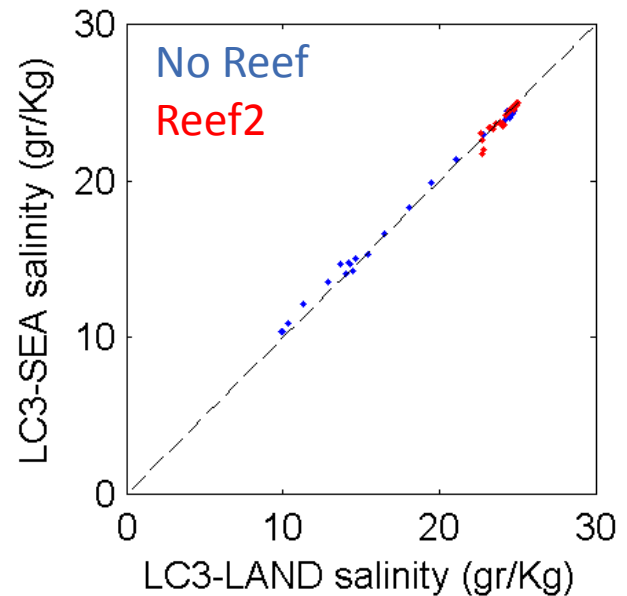33% (90%)   16% (85%)   0% (43%)
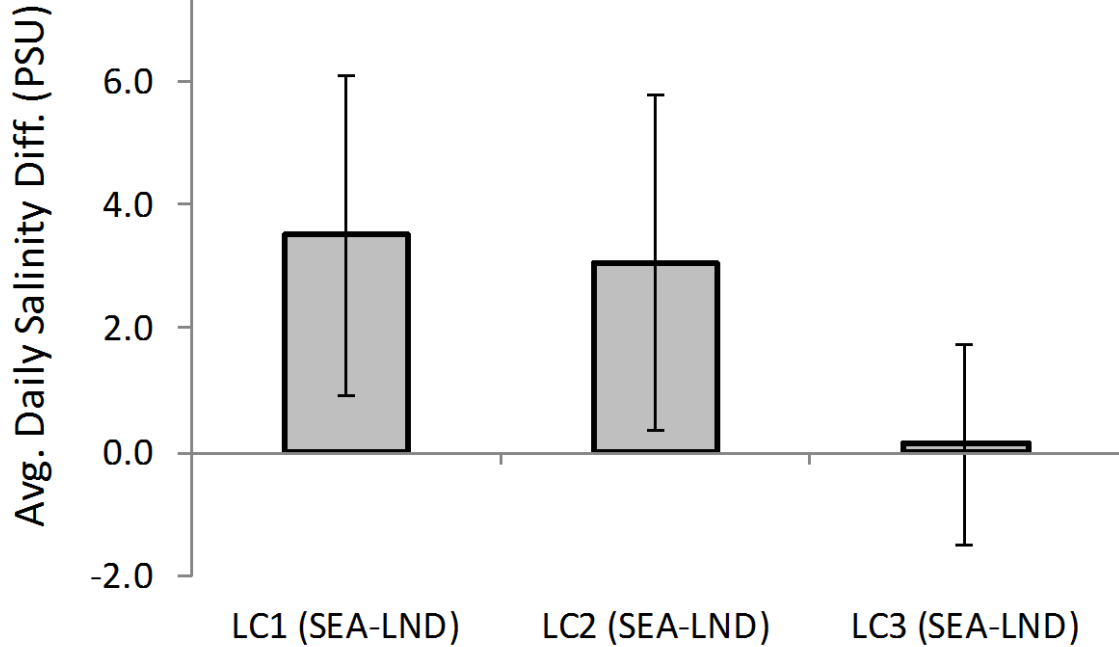
Results: Field + **Models**

Discharge = 10 m^3 s^{-1}

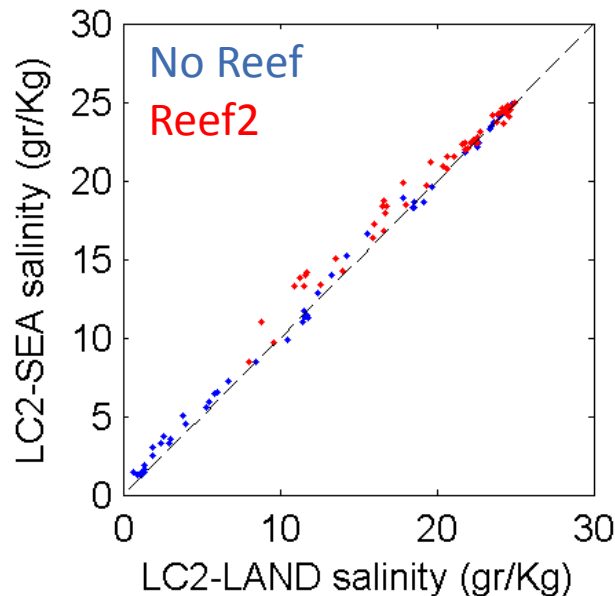**BLUE**: No Reef

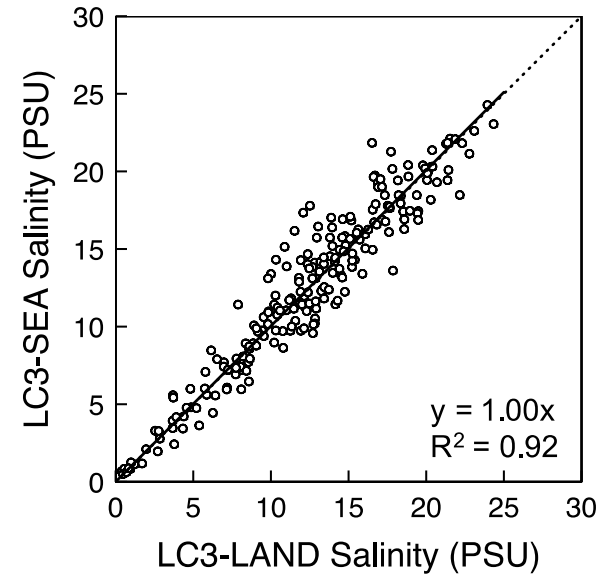**RED**: Reef2 - 50 m wide, MWL, 50 m inlets ("Current")

Results: **Field + Models**

C2

1:1 line

y = 1.36x
R² = 0.70

y = 1.22x
R² = 0.73

d. LC3

y = 1.00x
R² = 0.92

LC3-SEA Salinity (PSU)

LC3-LAND Salinity (PSU)

No Reef
Reef2

LC1-SEA salinity (gr/Kg)

LC1-LAND salinity (gr/Kg)

No Reef
Reef2

LC2-SEA salinity (gr/Kg)

LC2-LAND salinity (gr/Kg)

No Reef
Reef2

LC3-SEA salinity (gr/Kg)

LC3-LAND salinity (gr/Kg)

Results: **Field + Models**

Model vs. Data

- Simplified vs. actual bathymetry
- Constant vs. varying Suwannee River discharge
- Modeled vs. actual tides
- No wind vs. wind
- ...
- **LAND vs. SEA mean salinity differences:**
  - **LC-1: 27% (Model) vs. 33% (Data)**
  - **LC-2: 5% (Model) vs. 16% (Data)**
  - **LC-3: 0% (Model) vs. 0% (Data)**
- **Reef effect declines with distance from Suwannee R.**

Results: Field + **Models** (Q = 10 m³ s⁻¹)

Reef Geometry: Presence, Length, Inlets, Surprises?
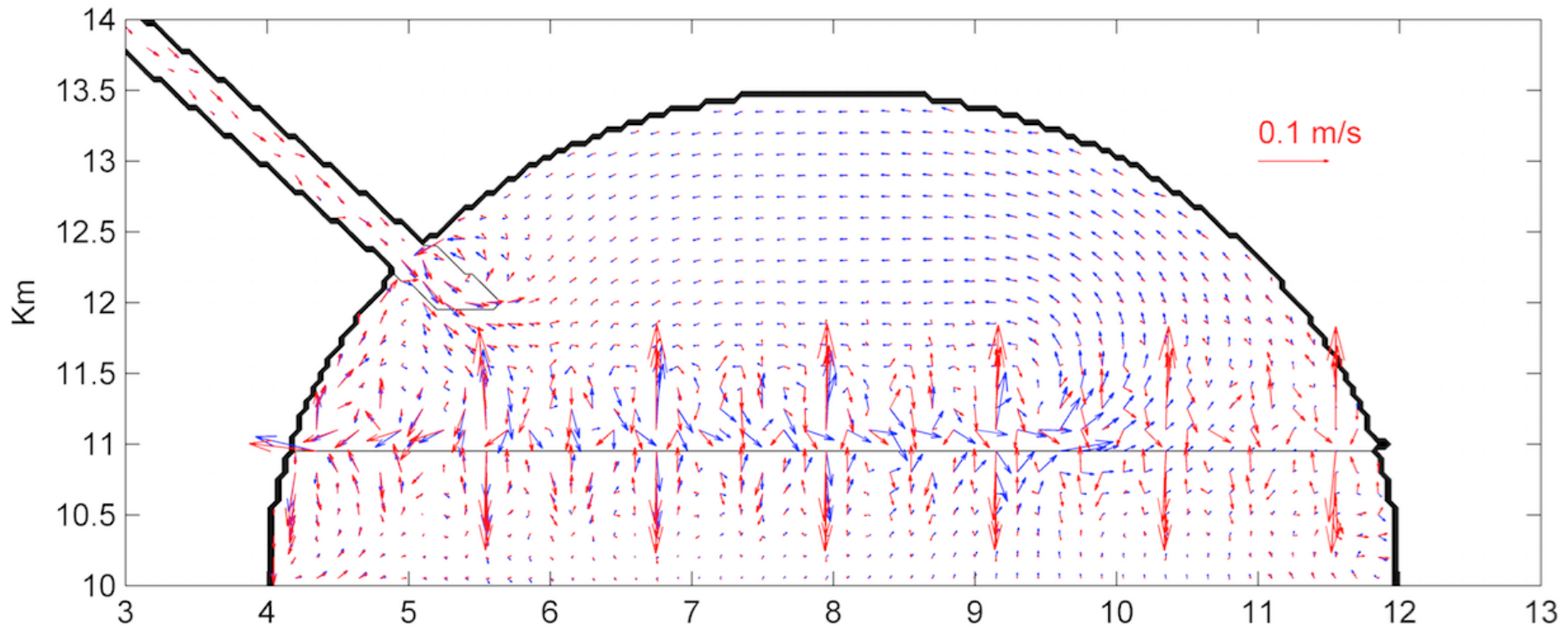
Results: Field + **Models** (Q = 10 m³ s⁻¹)

Reef Geometry: Presence, Length, Inlets, Surprises?
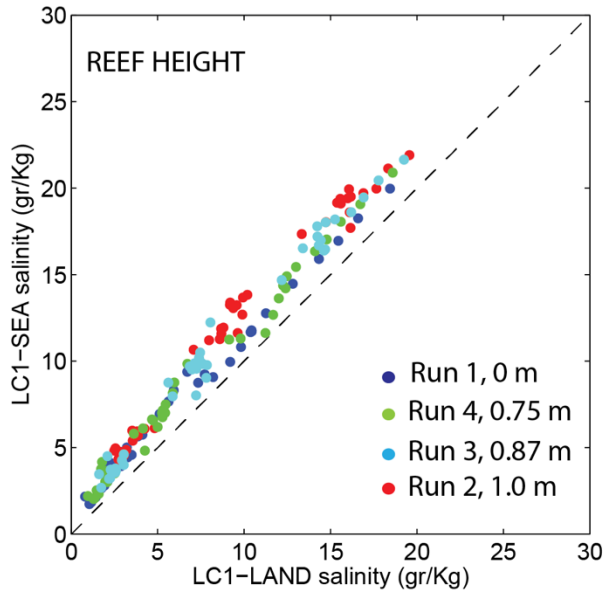
Results: Field + **Models** (Q = 10 m³ s⁻¹)

Reef Geometry: Presence, Length, Inlets, Surprises?

Velocity vectors for *partial* **(blue)** and *complete* **(red)** reef chain

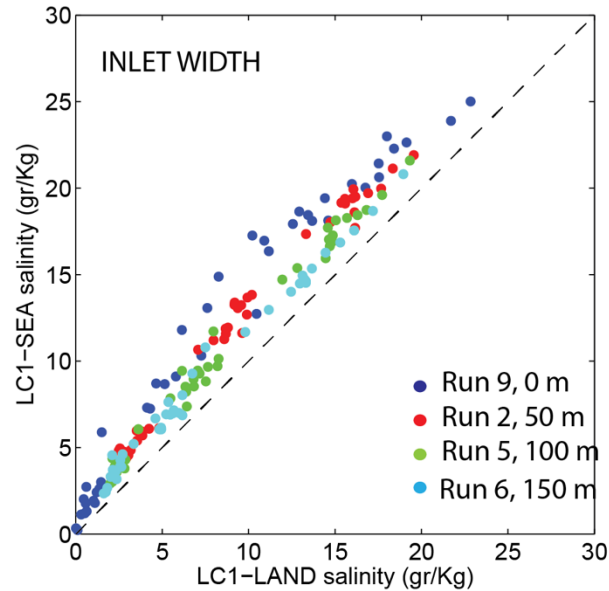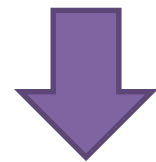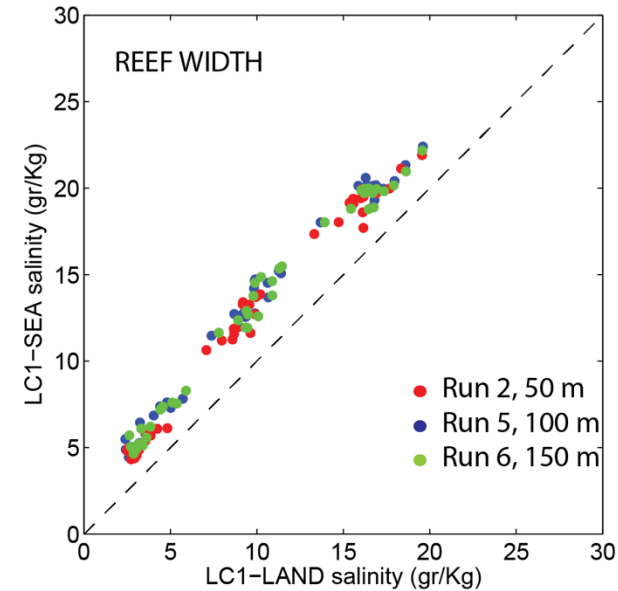# Results: Field + **Models** (Q = 10 m^3 s^{-1})

Reef Geometry: Height, Reef Width, Inlet Width

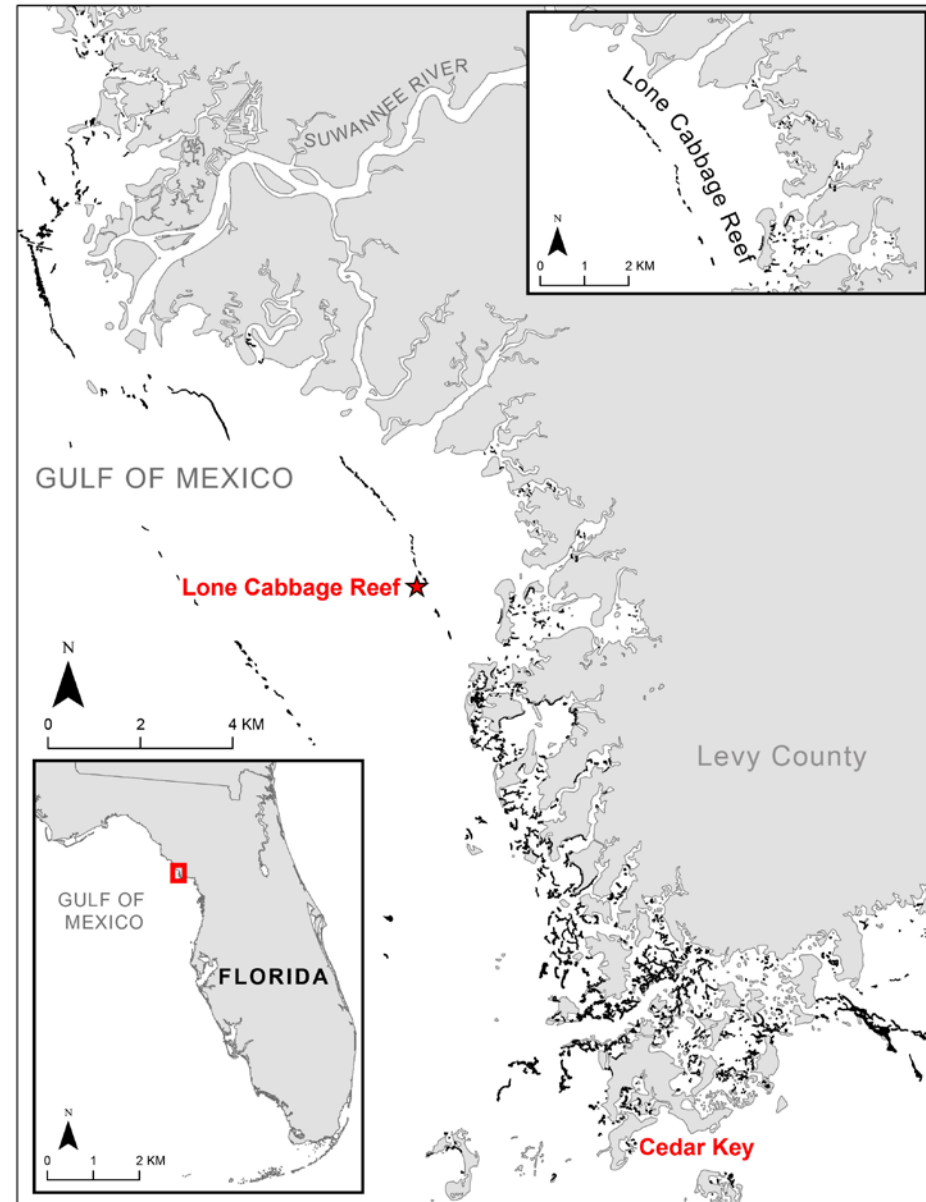(+) Reef Height ~ Salinity Differences

(-) Inlet Width ~ Salinity Differences

(0) Reef Width ~ Salinity Differences

Conclusions and Applications

- Shore-parallel oyster reefs can detain fresh water and influence salinity over large areas...

- Driven by reef, inlet, & river geometry → use to guide restoration

- Intertidal vs. subtidal reefs?

Conclusions and Applications

Lone Cabbage: reef degradation begins in the southeast (far from FW inflows), likely initiated by reduced freshwater flow (Seavey et al. 2011)...

...this allows tidal currents to propagate through the Sound and get stuck behind reef, raising salinity and driving further degradation
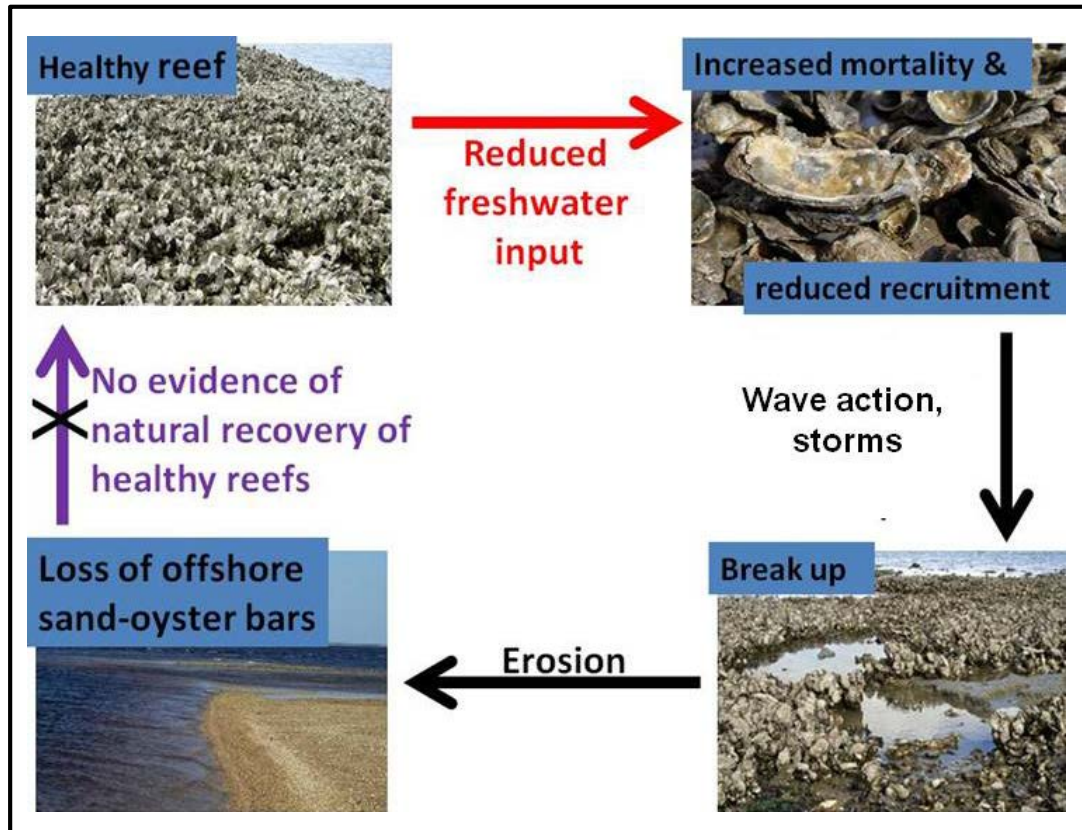

Q = 10 m³ s⁻¹...but flow is dynamic
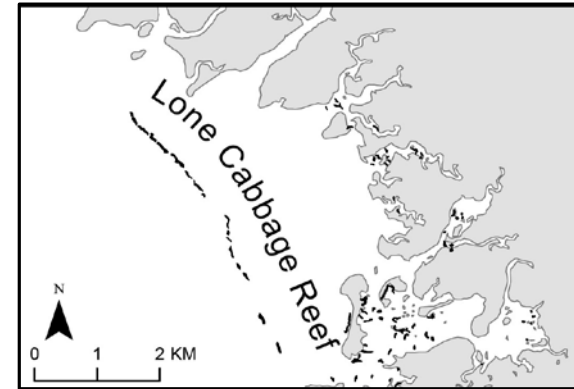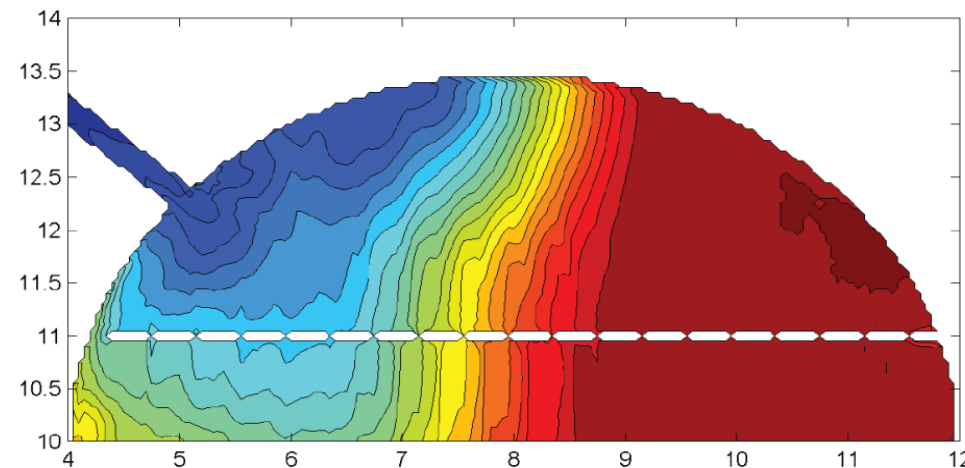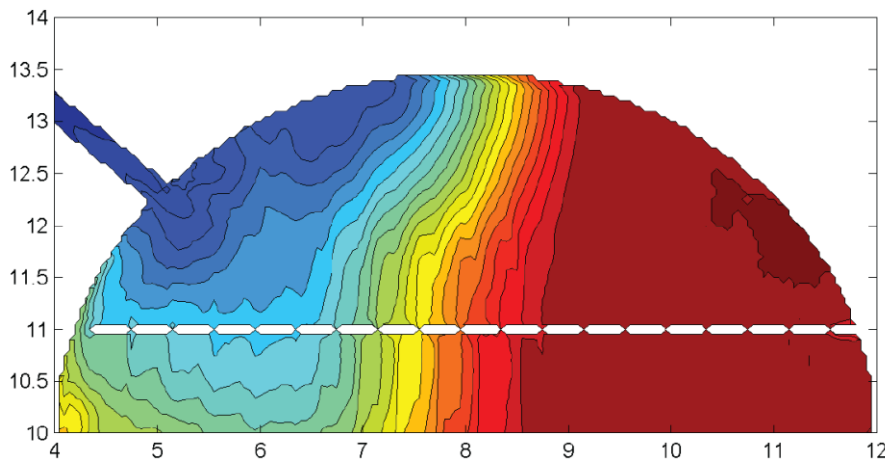
$Q = 10\ \mathrm{m^3\ s^{-1}}$...but flow is dynamic

Conclusions and Applications

Reef degradation → decreased FW detention → higher salinities → increased predation → high oyster mortality → **reef collapse?!**

Frederick et al. 2014

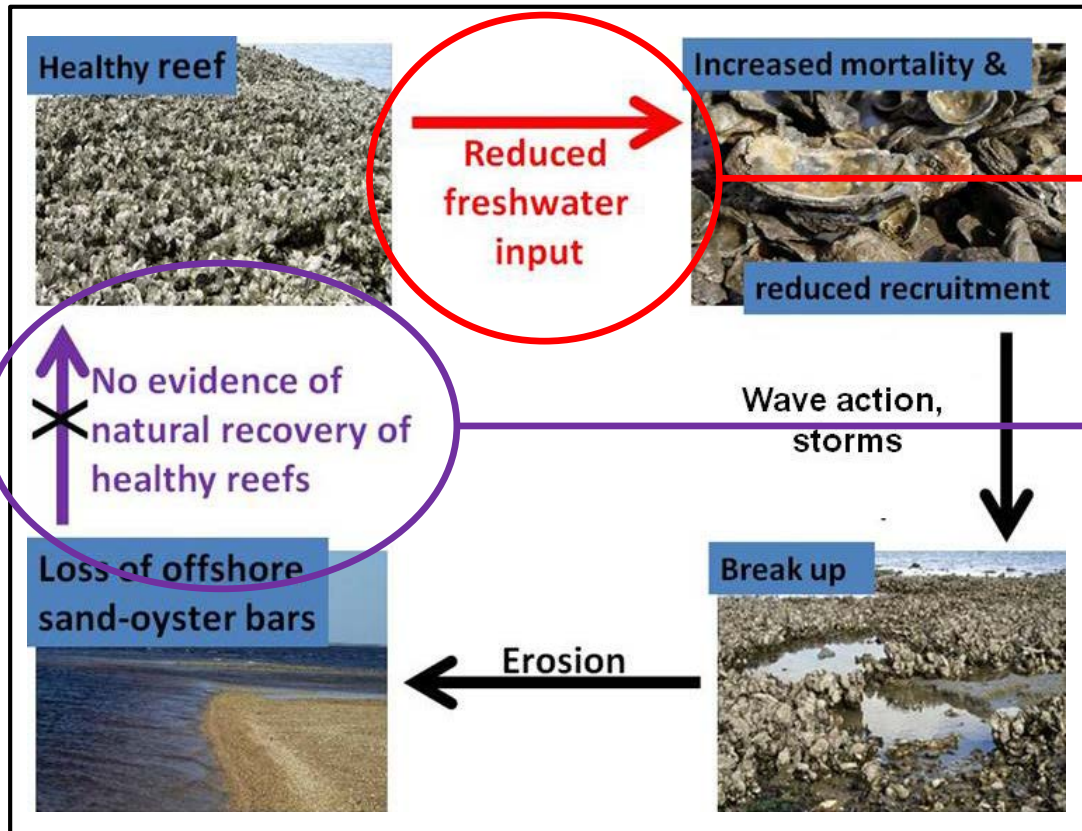# Conclusions and Applications

Reef degradation → decreased FW detention → higher salinities → increased predation → high oyster mortality → **reef resilience!**

Freshwater Flow Mgmt:
<u>BUT</u>: Consumptive Use, SLR, Climate Change...

Reef Restoration:
<u>BUT</u>: Plan for periodic high mortality → use resilient structure to maintain the "keystone" service & break cycle!

Frederick et al. 2014

Thank you!
Questions?

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www.watershedecology.org