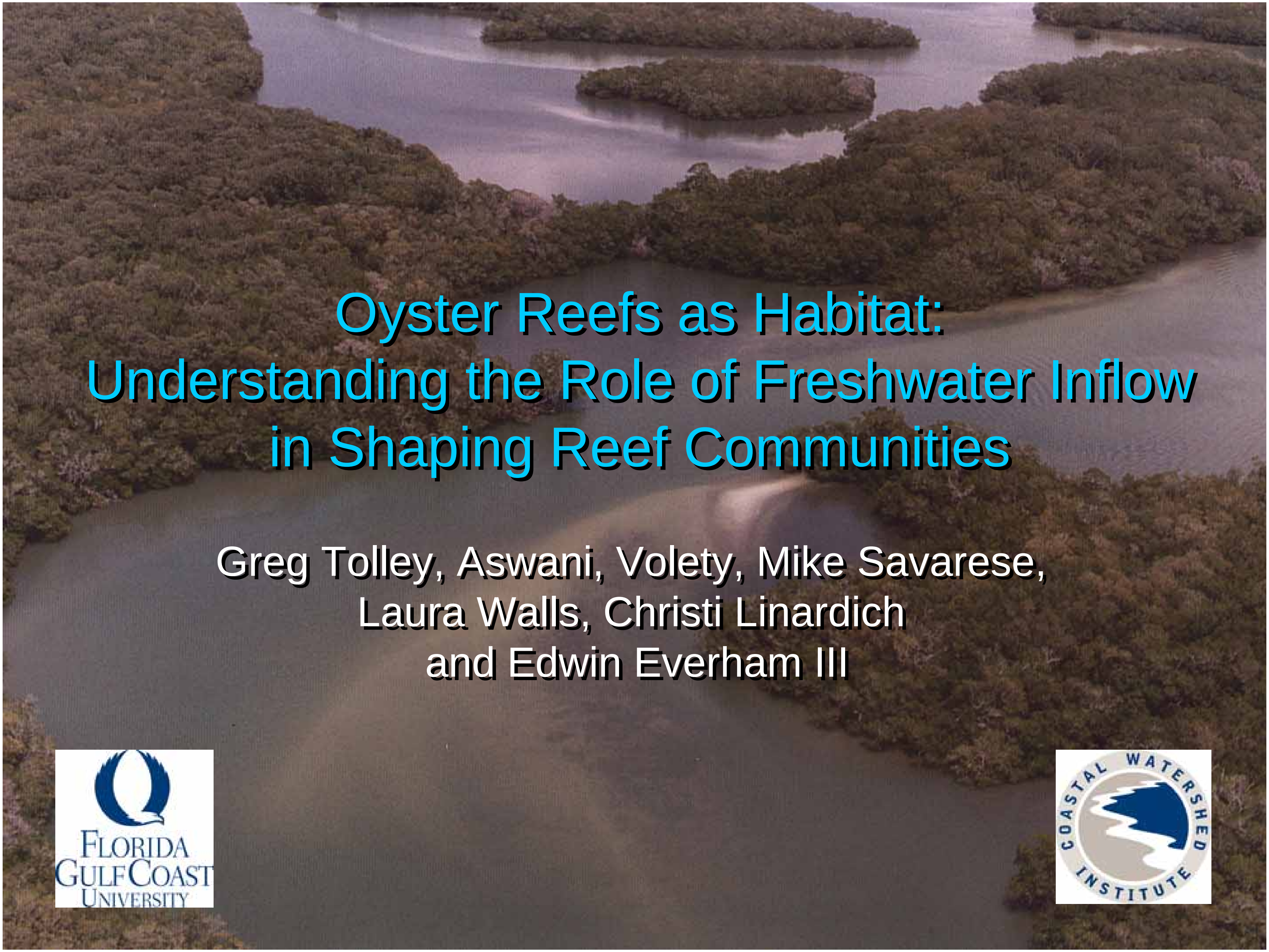


# Oyster Reefs as Habitat: Understanding the Role of Freshwater Inflow in Shaping Reef Communities


Greg Tolley, Aswani, Volety, Mike Savarese,
Laura Walls, Christi Linardich
and Edwin Everham III

FLORIDA GULF COAST UNIVERSITY

COASTAL WATERSHED INSTITUTE

# Oysters: West Coast of Florida
## (Cedar Key to Key West)

**1876**

***...On every hand I found these immense reefs and beds of oysters in such seemingly inexhaustible supplies that it frequently occurred to me that the great God of nature must have gone ahead of me and, with hands wide open, scattered right and left and out into the depths so far that I failed to find their limits.***

**1897**

***... natural oyster-bars are a magnificent inheritance that has cost us nothing, and we are not only using but abusing nature's providence by the most extravagant wastefulness and improvidence, and it is only by the education of the masses along these lines that we may hope for success in the restoration of our depleted oyster bars...***

**SOURCE: HA Smeltz. 1897. The oyster-bars of the west coast of Florida: their depletion and restoration. *Bull US Fish Comm* 17:305–308**

# Ecosystem Function

## Seston Removal

Improved water quality: removal of bacteria & contaminants (dioxins, furans, dioxin-like PCBs, arsenic, cadmium, copper, mercury) from water column

(Valette-Silver et al. 1999; Jones et al. 2001; Cressman et al. 2003; Karouna-Renier et al. 2007)

Limited mitigation of eutrophication effects: removal of chlorophyll *a*, bacteria, total N (burial & denitrification)

(Dame et al. 1984; Newell 1988; Gerritsen et al. 1994; Jones et al. 2001; Nelson et al. 2004; Newell 2004; Grizzle et al. 2006; Grant et al. 2007)

Increased light penetration for SAV: reduced turbidity & chlorophyll *a*

(Peterson & Heck 2001; Newell 2004; Newell & Koch 2004)

# Ecosystem Function

## Bentho-pelagic Coupling

Nutrient remineralization

- Net decrease in particulate nutrients
- Net increase in dissolved inorganic nutrients
- Oyster reefs as source for $NH_4^+$

(Dame et al. 1984, 2002; Jones et al. 2001)

Conversion of POM (DOM?) to benthic food source

- Preferential removal of N over C
- Biodeposition (faeces & pseudofaeces)

(Newell & Jordan 1983; Manahan et al. 1984; Clark & Wikfors 1998)

# Ecosystem Function

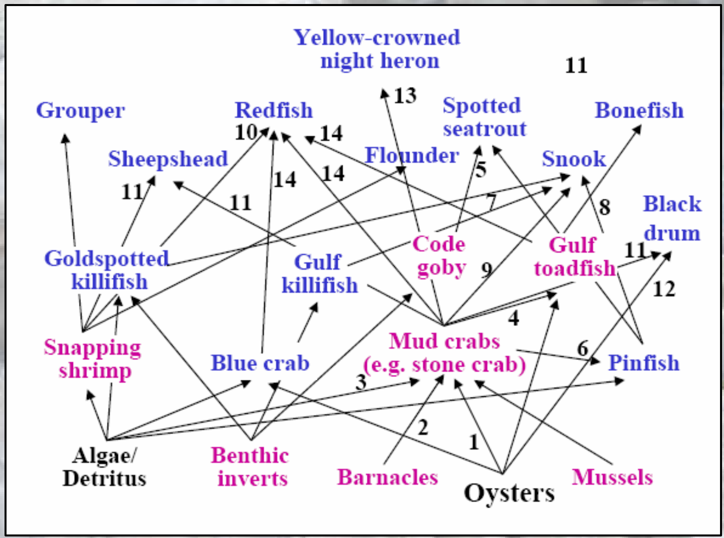
## Habitat Creation: Essential Fish Habitat

Refuge from predation: alpheid shrimps, mud crabs, porcellanid crabs, juvenile fishes
(McDonald 1982; Williams 1984)

Mitigation against desiccation: microhabitat utilization
(Grant & McDonald 1979)

Nest/egg laying: blennies, skilletfish, gobies, gastropods
(Runyan 1961; Peters 1983; Breitburg 1999)

Forage: mud crabs, stone crabs, commercially/recreationally important fishes, birds
(Ingle and Smith 1956; Menzel & Hopkins 1956; Peters & McMichael 1987; Watts 1988; Meyer & Townshend 2000; Harding & Mann 2001)

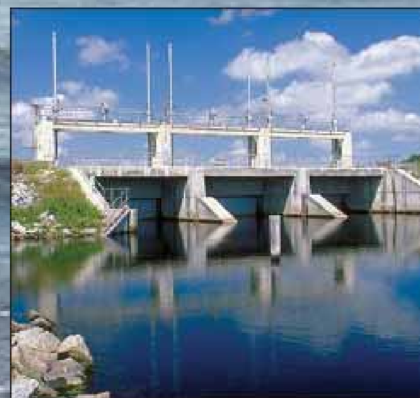


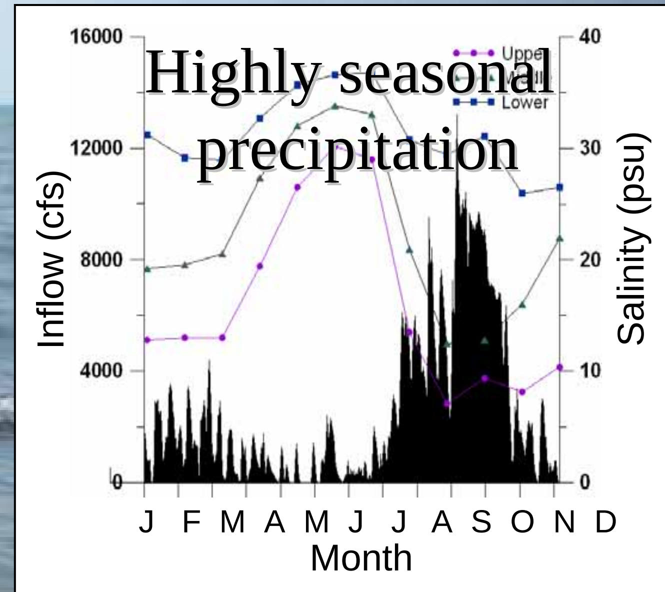
# Oysters and Freshwater Inflow

***The three great natural conditions that work destruction to the [oyster] beds are the freezes, hurricanes, and freshets that occasionally occur, and the first two take place principally in the northern sections of the coast. The cause of the deterioration of the beds other than from natural sources is almost invariably due to overworking. The demand is too great for the supply...***

**Franklin Swift, U.S. Navy. 1897. The oyster-grounds of the West Florida coast: their extent, condition, and peculiarities. *Bull US Fish Comm* 17:285–287**

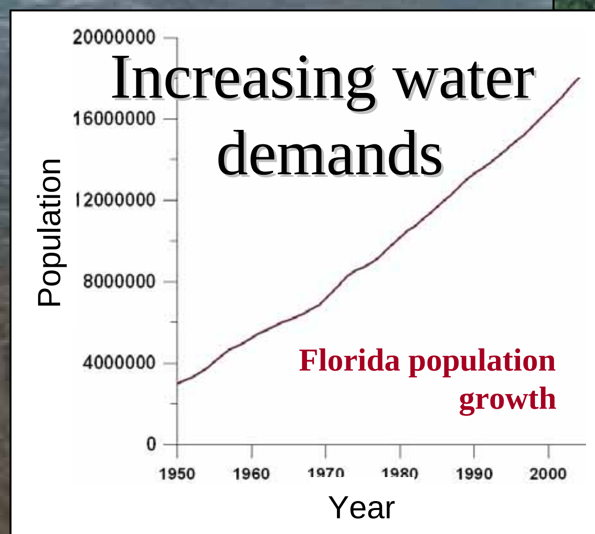
# Altered Freshwater Inflow





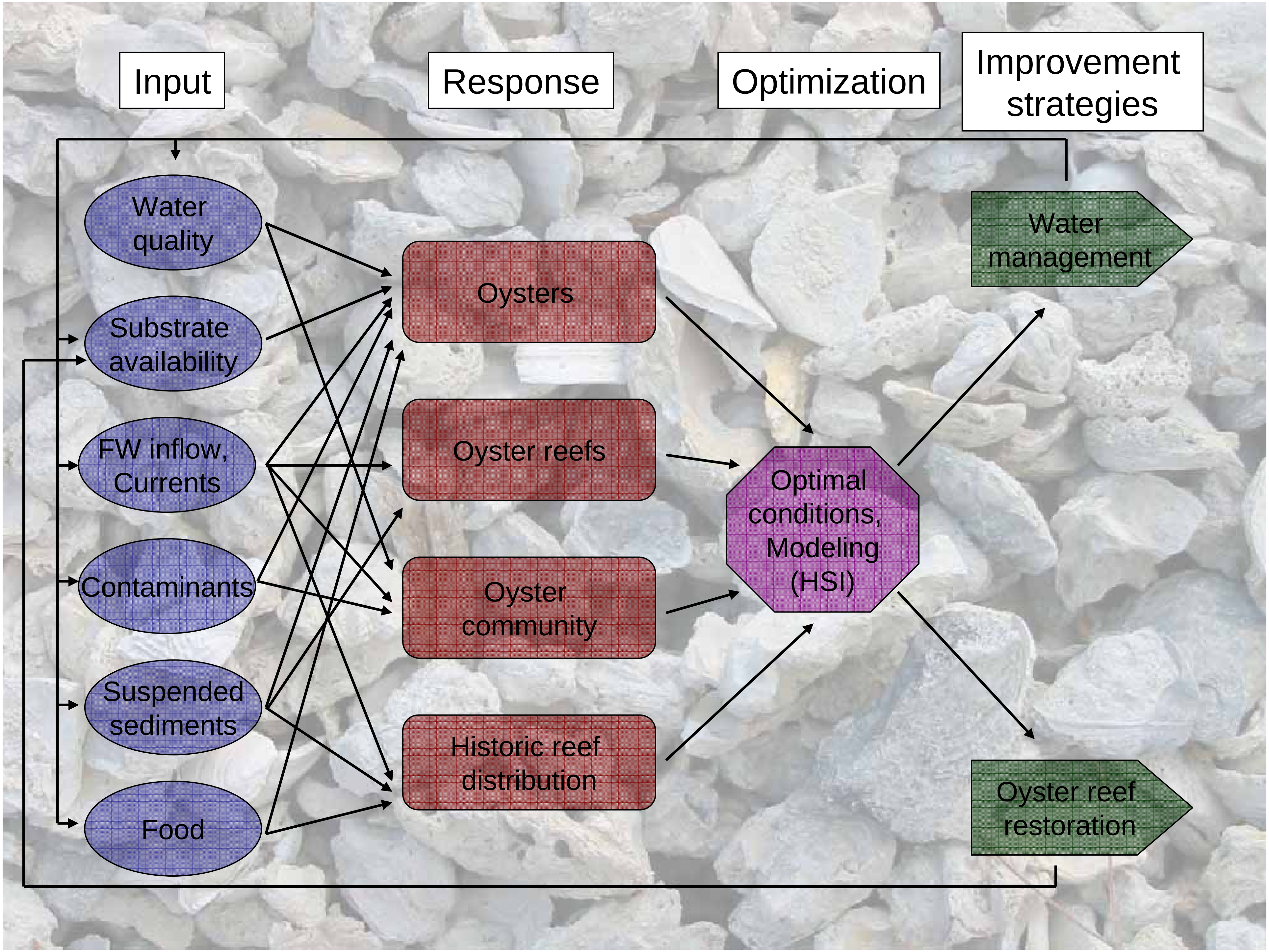

Highly seasonal precipitation

Highly altered watersheds




Increasing water demands

Highly managed flows


Input
Response
Optimization
Improvement strategies
Water quality
Substrate availability
FW inflow, Currents
Contaminants
Suspended sediments
Food
Oysters
Oyster reefs
Oyster community
Historic reef distribution
Optimal conditions, Modeling (HSI)
Water management
Oyster reef restoration

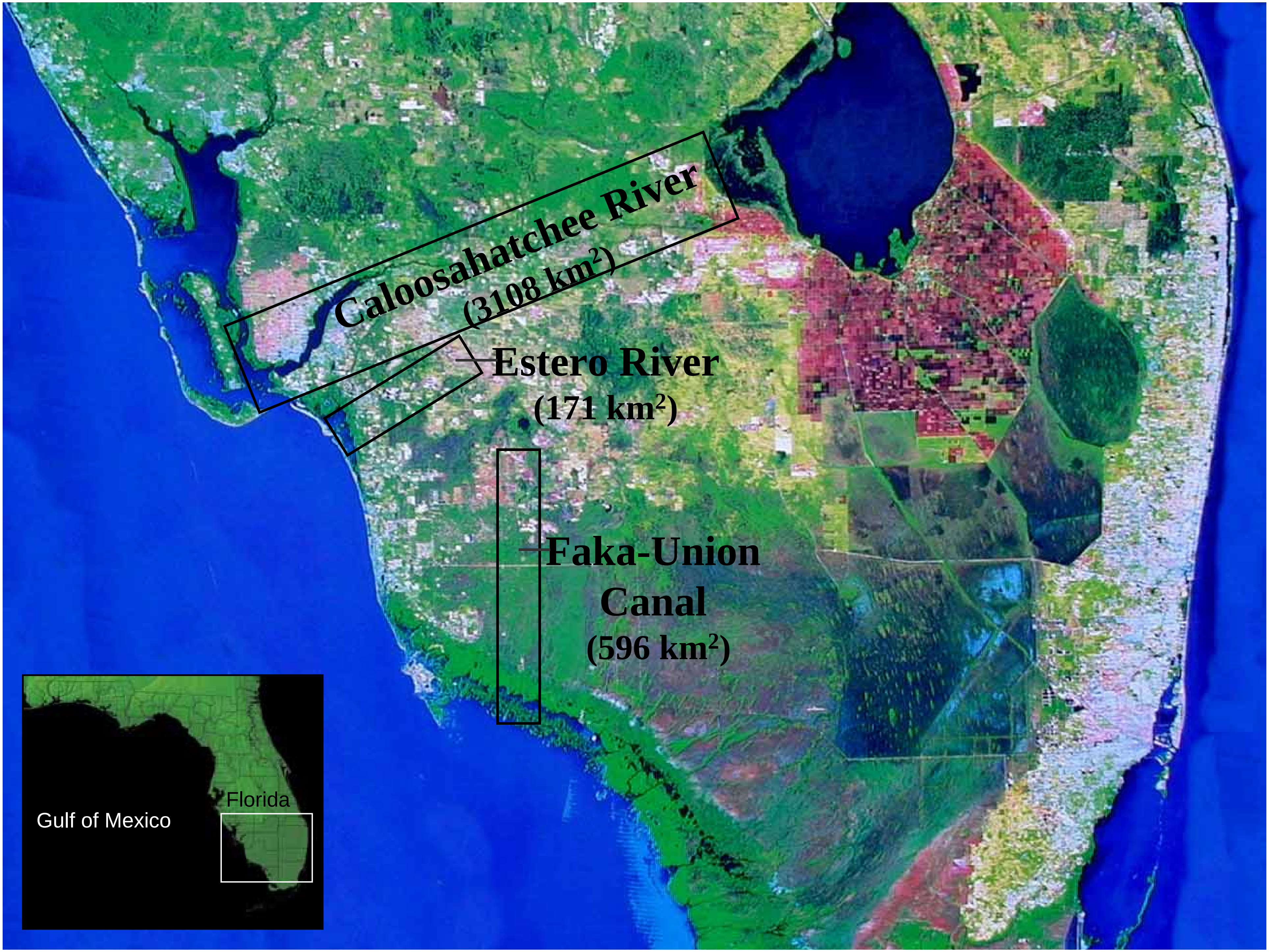
# Oyster-reef Community Responses

Seasonal (wet/dry) variation  reef communities

Spatial (upstream/downstream) variation in reef communities

Influence of freshwater inflow on reef communities and recruitment to reefs

Identify areas suitable for oyster-reef restoration


Caloosahatchee River
(3108 km$^2$)
Estero River
(171 km$^2$)
Faka-Union
Canal
(596 km$^2$)
Florida
Gulf of Mexico

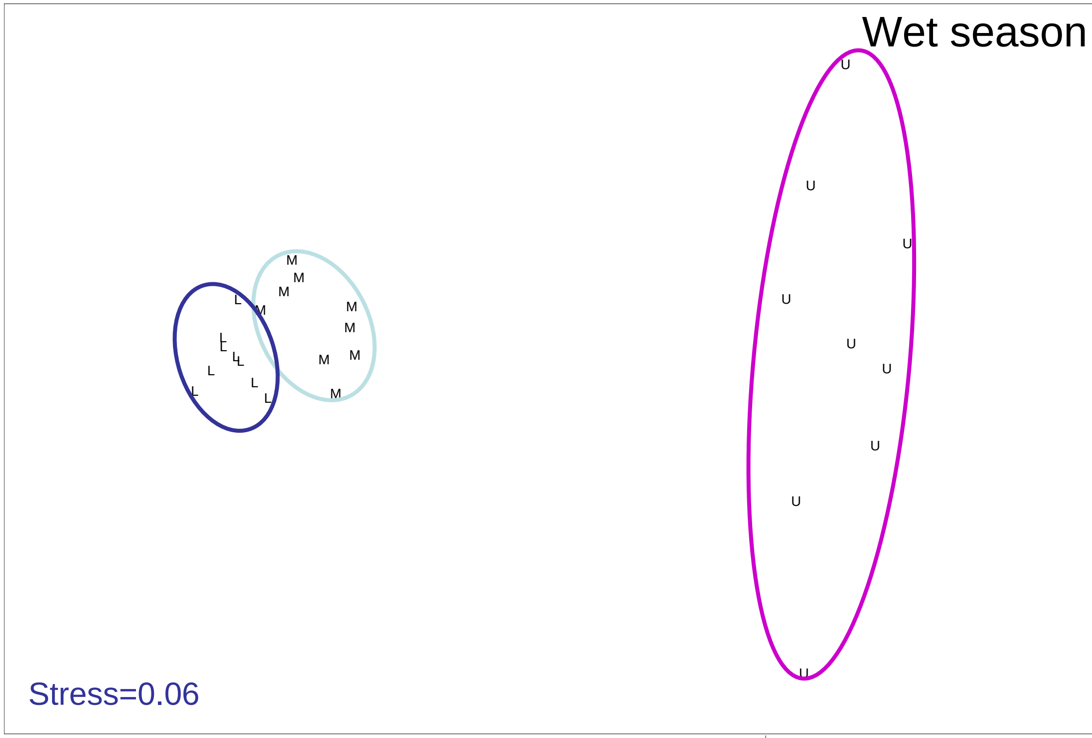
# Sampling Methods

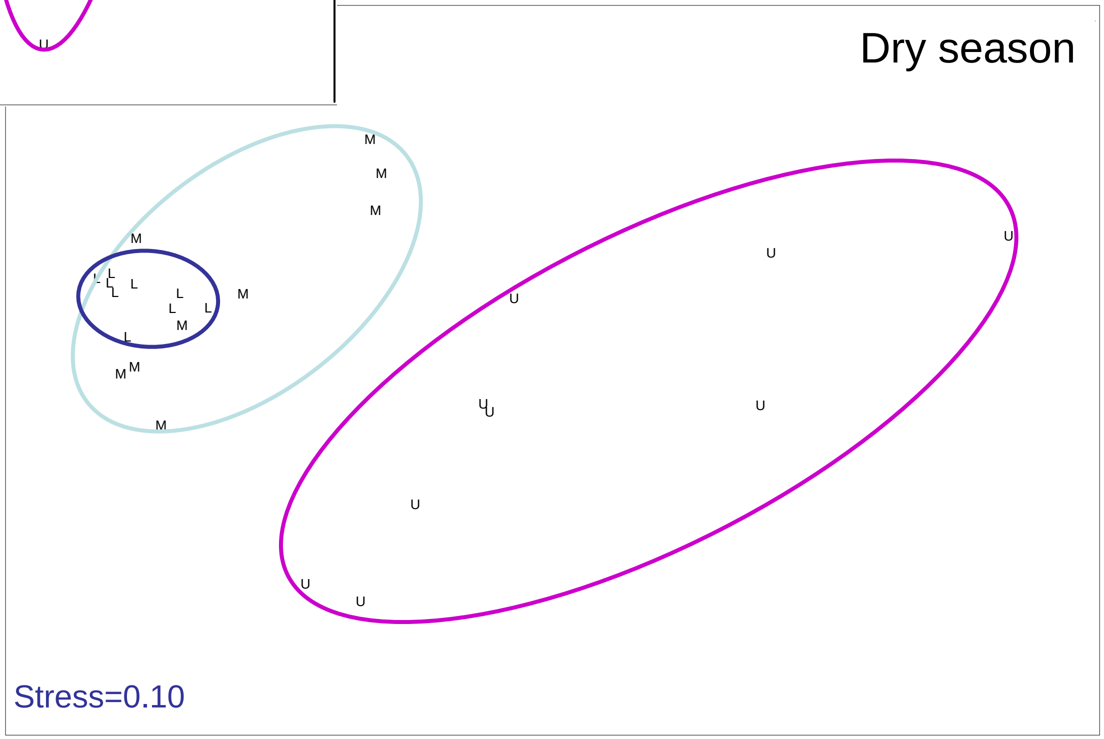
<u>Lift nets (Crabtree & Dean 1982)</u>

- 1 $m^{-2}$
- 6.4-mm netting (1.6-mm liner)
- seeded with 5 liters oyster clusters
- deployed intertidally for ~ 30d
- 3 replicates per reef
- 3 reefs along salinity axis

# Multidimensional Scaling by Season

## Faka Union Canal & Bay

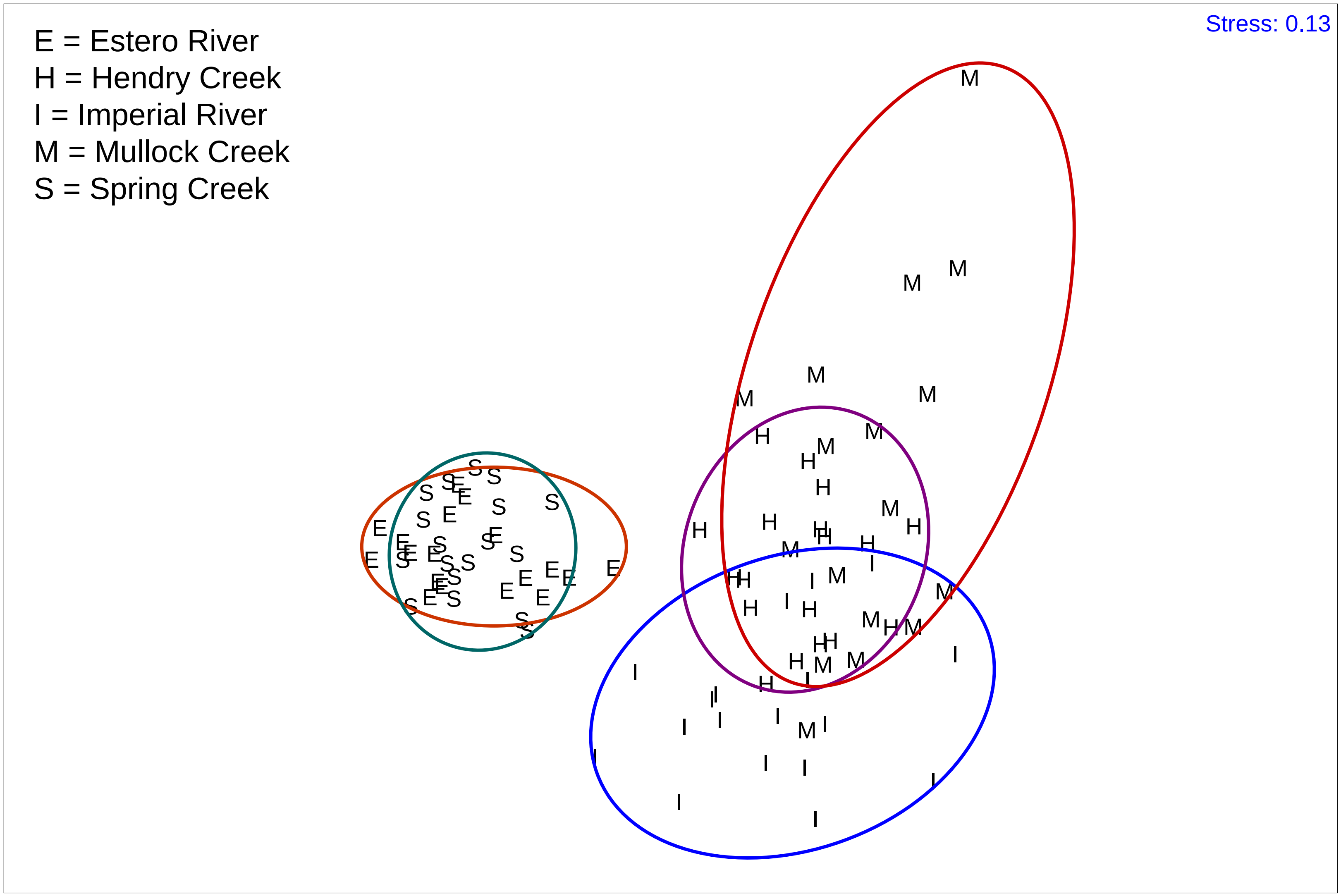


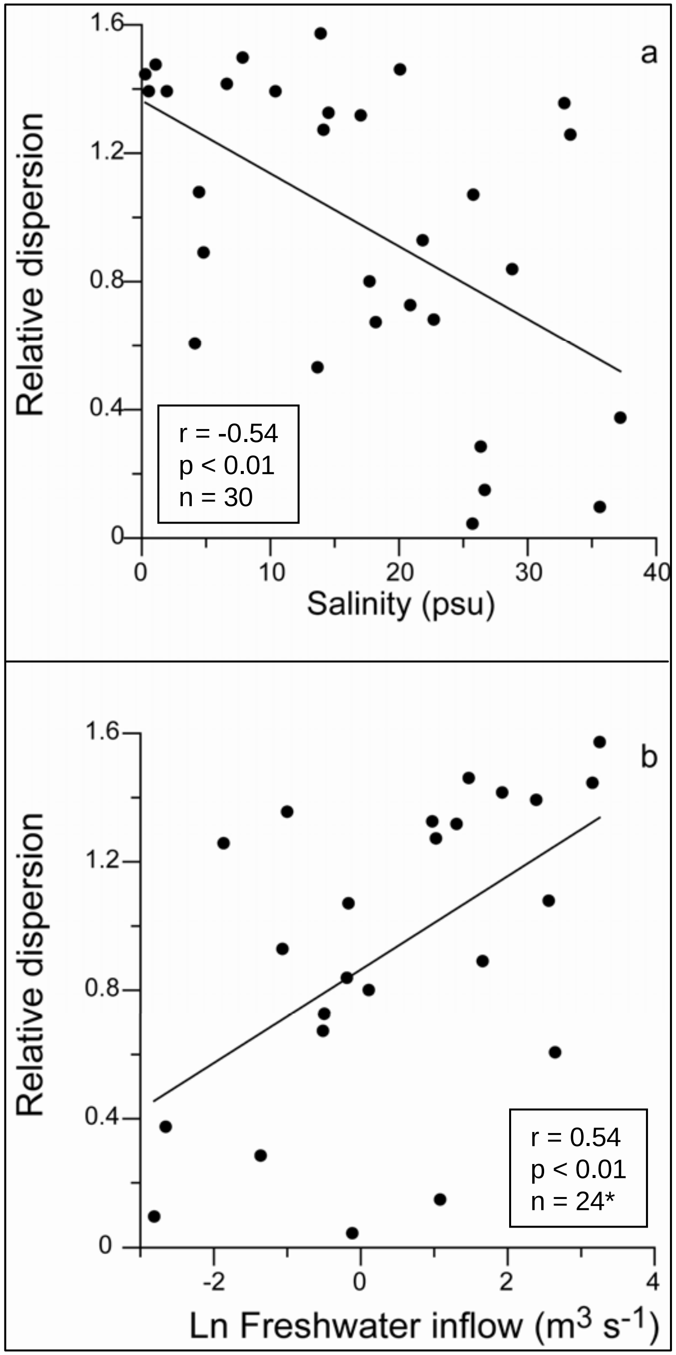



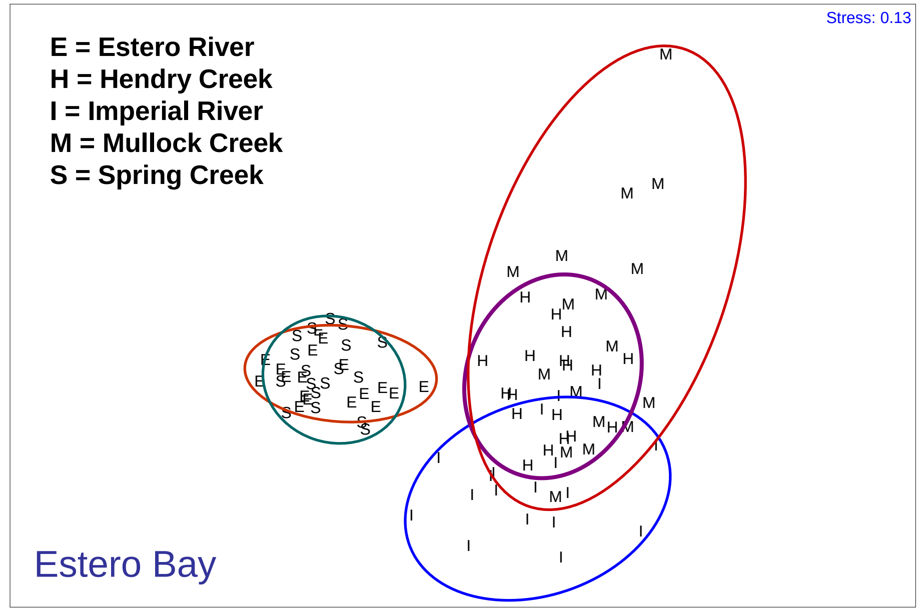
**Species contributions to similarity among oyster-reef communities. Only species accounting for 75% of the total are included. These species typify stations represented.**

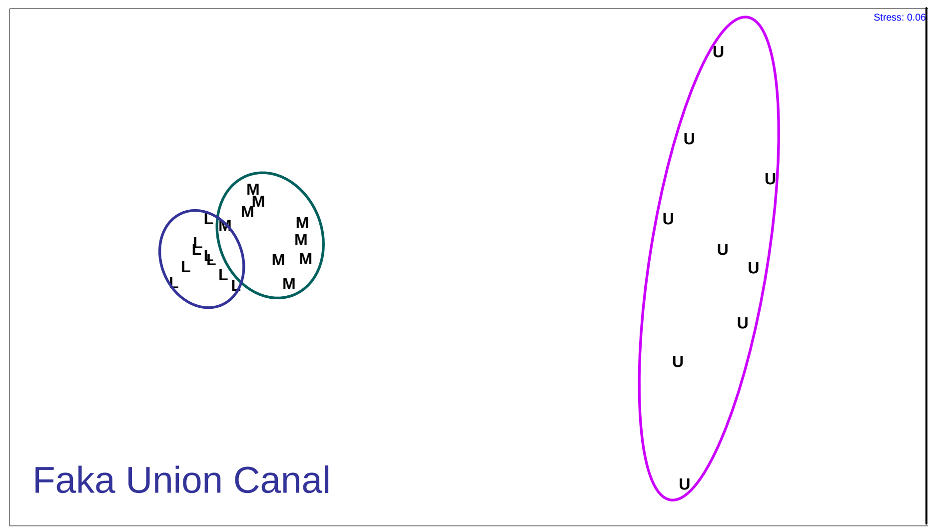
| Estuary | Station | Total similarity | Species | Average abundance | Average similarity | Contrib. % | Cum. % |
|---|---|---|---|---|---|---|---|
| Caloosahatchee | Upper | 63.98 | *E. depressus* | 75.56 | 40.13 | 62.73 | 62.73 |
| | | | *G. robustum* | 4.39 | 15.37 | 24.02 | 86.75 |
| | Middle | 71.95 | *E. depressus* | 83.00 | 26.47 | 36.79 | 36.79 |
| | | | *P. armatus* | 19.76 | 17.20 | 23.91 | 60.70 |
| | | | *P. obesus* | 2.94 | 9.65 | 13.41 | 74.11 |
| | | | *G. strumosus* | 1.35 | 5.12 | 7.12 | 81.23 |
| | Lower | 64.20 | *P. armatus* | 62.61 | 17.80 | 27.73 | 27.73 |
| | | | *E. depressus* | 42.44 | 16.92 | 26.35 | 54.08 |
| | | | *A. heterochaelis* | 3.94 | 6.89 | 10.73 | 64.81 |
| | | | *P. obesus* | 2.56 | 6.65 | 10.36 | 75.17 |
| Estero | Upper | 61.72 | *E. depressus* | 17.78 | 30.18 | 48.90 | 48.90 |
| | | | *L. cyprinoides* | 6.22 | 19.29 | 31.25 | 80.15 |
| | Middle | 72.50 | *E. depressus* | 82.44 | 30.92 | 42.64 | 42.64 |
| | | | *P. armatus* | 115.00 | 29.03 | 40.04 | 82.68 |
| | Lower | 80.04 | *P. armatus* | 107.93 | 33.16 | 41.42 | 41.42 |
| | | | *E. depressus* | 56.87 | 28.28 | 35.32 | 76.75 |
| Faka Union | Upper | 43.69 | *E. depressus* | 9.72 | 29.09 | 66.60 | 66.60 |
| | | | *L. cyprinoides* | 0.61 | 3.73 | 8.54 | 75.15 |
| | Middle | 64.72 | *E. depressus* | 91.61 | 32.09 | 49.52 | 49.52 |
| | | | *P. armatus* | 62.06 | 23.56 | 36.36 | 85.88 |
| | Lower | 79.85 | *P. armatus* | 220.33 | 34.56 | 43.29 | 43.29 |
| | | | *E. depressus* | 67.56 | 25.90 | 32.44 | 75.72 |

# Estero Bay Tributaries

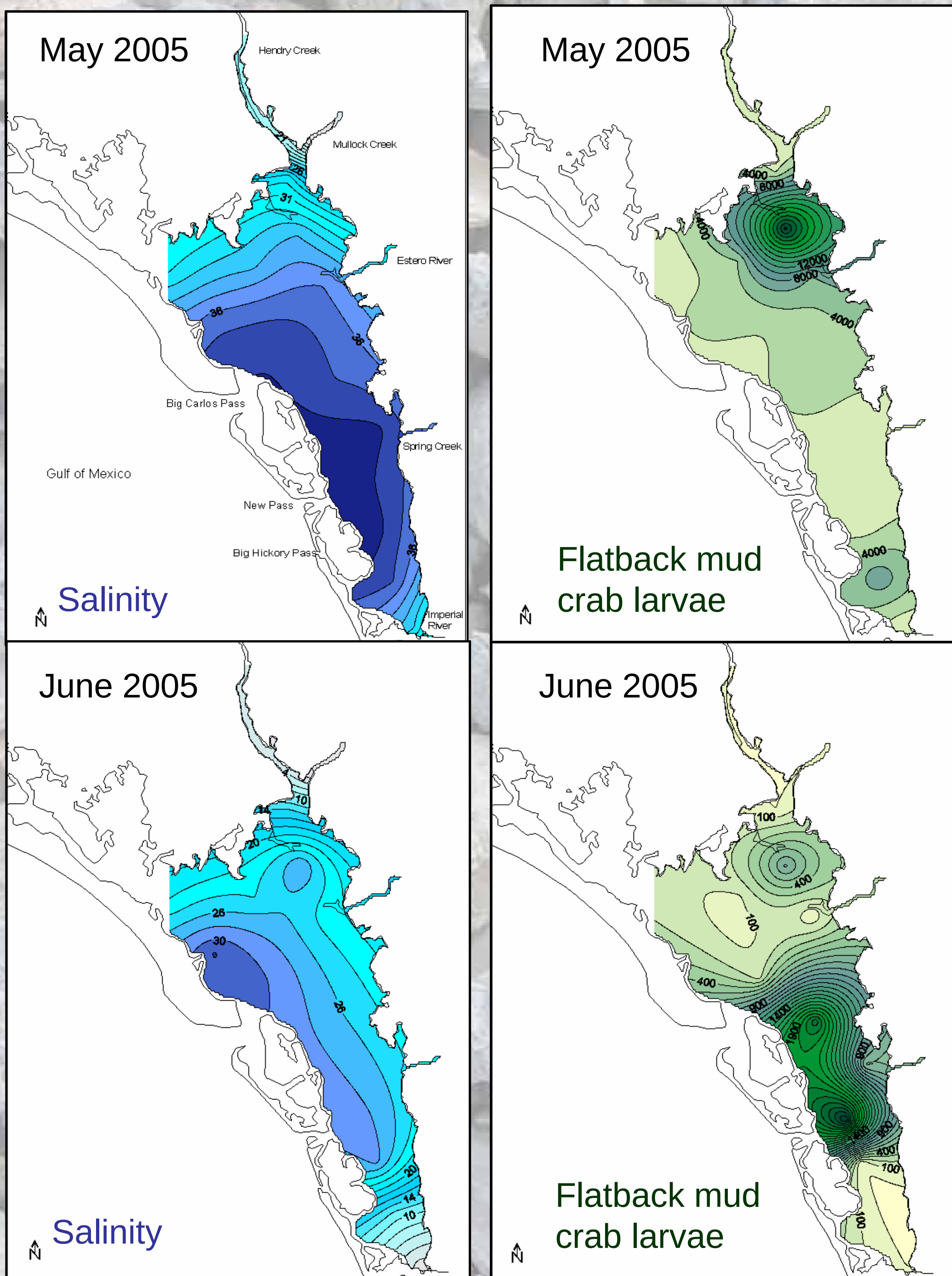





**Warwick & Clarke. 1993. Increased variability as a symptom of stress in marine communities. *J Exp Mar Biol Ecol* 172:215-226**



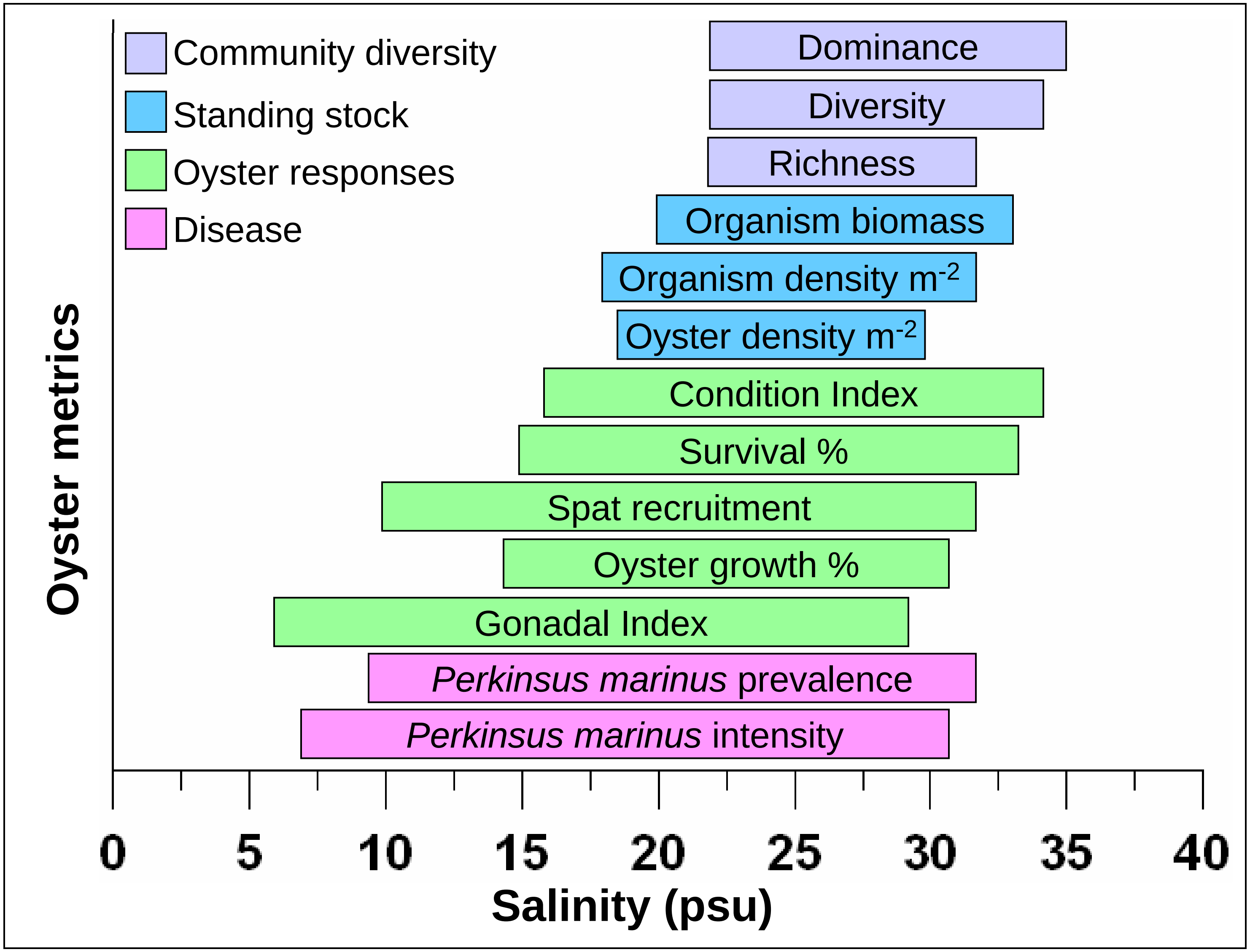

Dry Season

Wet Season

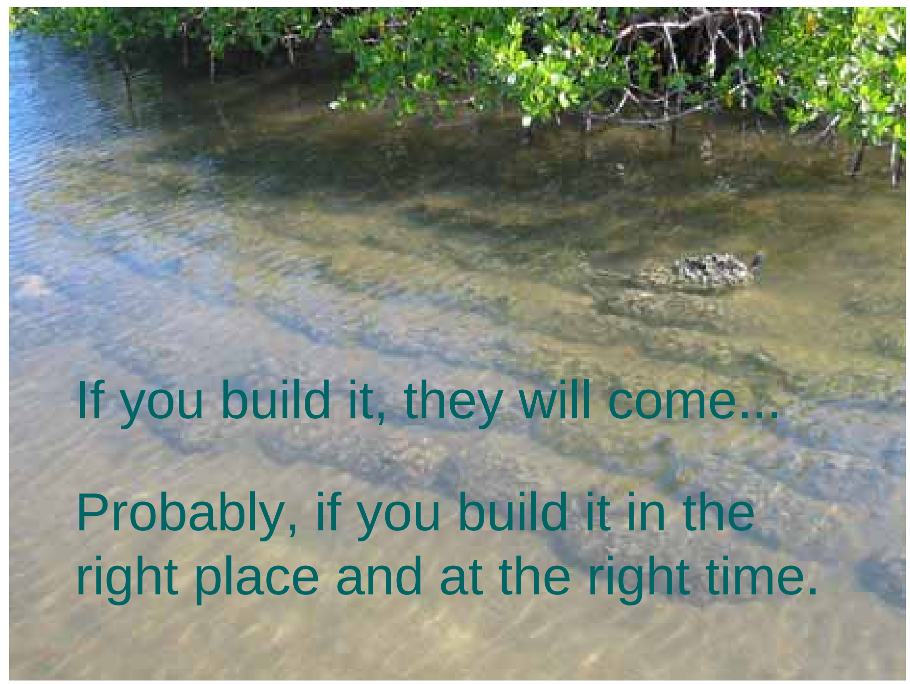
# Oyster reef recruitment

Larval supply of oyster-reef organisms
- environmental conditions
- juveniles/ adults on reefs

# Developing Salinity Envelopes*




* Salinity envelopes calculated using 75th or 25th percentile of metrics


If you build it, they will come...
Probably, if you build it in the right place and at the right time.

# Restoration Target

Healthy oysters
Increased extent of reefs
Mature reef communities
Enhanced ecosystem function

# Acknowledgements


## Institute Staff

Erin Dykes (DEP)
Lesli Haynes
Amanda Bridges

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South Florida Water Management District

U.S. Environmental Protection Agency

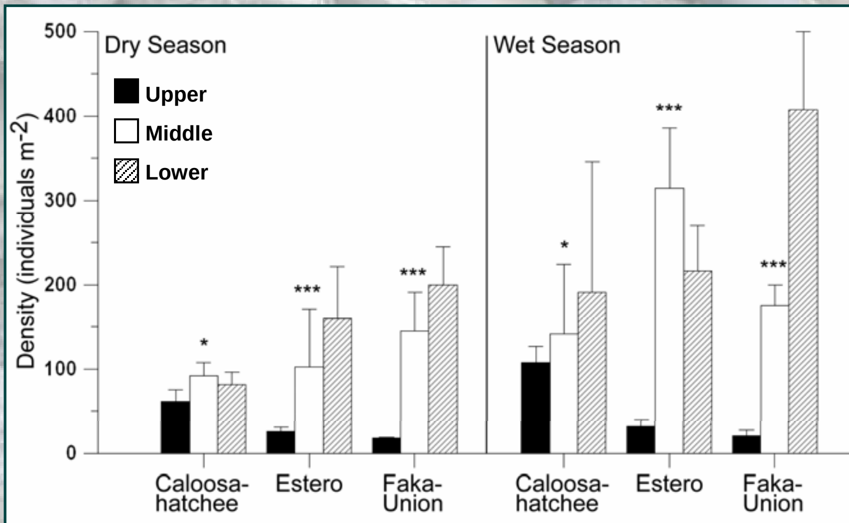
U.S. Department of Education

Florida Gulf Coast University

## Graduate Students/Interns

| | | |
|---|---|---|
| Marty Berry | Brad Kolhoff | Tim Schwan |
| William Bluhm | Raymond Leary | Jennifer Smith |
| Amanda Bridges | Christi Linardich | Laura Walls |
| Brooke Denkert | Laura Markley | Abby Walthier |
| Andrew Erickson | Stephanie Martin | Miranda Westphal |
| Lindsey Garvin | Rachel Miner | Noel Wingers |
| Jason Hahner | Anthony Myers | Mallory Young |
| Ashley Inslee | Christina Panko | |
| Rheannon Ketover | | |

# Spatial trends: oyster-reef community metrics

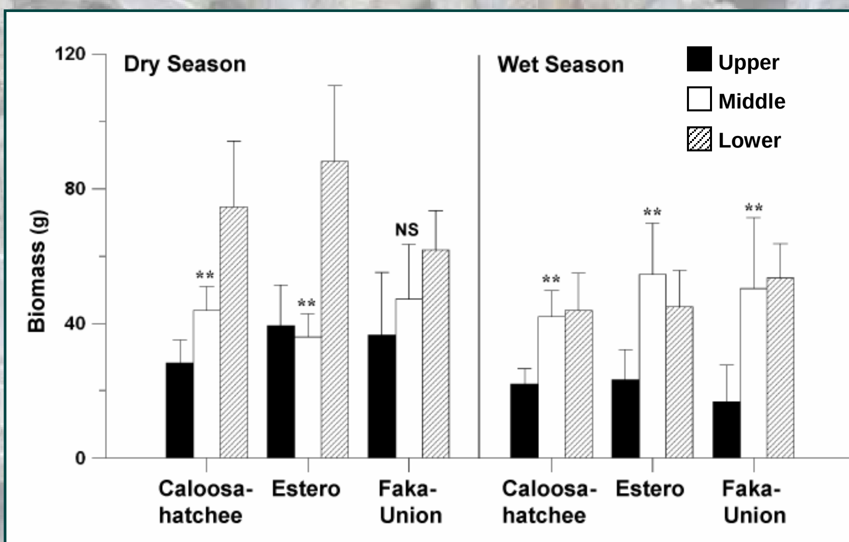


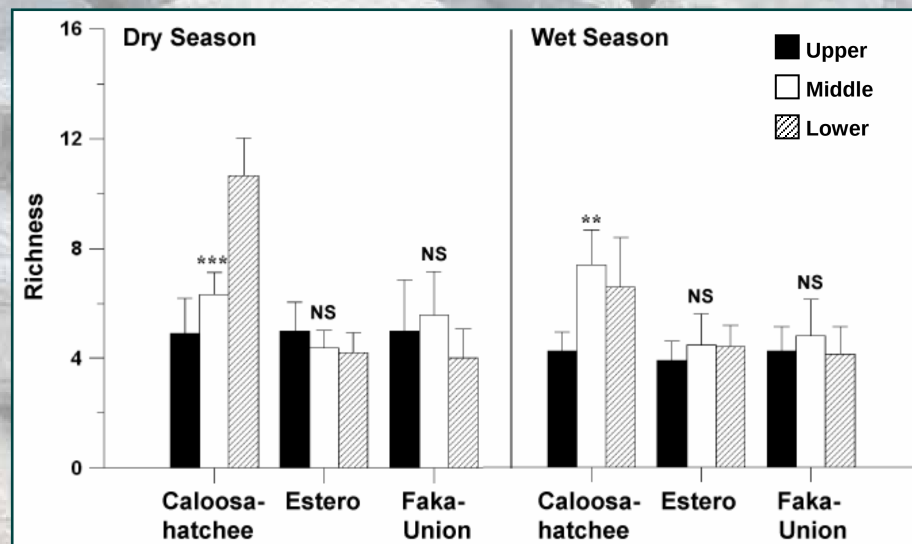

## Seasonal Patterns

Density lower in dry season
Biomass greater in dry season (Caloosahatchee only)

## Spatial Patterns

Density increases downstream
Biomass increases downstream
Richness and evenness increase downstream (Caloosahatchee)



Pearson correlation coefficients for various community metrics and flow parameters. Lag flow of 0 represents mean flow for the 30-d period the lift nets were deployed. Flow data are log+1 transformed. Metrics were calculated for the station at the mouth of the river ( n = 40).

| Metric | Station | Lag flow (months) 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Density | | | | | | | | | | | | | | |
| | Upper | 0.066 | -0.025 | 0.065 | 0.052 | 0.184 | 0.268 | 0.083 | -0.104 | -0.036 | 0.299 | **0.468**** | **0.575**** | **0.604***** |
| | Middle | 0.236 | **0.350*** | **0.387**** | **0.398**** | **0.430**** | **0.410**** | **0.460**** | **0.434**** | **0.436**** | **0.421**** | **0.449**** | **0.458**** | **0.391**** |
| | Lower | 0.260 | **0.321*** | **0.400**** | **0.387**** | **0.294*** | 0.191 | 0.231 | 0.280 | **0.292*** | **0.314*** | **0.360*** | **0.363*** | **0.340*** |
| Biomass | | | | | | | | | | | | | | |
| | Upper | **-0.523**** | **-0.346*** | 0.002 | 0.140 | 0.283 | 0.333 | 0.168 | 0.196 | 0.218 | 0.225 | 0.252 | 0.252 | -0.041 |
| | Middle | -0.179 | -0.061 | -0.018 | 0.056 | 0.106 | 0.200 | 0.265 | **0.451**** | **0.466***** | **0.551***** | **0.605***** | **0.466**** | **0.354*** |
| | Lower | 0.034 | 0.100 | 0.097 | 0.146 | 0.101 | 0.025 | 0.127 | 0.268 | **0.376**** | 0.265 | **0.297*** | 0.191 | -0.041 |
| Richness | | | | | | | | | | | | | | |
| | Upper | -0.315 | **-0.430**** | **-0.516**** | **-0.468**** | **-0.373*** | -0.128 | -0.111 | 0.166 | 0.311 | **0.370*** | 0.310 | 0.214 | -0.017 |
| | Middle | -0.130 | **-0.307*** | **-0.313*** | **-0.438**** | **-0.669***** | **-0.449**** | **-0.326*** | **-0.405**** | -0.287 | -0.082 | -0.066 | 0.031 | -0.142 |
| | Lower | -0.167 | -0.122 | -0.251 | **-0.291*** | **-0.349*** | **-0.426**** | **-0.450**** | **-0.412**** | **-0.330*** | **-0.415**** | -0.284 | **-0.457**** | **-0.516***** |
| Diversity | | | | | | | | | | | | | | |
| | Upper | -0.220 | **-0.346*** | **-0.450**** | **-0.357*** | **-0.408*** | -0.169 | 0.329 | 0.330 | **0.407*** | 0.329 | 0.193 | -0.013 | -0.180 |
| | Middle | **-0.321*** | **-0.481***** | **-0.439**** | **-0.489***** | **-0.595***** | **-0.484***** | **-0.491***** | **-0.496***** | **-0.465**** | -0.278 | -0.260 | -0.212 | **-0.350*** |
| | Lower | -0.175 | -0.182 | **-0.293*** | **-0.351*** | **-0.393**** | **-0.407**** | **-0.413**** | **-0.383**** | **-0.325*** | **-0.444**** | **-0.305*** | **-0.506***** | **-0.589***** |
| Dominance | | | | | | | | | | | | | | |
| | Upper | 0.103 | 0.283 | **0.349*** | 0.274 | **0.351*** | 0.159 | 0.007 | -0.318 | **-0.371*** | -0.312 | -0.182 | -0.051 | 0.125 |
| | Middle | **0.340*** | **0.489***** | **0.452**** | **0.488***** | **0.563***** | **0.500***** | **0.555***** | **0.532***** | **0.556***** | **0.363*** | **0.361*** | 0.258 | **0.336*** |
| | Lower | 0.139 | 0.120 | 0.275 | **0.351*** | **0.400**** | **.406**** | **0.348*** | **0.349*** | **0.306*** | **0.435**** | 0.278 | **0.432**** | **0.480***** |

*$p \leq 0.05$; **$p<0.01$; ***$p<0.001$

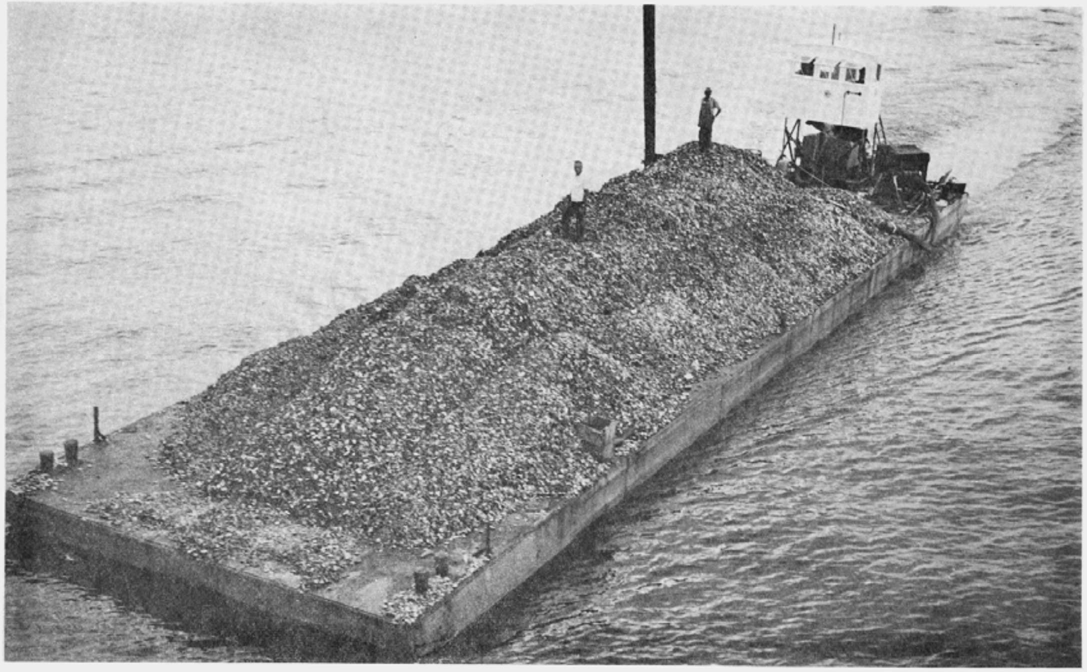


Figure 1. Self-propelled barge loaded with shucked shell under way to a planting site in Apalachicola Bay.

# Florida Department of Natural Resources (1949–1971)

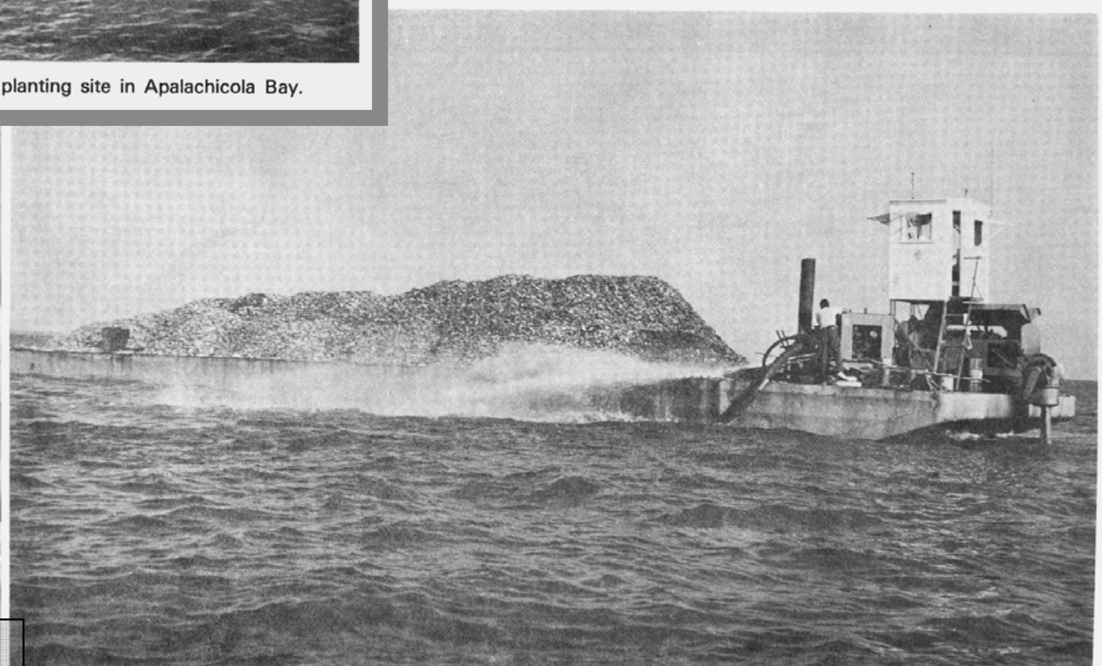
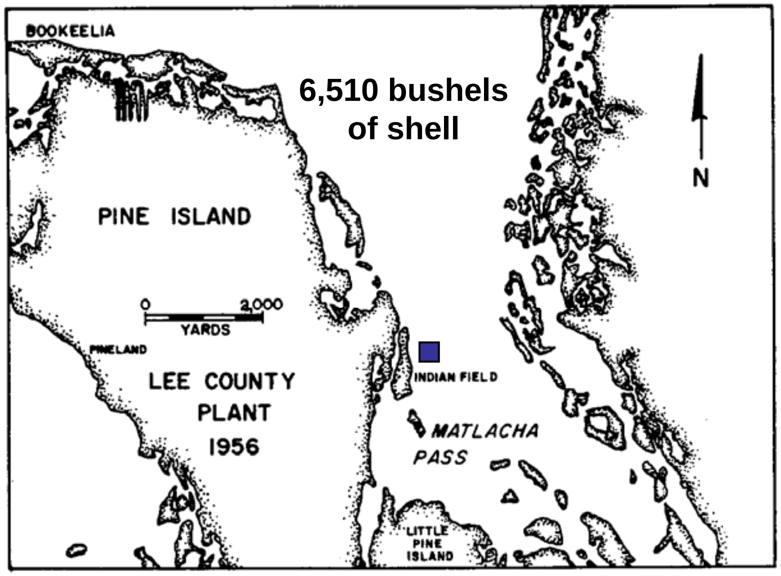


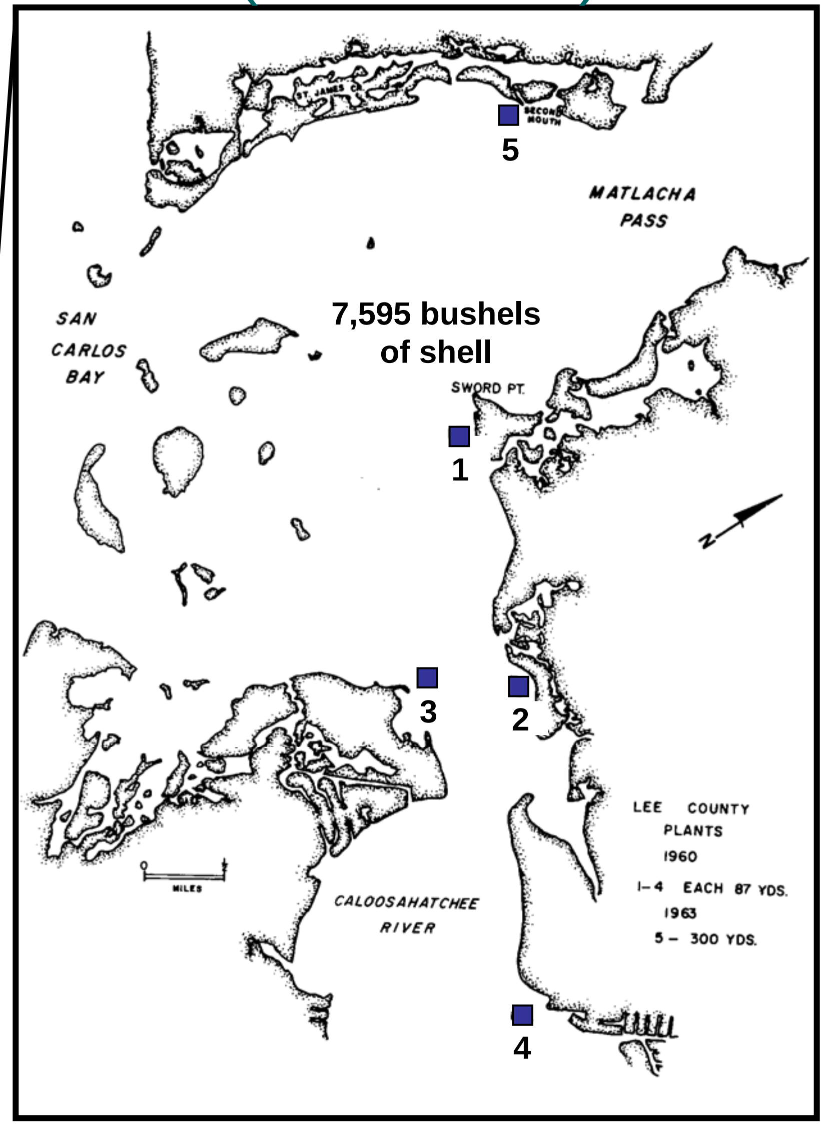
Figure 2. Shell being unloaded from barge anchored by spud using a high pressure water stream.

**SOURCE: Whitfield, WK, Jr. 1973. Construction and rehabilitation of commercial oyster reefs in Florida from 1949 through 1971 with emphasis on economic impact in Franklin County. FL Dept Nat Resour, Spec Scient Rep 38, 42 pg**

# Lee Co. Oyster-reef Restoration (1956–1963)

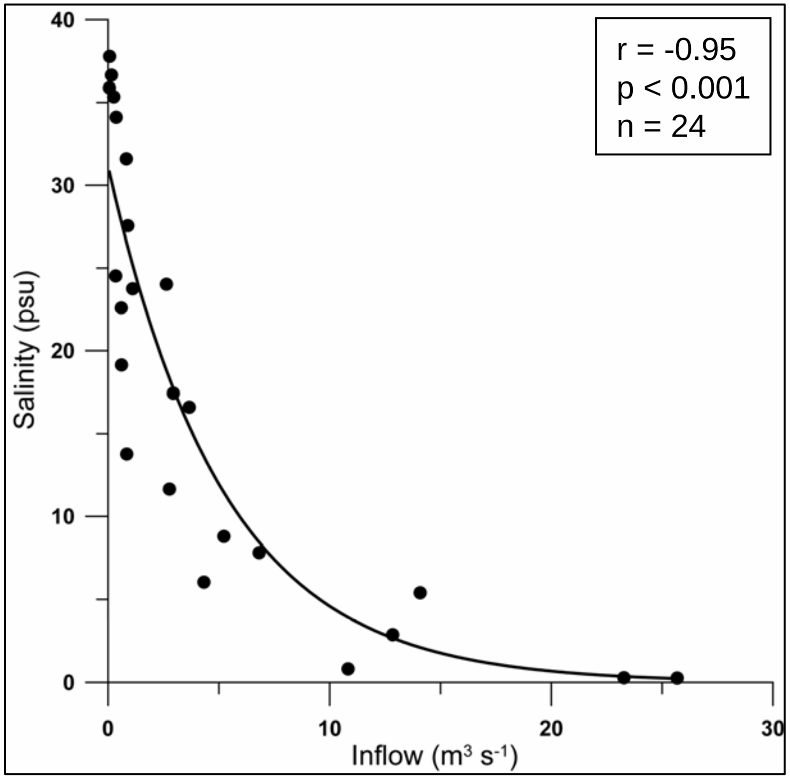






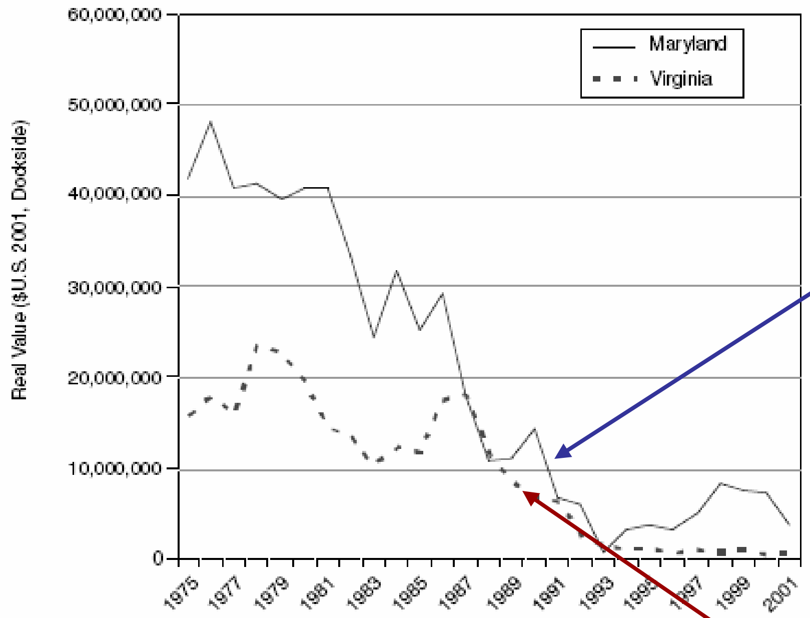

**SOURCE: Whitfield, WK, Jr. 1973. Construction and rehabilitation of commercial oyster reefs in Florida from 1949 through 1971 with emphasis on economic impact in Franklin County. FL Dept Nat Resour, Spec Scient Rep 38, 42 pg**

# Salinity and freshwater inflow: Estero Bay

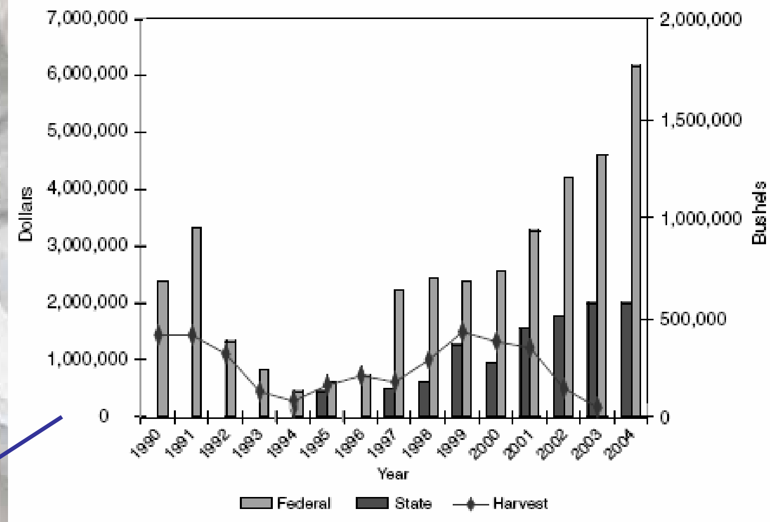



Interaction between Hendry and Mullock Creeks

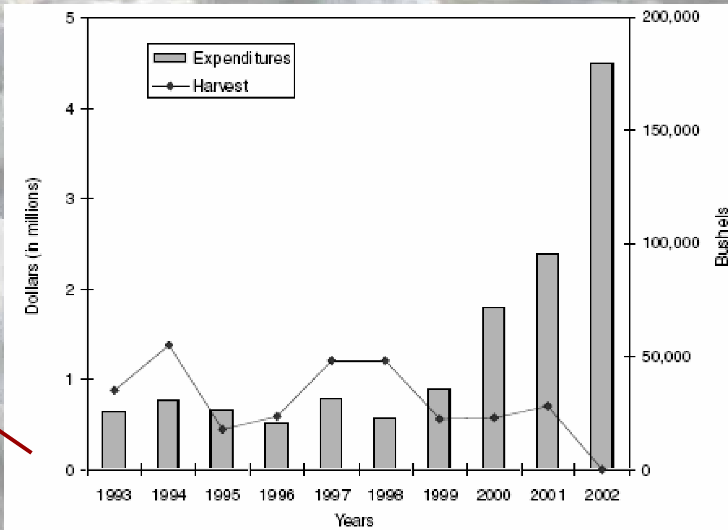
# Oyster-reef Restoration




Real (2001 $US value of Maryland's and Virginia's oyster harvest. (NMFS 2003, US Dept Labor, Bureau of Labor Statistics)




Annual funding of Maryland oyster projects versus harvest. (C Judy, Maryland Dept Nat Resour, pers comm, 2003)




Virginia expenditures on oyster restoration and oyster landings. (J Wesson, VMRC, pers comm, 2003)

SOURCE: Whitfield, WK, Jr. 1973. Construction and rehabilitation of commercial oyster reefs in Florida from 1949 through 1971 with emphasis on economic impact in Franklin County. FL Dept Nat Resour, Spec Scient Rep 38, 42 pg

# Habitat Use: Individual Species

**Live clusters/cleaned shell > sand bottom**

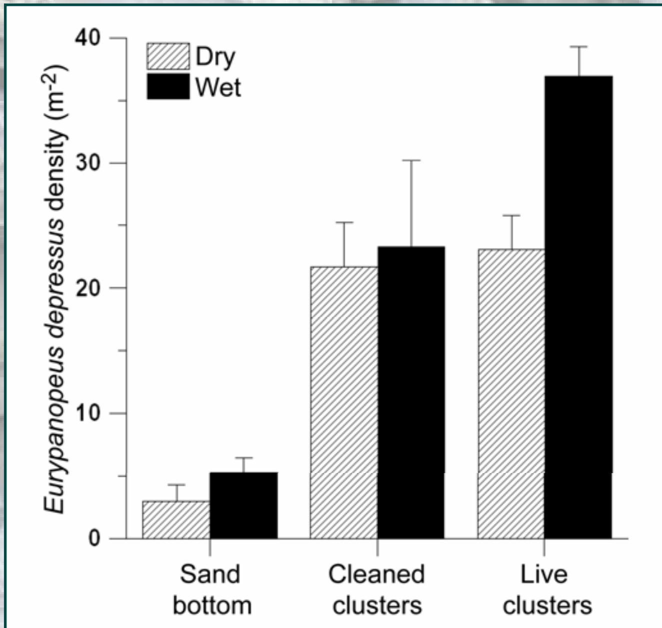
- *Eurypanopeus depressus* ($p < 0.001$)
- *Petrolisthes armatus* ($p<0.001$)
- *Alpheus heterochaelis* ($p<0.01$)
- *Opsanus beta* ($p<0.001$)

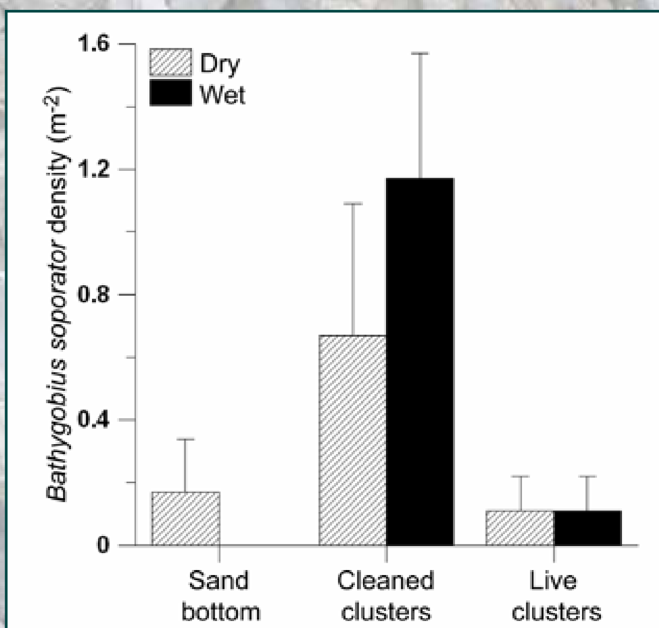
**Cleaned shell > live clusters/sand bottom**

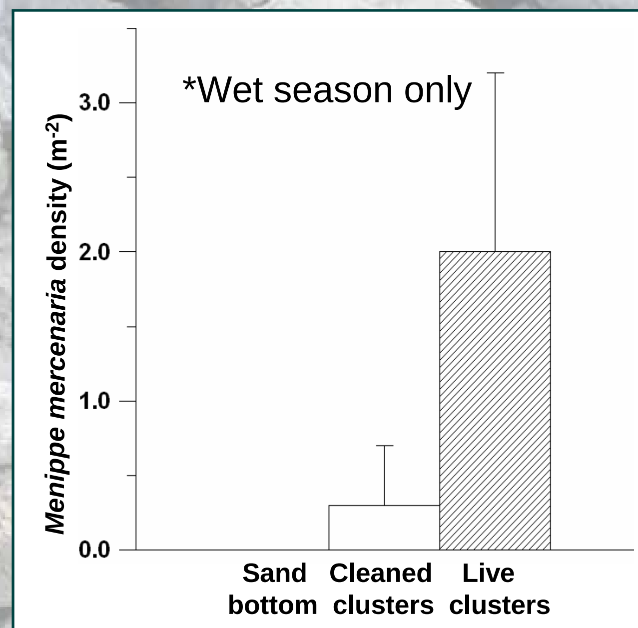
- *Bathygobius soporator* ($p<0.001$)

**Live clusters > cleaned shell/sand bottom**

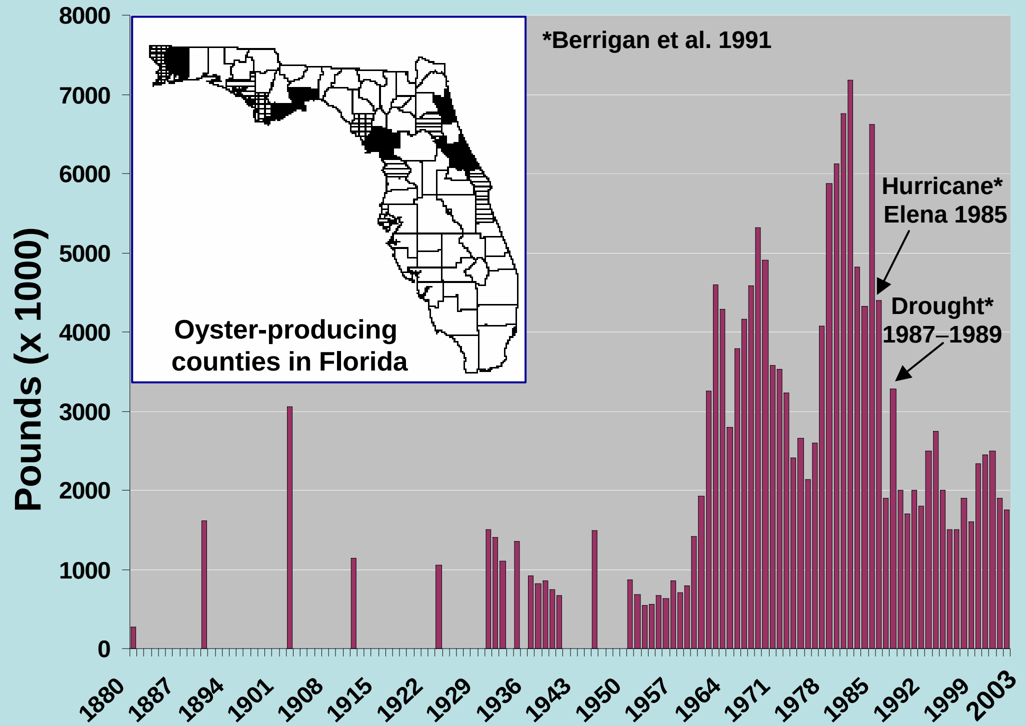
- *Menippe mercenaria** ($p=0.001$)



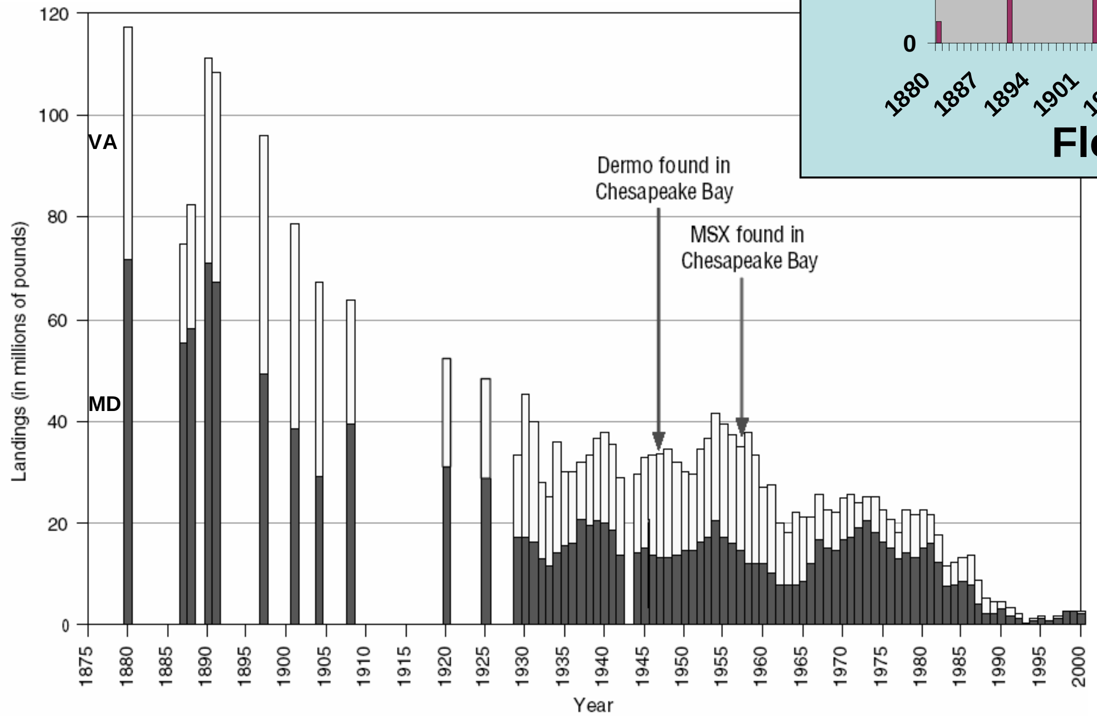



# Historic Decline of Oysters



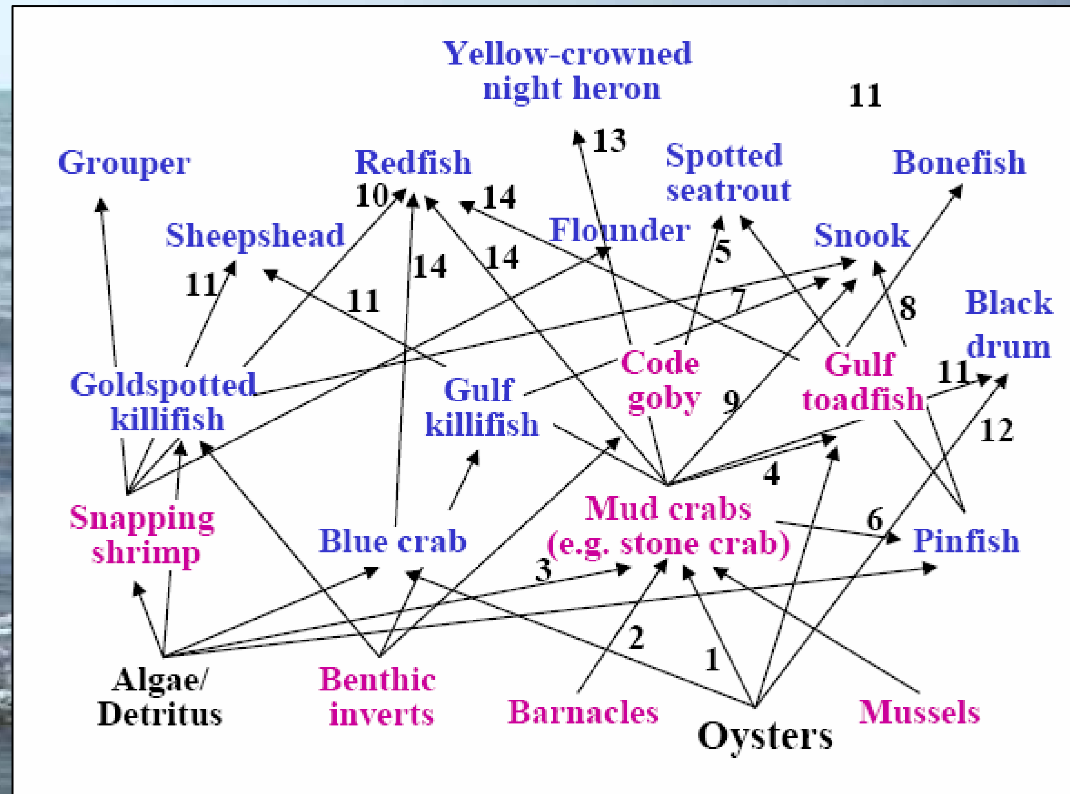

Florida Gulf Coast Landings




Historical commercial landings in Chesapeake Bay

SOURCES: (1) Nonnative oysters in the Chesapeake Bay. 2004. National Academic Press, Washington, DC, 345 pg (2) King, JL & K McGraw. 2004. Oyster restoration series: status of the US oyster resource. Habitat Connections 5, 4 pg. (3) Kilgen, RH & RJ Dugas. 1989. The ecology of oyster reefs in the northern Gulf of Mexico. US Dept Interior, 89-03, 124 pg (4) Murphy, MD, GA Nelson & RG Muller. 2005. Florida's inshore and nearshore species: 2005 Status and Trends Report. FL Fish Wildlife Conserv Comm

# Oyster-reef food webs




References

[1] Meyer 1994
[2] Bahr 1974
[3] Gibbons & Blogoslawski 1989
[4] Bisker et al. 1989
[5] McMichael & Peters 1989
[6] Grant & McDonald 1979
[7] Fore & Schmidt 1973
[8] Gilmore et al. 1983
[9] Marshall 1958
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# Cluster Analysis
# Caloosahatchee Oyster-reef Communities

**Samples**
**U** Upper
**M** Middle
**L** Lower