SOUTH FLORIDA WATER MANAGEMENT DISTRICT

# WELCOME

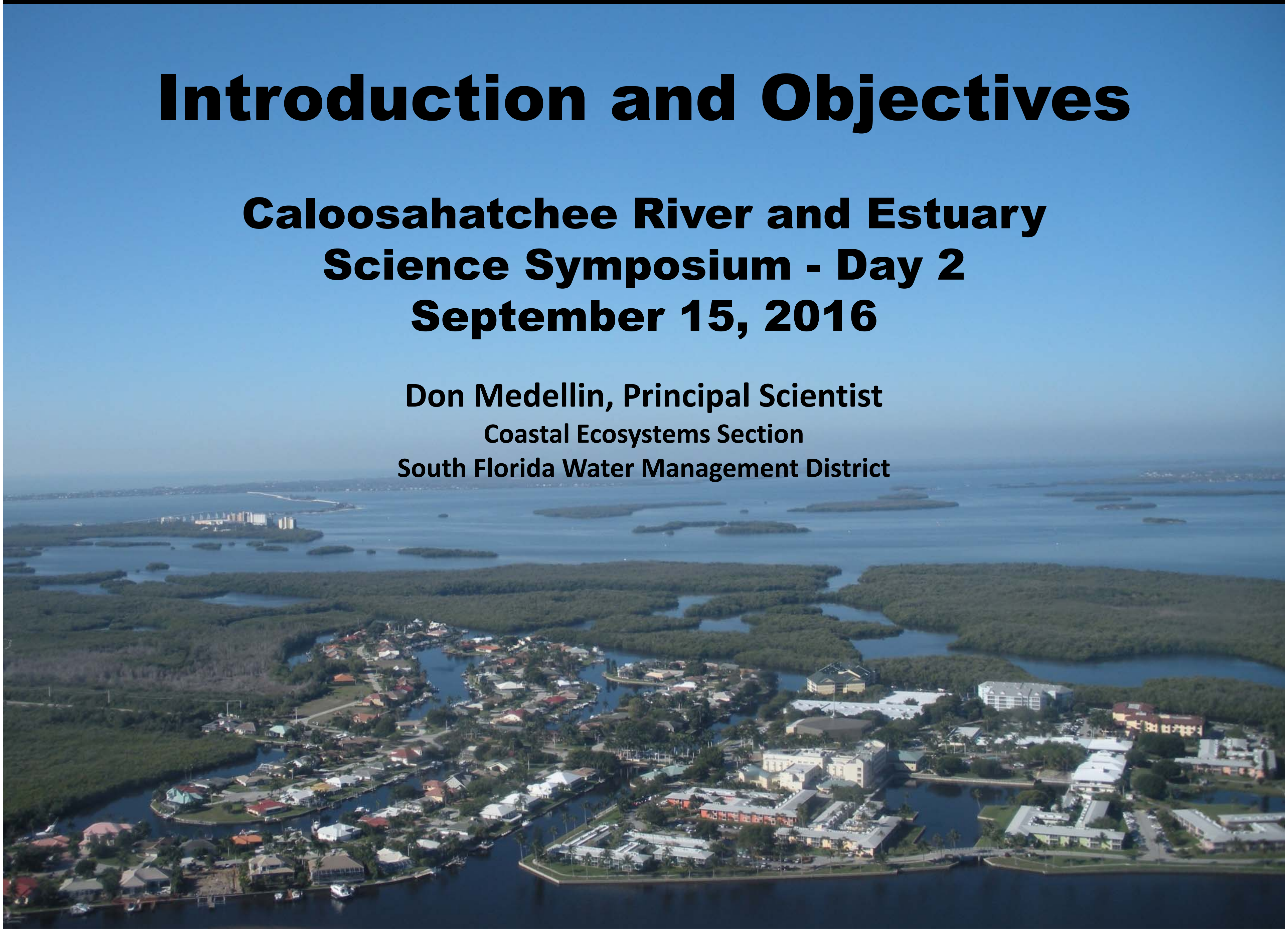
## Caloosahatchee River and Estuary Science Symposium

### September 14-15, 2016

# Introduction and Objectives

## Caloosahatchee River and Estuary Science Symposium - Day 2 September 15, 2016

**Don Medellin, Principal Scientist**
Coastal Ecosystems Section
South Florida Water Management District



# Purpose and Objectives of Science Components

## Purpose:

- To provide a comprehensive assessment of the science for the Caloosahatchee River Estuary for the current Minimum Flows and Levels Re-evaluation
  - Science will provide a strong technical science foundation for the MFL technical document

## Objectives:

- Compile and document information about dry season freshwater inflows and salinity patterns relative to multiple indicators
- Examine the responses of a suite of ecological indicators to dry season inflows
- Estimate the low inflows to which the indicator might respond negatively

# Science Approach

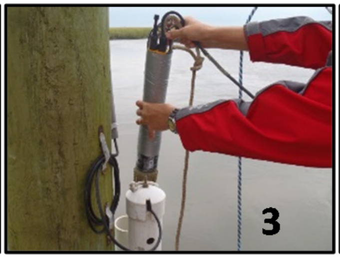
- Explores new data since adoption of the MFL (2001), analyzes older data, uses updated statistical approaches and updated modeling
- Provides an evaluation of multiple indicators within the estuary including, zooplankton, icthyoplankton, submersed aquatic vegetation, oysters, benthic communities, blue crabs and sawfish
- Evaluates the effects of dry season freshwater inflow on the hydrology and ecology of the Caloosahatchee River Estuary

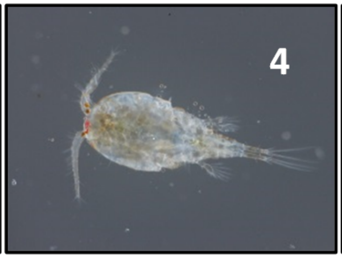
Blue Crab

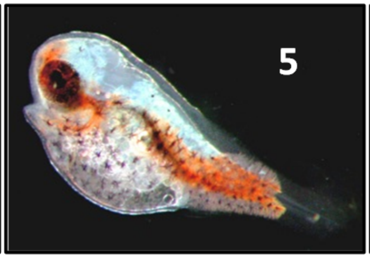
Oysters

# SCIENCE COMPONENTS / STUDIES

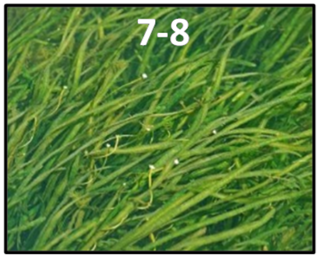
| | Component | Method |
|---|---|---|
| 1 | Hydrodynamics | Influence of alterations on hydrodynamics |
| 2 | Inflow vs. Salinity | Monthly freshwater-salinity relationships |
| 3 | Water Quality | Fine scale relationships between water quality and inflow |
| 4 | Zooplankton | Inflow, zooplankton and habitat compression |
| 5 | Ichthyoplankton | Relationships between ichthyoplankton and inflow |
| 6 | Benthic Fauna | Macrofauna-salinity patterns relative to inflow |
| 7 | *Vallisneria* data | Empirical relationships between tape grass, S, and inflow |
| 8 | *Vallisneria* model | Model exploration of tape grass, S, light, and inflow |
| 9 | Oyster Habitat | Assess conditions for oyster survival and growth in lower CRE |
| 10 | Blue Crabs | Relationships between blue crab landings, rainfall, and inflow |
| 11 | Sawfish | Relationships between low inflow, salinity range, and depth |

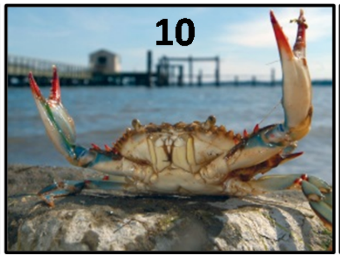












# Goal and Objectives of Symposium

## Goal: Keep comments focused on the science

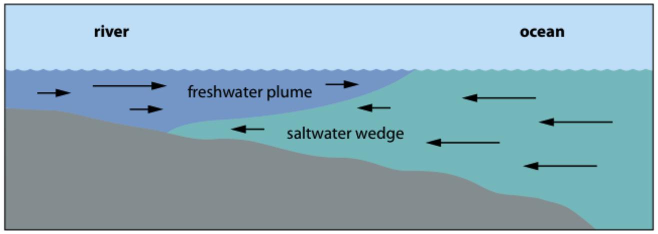
## Objectives:

- Communicate with stakeholders to explain the scientific approach taken to evaluate all of the science information that was available
- Communicate with stakeholders to see if other data sets or analyses could add to this scientific body of knowledge
- Receive feedback on the science study during the 2-day science symposium and the 60-day public comment period
- Outline the process and specific steps for the MFL reevaluation

# Component Study 6: Summary and interpretation of benthic community properties relative to salinity and inflow in the Caloosahatchee River Estuary

**Christopher Buzzelli & Peter Doering**
Coastal Ecosystems Section
South Florida Water Management District

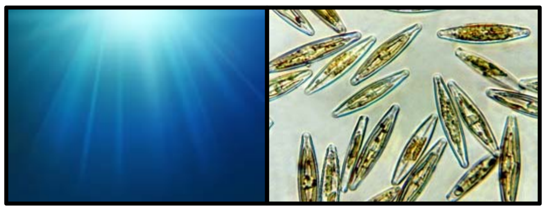
# INDICATORS OF ESTUARINE RESPONSE TO LOW INFLOW




Changes in isohaline position with upstream encroachment of saltier water

Alter benthic community upon which many estuarine fauna are dependent

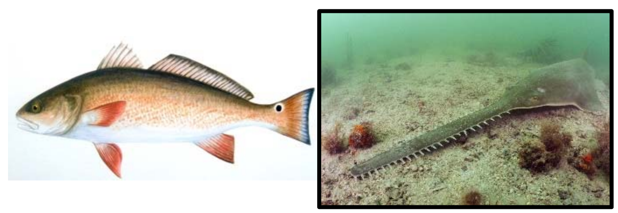
Damaging to the freshwater *Vallisneria americana* (tape grass)



Reduced flushing and enhanced light can stimulate phytoplankton in upper estuary

Impact physiology and habitat attributes of eastern oyster

Zooplankton and ichthyoplankton assemblages move upstream but can be impinged by structure



Affect coastal fish populations dependent upon estuaries as nurseries

Negatively impact harvests of important fisheries

# SCIENCE COMPONENTS / STUDIES

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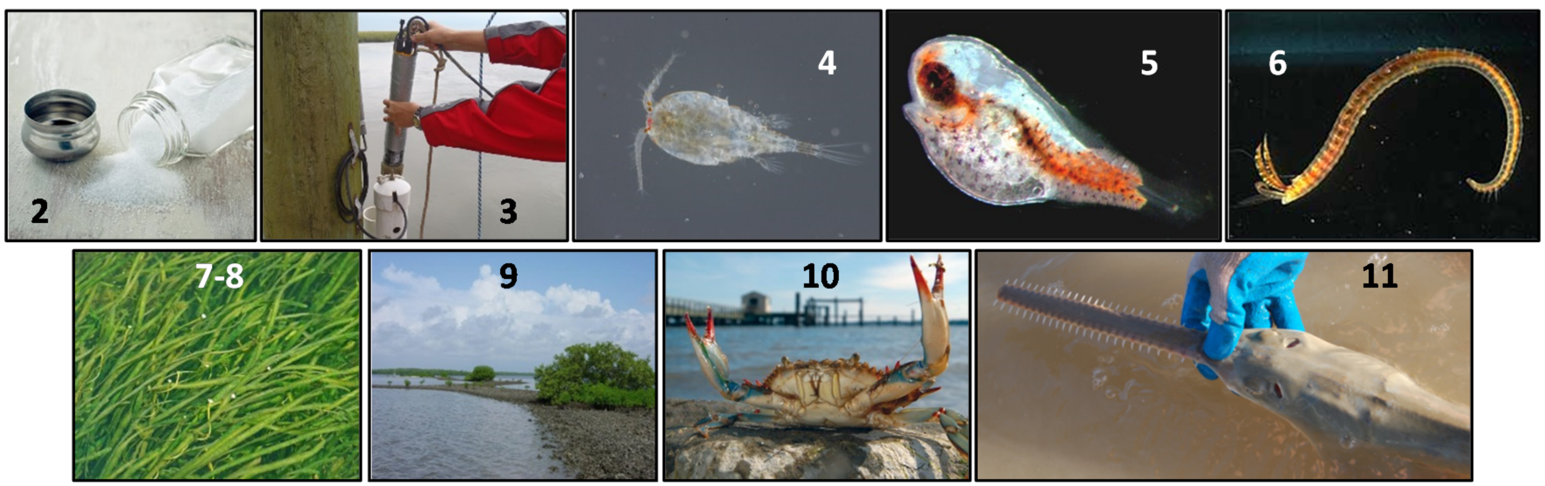


# ACKNOWLEDGMENTS

## Determining the Effects of Freshwater Inflow on Benthic Macrofauna in the Caloosahatchee Estuary, Florida

*Terence A Palmer,*† Paul A Montagna,† Robert H Chamberlain,‡§ Peter H Doering,‡ Yongshan Wan,‡ Kathleen M Haunert,‡ and Daniel J Crean‡*

*†Texas A&M University-Corpus Christi, Harte Research Institute for Gulf of Mexico Studies, Corpus Christi, TX, USA*
*‡South Florida Water Management District, West Palm Beach, FL, USA*
*§St Johns River Water Management District, Palatka, FL, USA*

TEXAS A&M UNIVERSITY CORPUS CHRISTI | HARTE RESEARCH INSTITUTE FOR GULF OF MEXICO STUDIES

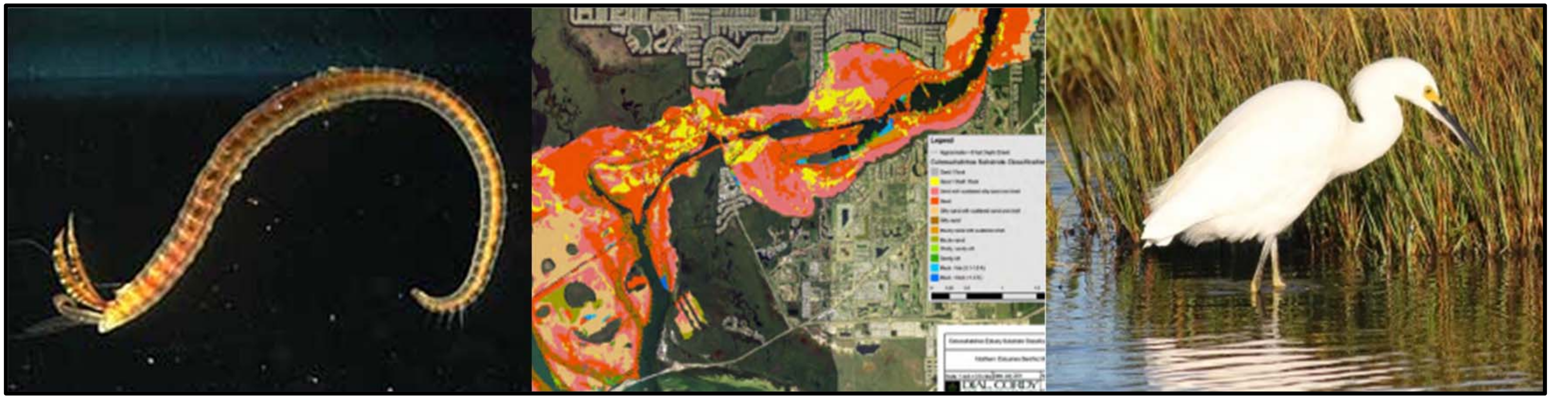
SOUTH FLORIDA WATER MANAGEMENT DISTRICT — PROTECTION OF THE EVERGLADES SINCE 1949

# WHY DO THIS STUDY?

- **Benthic organisms support aquatic food webs and important fauna across the entire salinity gradient**

- **Benthic organisms are good indicators of environmental conditions**
  - **Limited mobility**
  - **Long lifespans relative to plankton**
  - **Sensitivity to changes in water and sediment quality**

- **The composition, distribution and density of the benthic meio-, macro-, and infaunal community changes with salinity in estuaries**



# METHODS – DATA COLLECTION & ANALYSES

- **Benthic fauna vs. salinity in dry (Nov-Apr) and wet (May-Oct) seasons**

- **Benthic samples at seven stations (B1 – B7) during two periods:**
  - **February 1986 to April 1989 (Period 1; time of relatively low inflow)**
  - **October 1994 to December 1995 (Period 2; time of much higher inflow)**

- **Benthic sampling**
  - **Wildco® petite ponar grab (0.02323 $m^2$)**
  - **Five replicates within a 30-50 m area**
  - **Samples sieved through 500 µm**
  - **Preserved in formalin and stained**

- **Data Processing and Analyses**
  - **95% of organisms identified to the species level**
  - **Benthic fauna diversity indices**
  - **Salinity relationships for a variety of taxa**
  - **Fauna-based criteria used to define salinity zones in the CRE**

- **Focus on dry season patterns for this analyses**

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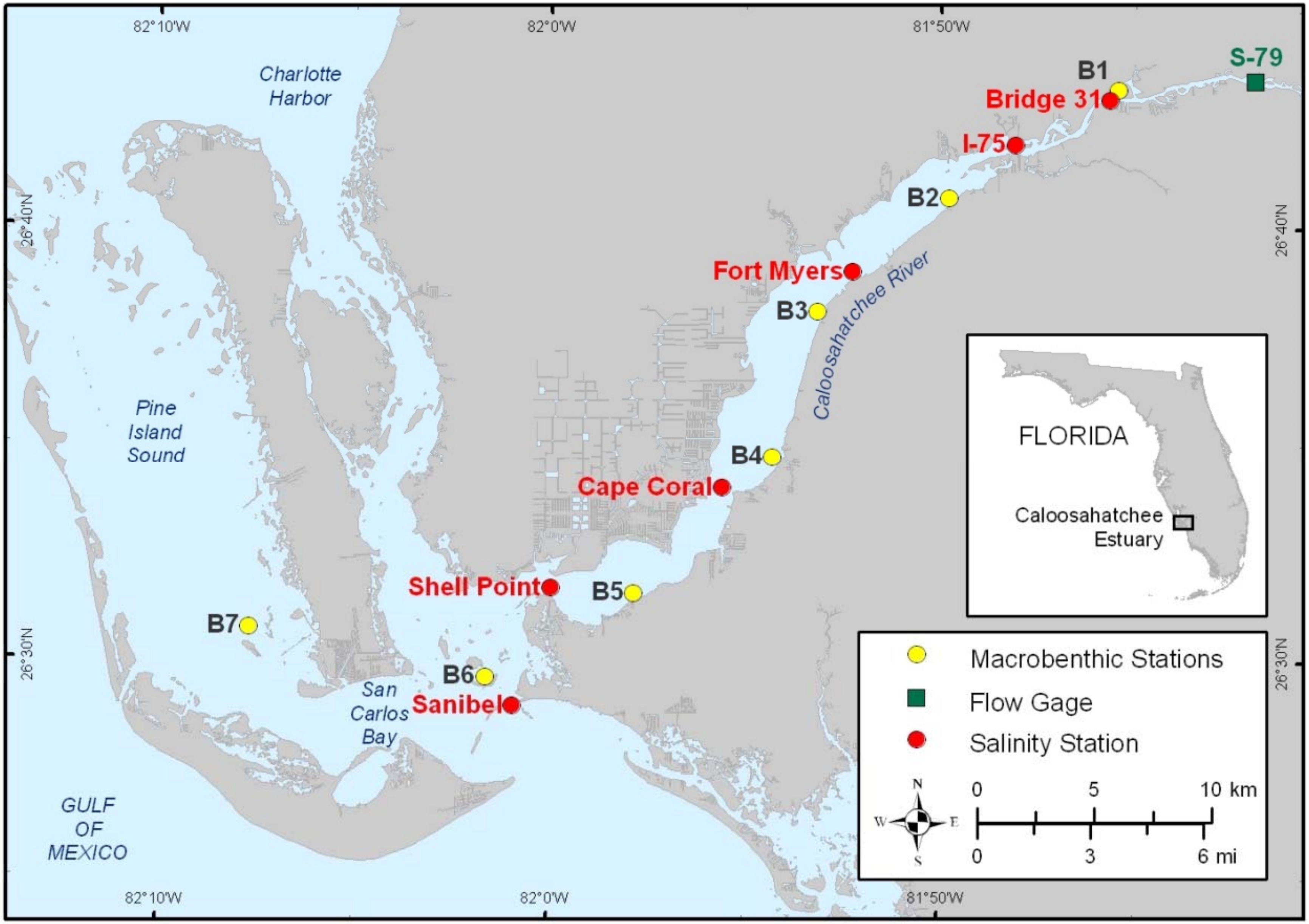
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

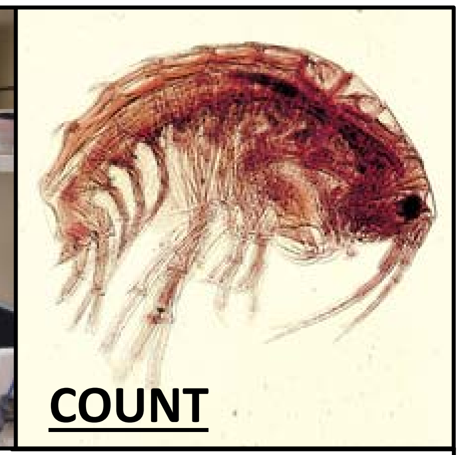
# CALOOSAHATCHEE RIVER ESTUARY



# RESEARCH COMPONENT METHODS



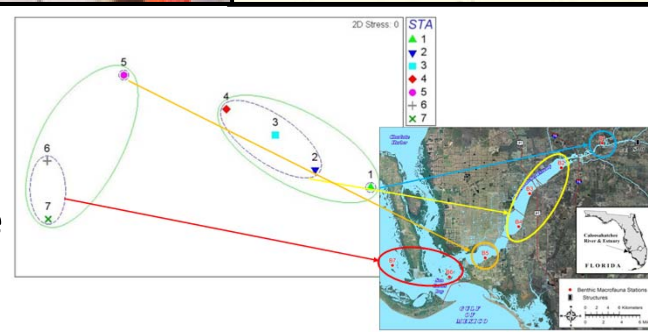





Ponar Grab

## ANALYSES

Multi-dimensional analyses of species composition to define salinity zones



# RESEARCH COMPONENT METHODS

- **Determination of community attributes over salinity gradient**
  - **Total number of individuals**
  - **Species abundance**
  - **Species diversity**

- **Non-parametric multi-dimensional scaling and cluster analysis**
  - **Separate and identify faunal communities based on individual species in association with environmental variables**
  - **Classify estuary into zones based on salinity and macrofauna community**

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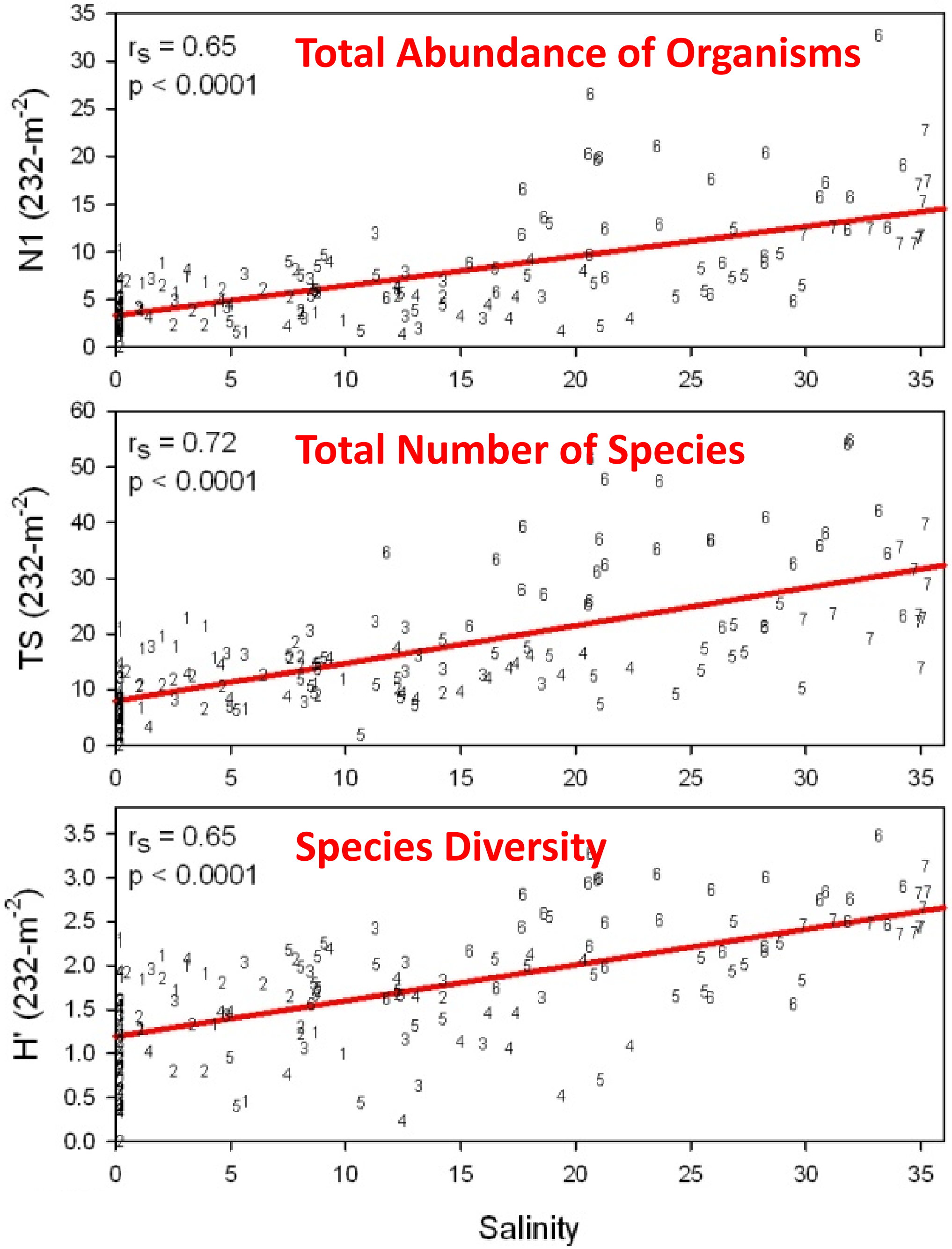
# BENTHIC COMMUNITY ATTRIBUTES

- **Abundance, Number of Species, and Species Diversity increase with salinity**
- **Typical in estuaries = more species and organisms at marine end**

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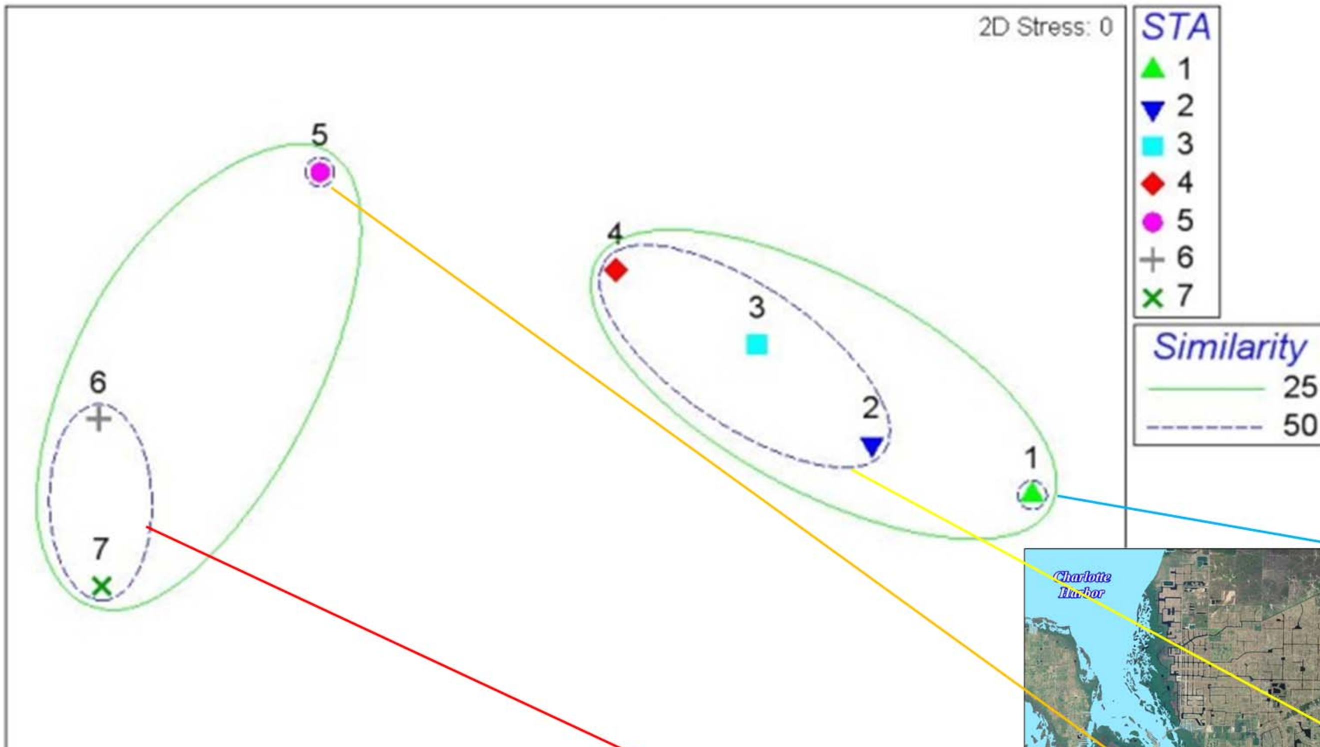
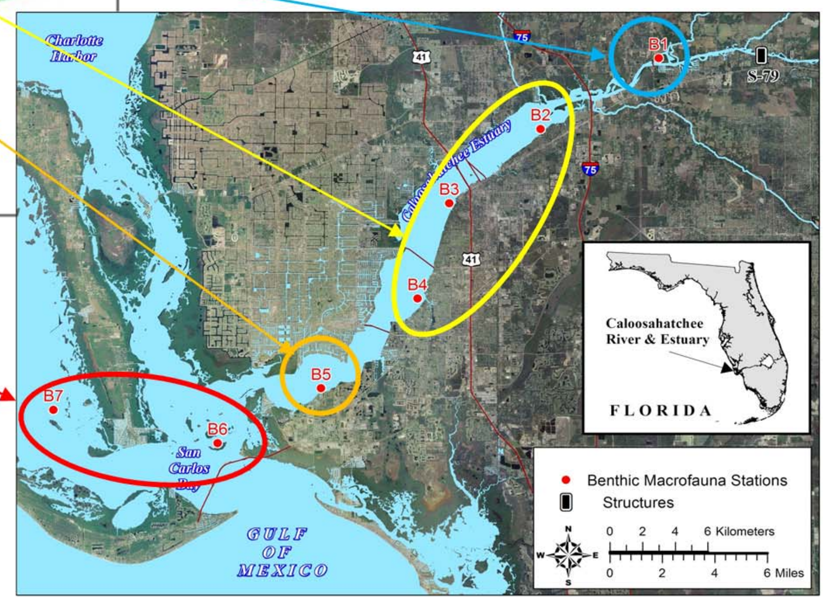
# FAUNA-BASED SALINITY ZONES




| Zone | Salinity Range |
|---|---|
| **Zone 1** | **0.2-4.2** |
| Oligohaline | 2.6-12.5 |
| Mesohaline | 15.1-24.9 |
| Polyhaline | 28.0-34.7 |

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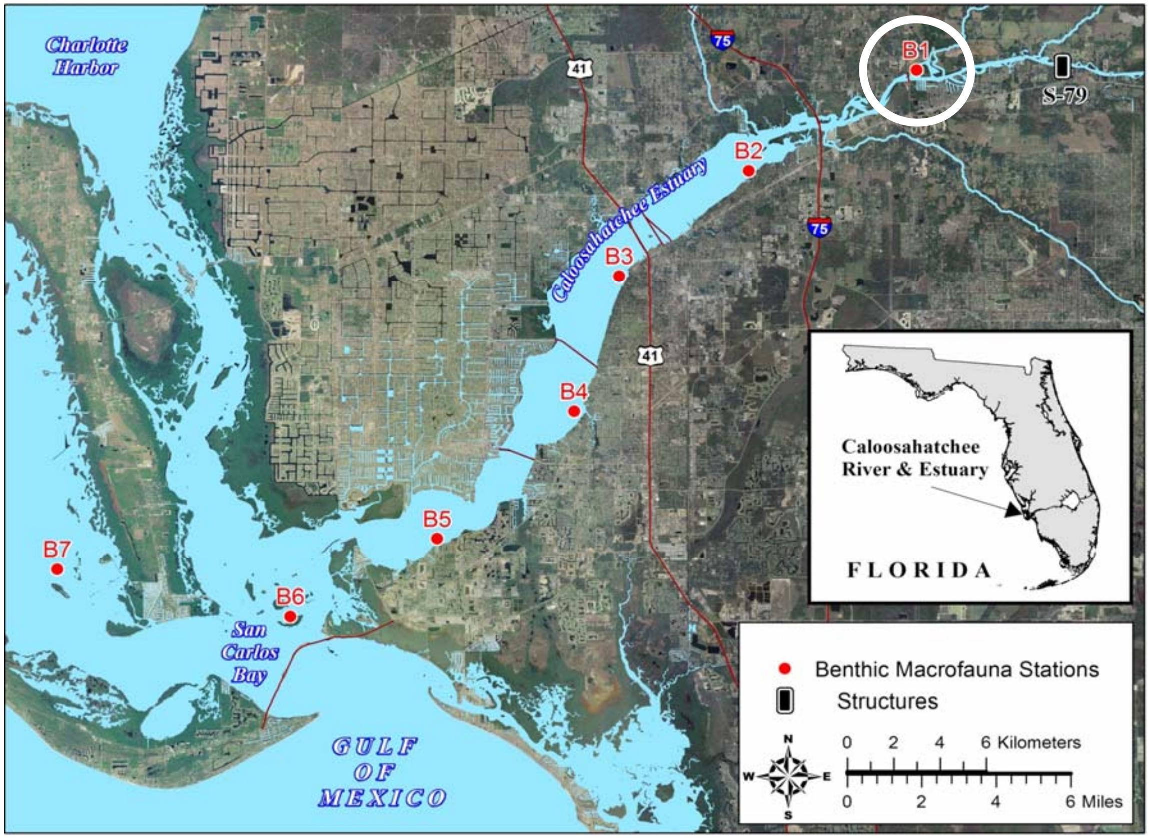
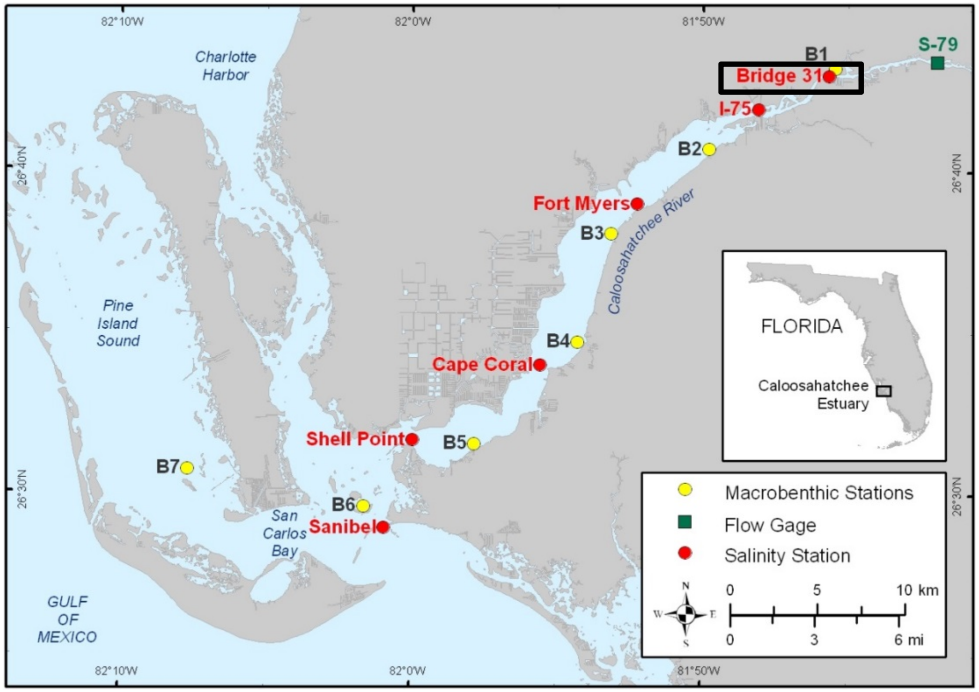
# FAUNA-BASED SALINITY ZONES

- The benthic community in the upper CRE (0-7 km from S-79)
  - Fauna in this area more sensitive to reduced freshwater inflow in dry season
  - Results from analyses by Montagna et al.
    - Zone 1 in upper CRE
    - Desirable salinity range of 0-4 for benthic communities



# APPLICATION TO CRE MFL

- **Long-term salinity data at Bridge 31 (BR31) in the upper CRE**
  - **Average daily salinity from 1/1992 to 8/2012**
  - **Merged with daily freshwater inflow at S-79 for same period of record**
  - **Categorized by water year (WY = 5/1 to 4/30) and season (dry vs. wet)**
- **Analyses**
  - **Dry season days only**
  - **Number and percentage of days in salinity classes: 0-1, 1-2, 2-3, 3-4, >4**
  - **Select inflows on the days where salinity was 3 to 4 (upper limit for zonal fauna)**
  - **Range and average and standard deviation (avg ± SD) of these inflows**



# STUDY RESULTS

**Table 1. The number (n) and percentages (%) of dry season daily salinity values at BR31 over a series of criteria (0-1, 1-2, 2-3, 3-4, >4, and all dry season days) from water year 1993-2012. Included are the range and average S-79 inflows for the selected days**

| Salinity Class | n | % | Salinity Avg±SD | Inflow S-79 (cfs) Range | Inflow S-79 (cfs) Avg±SD |
|---|---|---|---|---|---|
| 0-1 | 1388 | 38.7 | 0.3±0.2 | 0-15,700 | 3074±2777 |
| 1-2 | 208 | 5.8 | 1.5±0.3 | 0-6990 | 782±980 |
| 2-3 | 165 | 4.6 | 2.5±0.3 | 0-4260 | 596±782 |
| 3-4 | 181 | 5.0 | 3.5±0.3 | 0-3720 | 501±525 |
| >4 | 1649 | 45.9 | 9.0±3.6 | 0-4410 | 239±465 |
| All dry | 3591 | 100.0 | 4.5±4.8 | 0-15,700 | 1366±2201 |

# RESEARCH COMPONENT SUMMARY

- Zonation of benthic communities along salinity gradient in the CRE
- Species diversity increases with salinity (common in estuaries)

- 4 salinity zones were specified for the dry season in the CRE
  - Zone 1 = 0.2-4.2
  - Oligohaline Zone = 2.6-12.5
  - Mesohaline Zone = 15.1-24.9
  - Polyhaline Zone = 28.0-34.7

- Dry season salinity at BR31 (1992-2012)
  - Ranged from 0.3-11.7; Average 4.5±4.8 all dry season days (N = 3591)
  - Ranged from 0-4 on 54% of days
  - Ranged from 3-4 (upper limit for fauna-based salinity zone)
    - 5% of the days
    - S-79 inflow rate ranged from 0-3720 cfs
    - Averaged 501±525 cfs

- Low dry-season inflows can cause low-salinity benthic communities to be lost thereby affecting food webs and fauna populations

# Component Study 9:
# Assessment of dry season salinity and freshwater inflow relevant for oyster habitat in the Caloosahatchee River Estuary

**Christopher Buzzelli, Cassondra Thomas, Peter Doering**

**Coastal Ecosystems Section**

**South Florida Water Management District**

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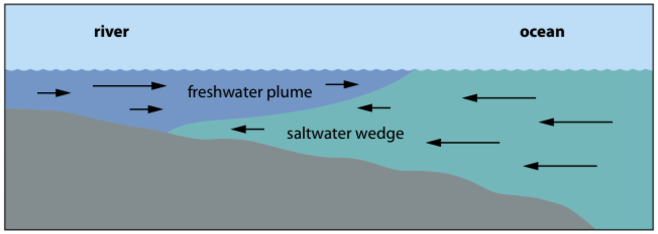


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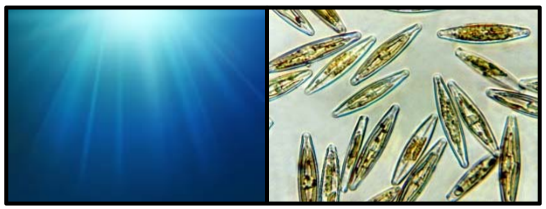

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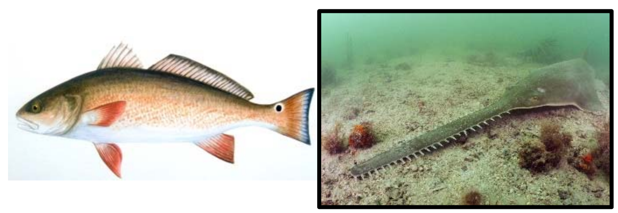

**Affect coastal fish populations dependent upon estuaries as nurseries**

**Negatively impact harvests of important fisheries**

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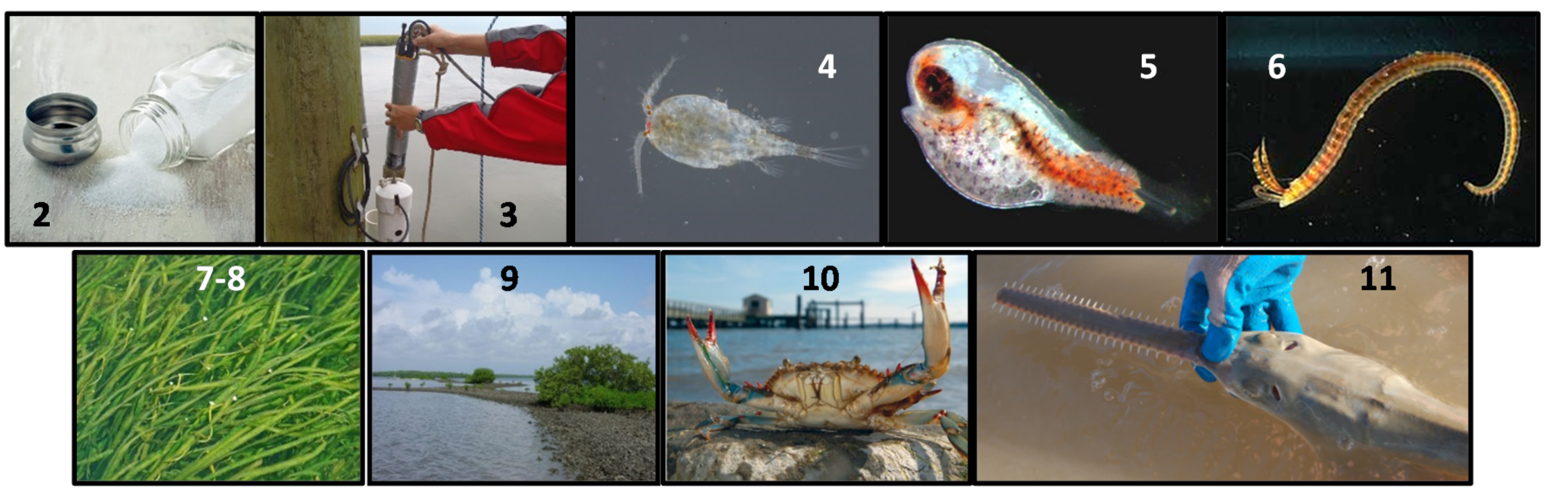
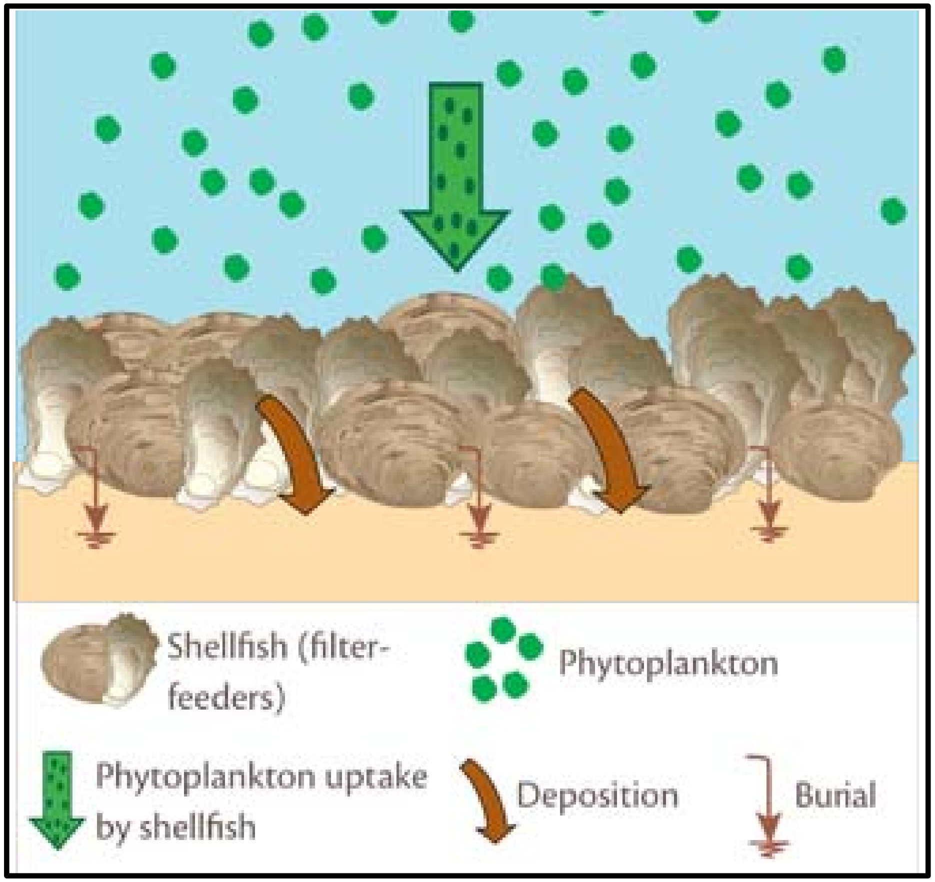
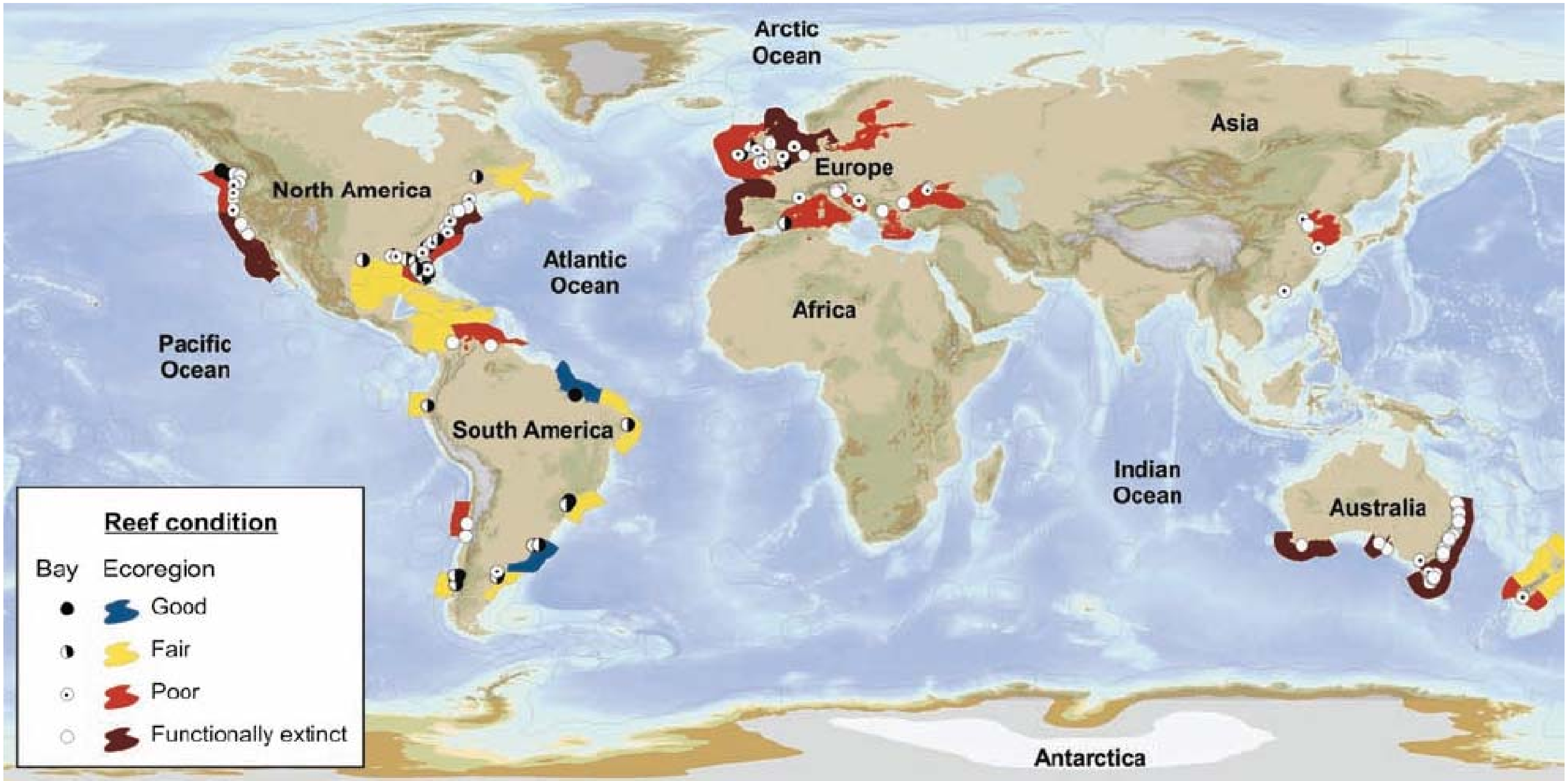


# WHY OYSTERS?

- Valuable ecosystem goods & services (~$17,000/hectare/year)
- Provide & stabilize essential habitat for estuarine fauna
- Improve water clarity * sequester nutrients
  - 5 L $oyster^{-1}$ $h^{-1}$ (~22 gallons/day)
  - Filter phytoplankton and particulate matter
- High rates of bio-deposition (6000 g C $m^{-2}$ $y^{-1}$)



# STUDY RATIONALE




**Oyster Reefs at Risk and Recommendations for Conservation, Restoration, and Management**

MICHAEL W. BECK, ROBERT D. BRUMBAUGH, LAURA AIROLDI, ALVAR CARRANZA, LOREN D. COEN, CHRISTINE CRAWFORD, OMAR DEFEO, GRAHAM J. EDGAR, BOZE HANCOCK, MATTHEW C. KAY, HUNTER S. LENIHAN, MARK W. LUCKENBACH, CAITLYN L. TOROPOVA, GUOFAN ZHANG, AND XIMING GUO

*February 2011 / Vol. 61 No. 2* • BioScience 107

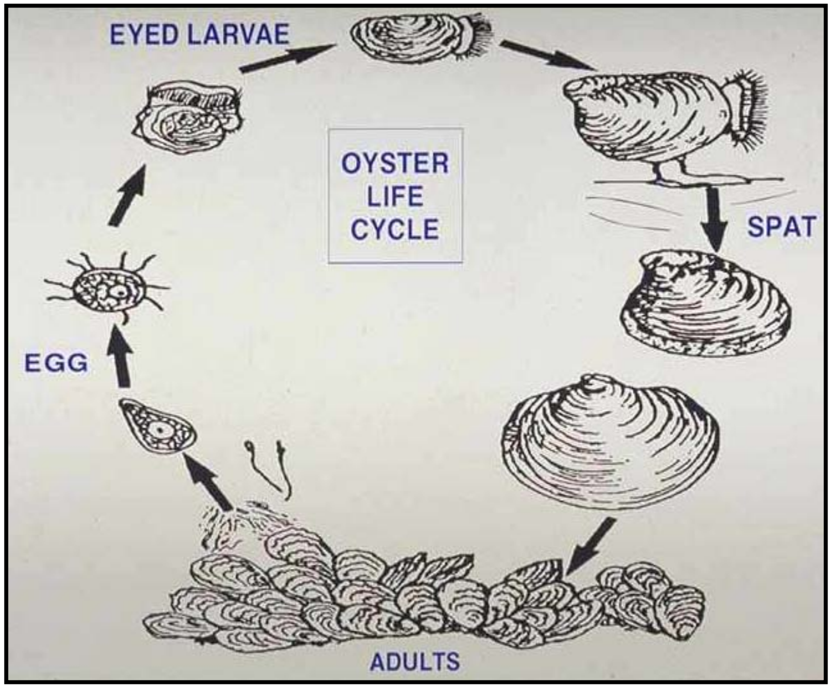
## OYSTER LOSS FACTORS

- Overfishing
- Disease
- Coastal salinity changes

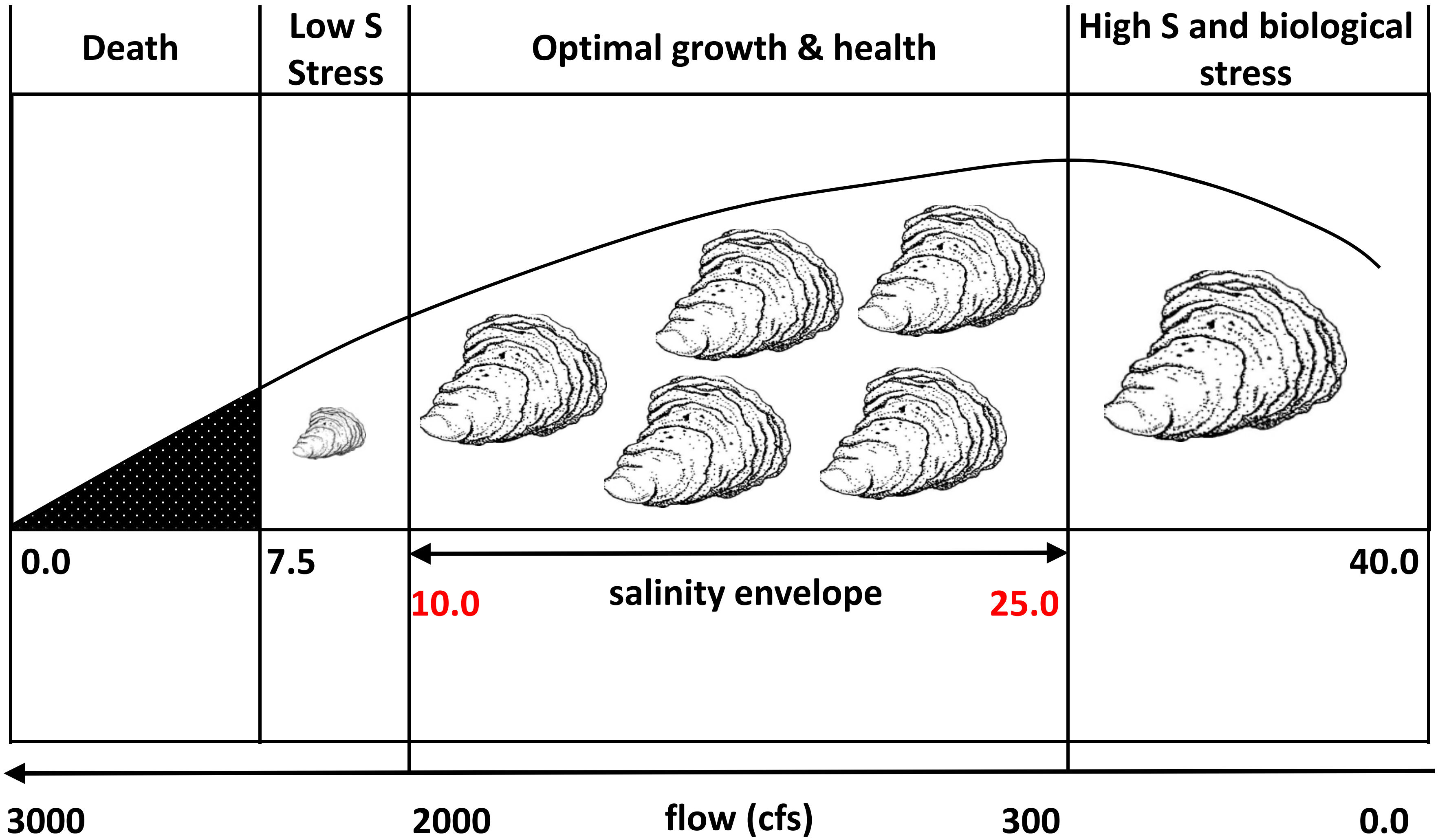
# STUDY RATIONALE

- **Salinity (S)**
  - **Main factor for oysters in Gulf of Mexico (GOM) estuaries (S = 10 to 25)**
  - **Each component of the oyster community has particular salinity tolerances**
    - **Larvae, juvenile, and adult oysters (oyster life cycle)**
    - **Protistan parasites (e.g. *Perkinsus marinus* or Dermo)**
    - **Epibiotic community; resident and transient consumers**

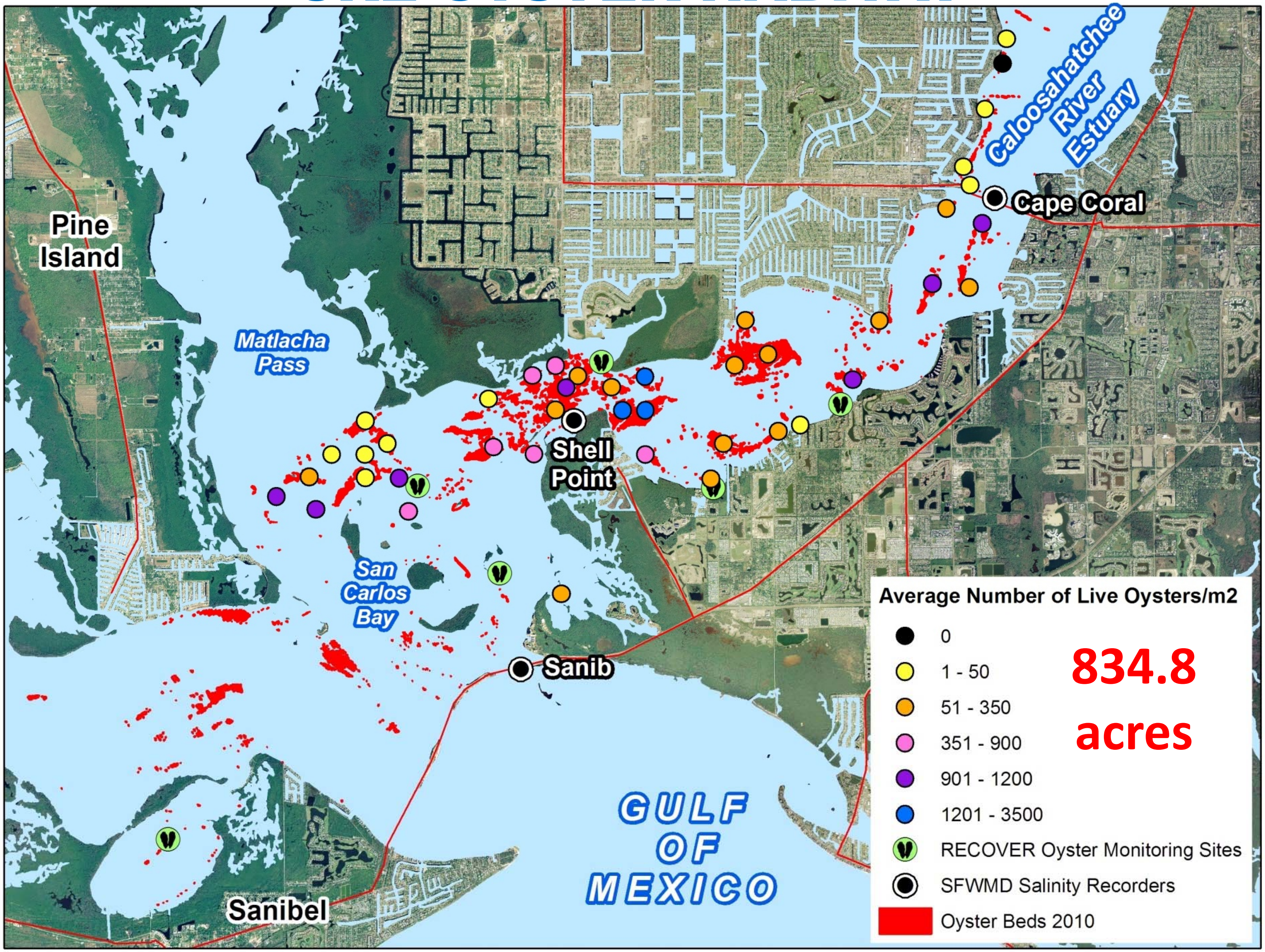
- **What are effects of reduced inflow on oyster habitat in the CRE?**
  - **Increased salinity = Increase in marine parasites and predators?**
  - **Episodic inflows = Suppress marine organisms; suppress oyster filtration**



# OYSTER SALINITY RELATIONSHIP



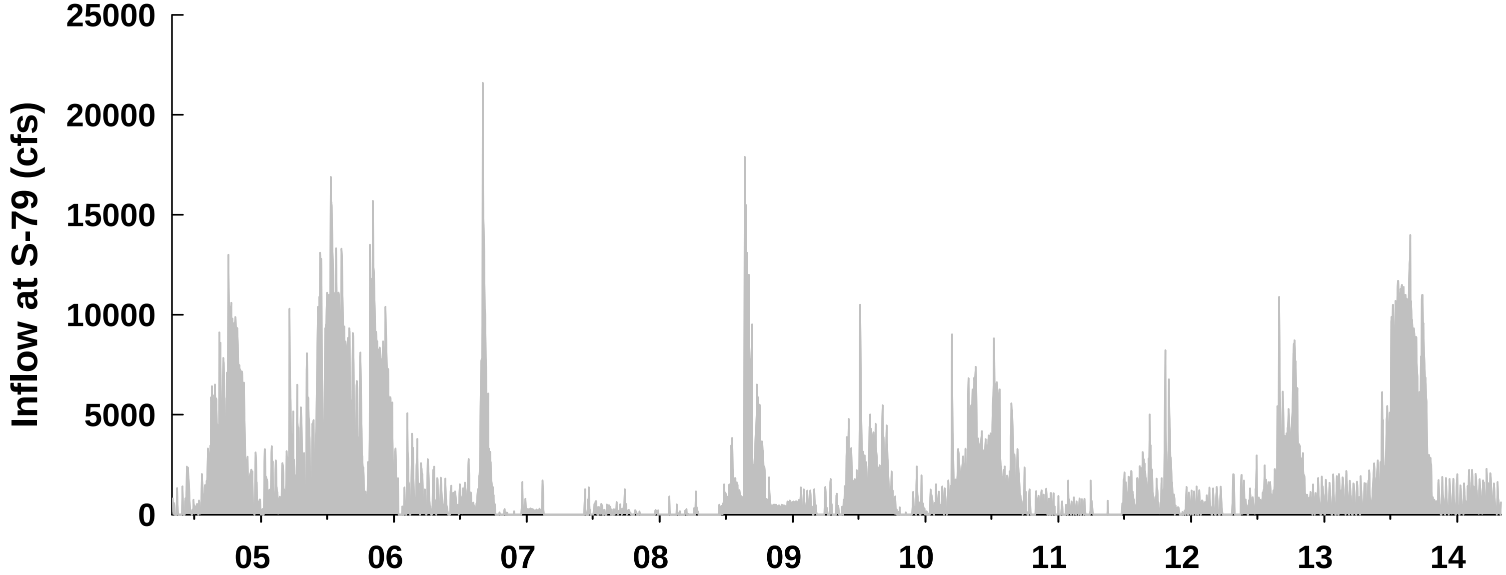
# CRE OYSTER HABITAT

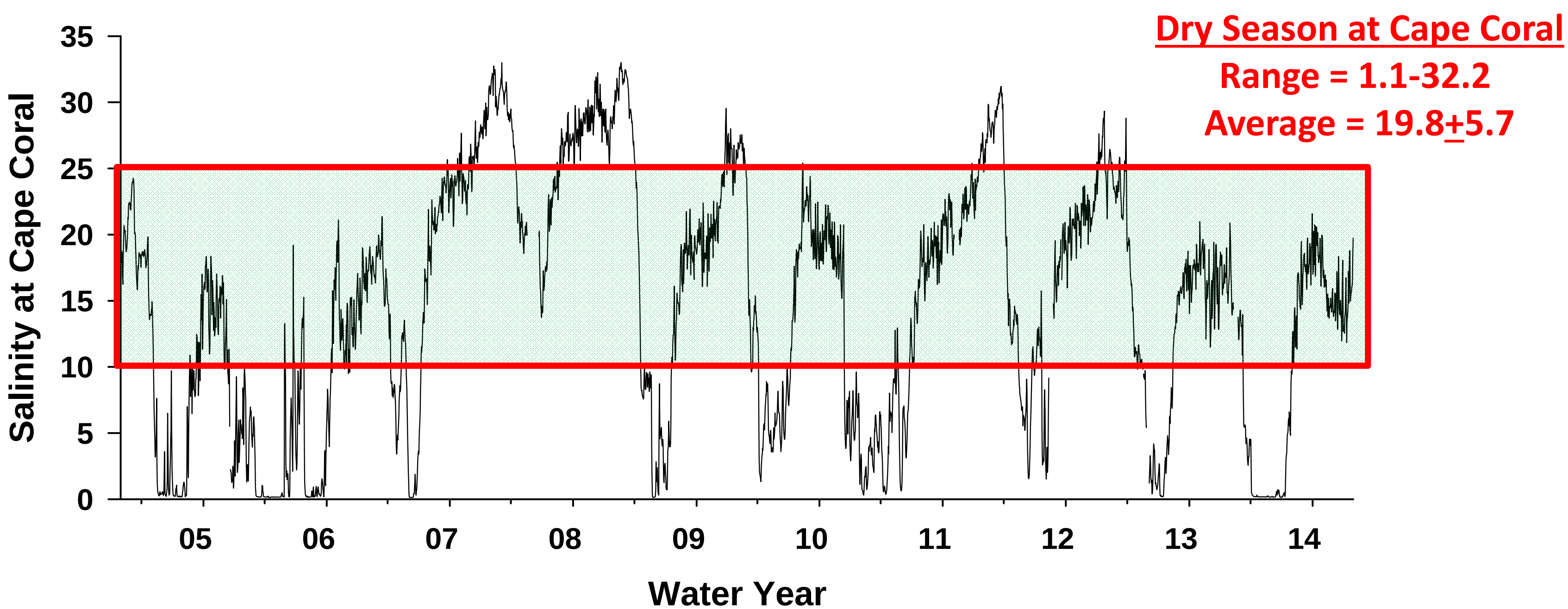


# STUDY METHODS

- Cape Coral assumed to be upper limit for oyster habitat in the CRE
- Evaluate salinity at Cape Coral in the dry season
- Salinity from WY2006-2014 dry seasons related to freshwater inflow at S-79
- Optimal oyster salinity range is 10-25
- Analyses
  - Salinity data split into five categories; <10; 10-15; 15-20; 20-25; >25
  - Number and percentage of dry season days for each category
  - Averages and standard deviations for inflow each salinity classes
  - Emphasize inflows associated with dry season salinity values of 20-25

# S79 INFLOW & SALINITY AT CAPE CORAL



# STUDY RESULTS

**Table Y. The number (n) and percentages (%) of dry season daily salinity values at Cape Coral over a series of criteria (<10,10-15, 15-20, 20-25, >25, and all dry season days) from WY2006-2014. Included are the range and average S-79 inflows for the selected days**

| | | Salinity | | S-79 (cfs) | |
|---|---|---|---|---|---|
| Salinity Class | n | Range | Avg±SD | Range | Avg±SD |
| <10 | 234 (13.1%) | 0.15-10.0 | 4.5±3.3 | 0-15,700 | 4002±2984 |
| 10-15 | 221 (12.4%) | 10.1-15.0 | 13.2±1.4 | 0-9030 | 1068±981 |
| 15-20 | 606 (34.0%) | 15.0-20.0 | 17.6±1.4 | 0-6990 | 670±693 |
| 20-25 | 422 (23.7%) | 20.0-25.0 | 22.3±1.4 | 0-2000 | 296±410 |
| >25 | 299 (16.8%) | 25.0-32.2 | 27.7±1.6 | 0-2030 | 90±273 |
| Total | 1782 | 0.15-32.2 | 18.1±7.1 | 0-15,700 | 967±1721 |

*Shell Point dry season S > 25 on 83.3% of days

# RESEARCH COMPONENT SUMMARY

- **Salinity patterns were favorable for oysters at the upstream limit (Cape Coral)**
  - **Dry season salinity averaged 19.8±5.7**
  - **Within the 10-25 range ~70% of days**

- **Oyster habitat more widespread with greater densities below Cape Coral**
  - **~1000 oysters $m^{-2}$ in the lower CRE around Shell Point**
  - **S > 25 at Shell Point for >80% of days**

- **Using oyster habitat as indicators of low freshwater inflow is difficult**
  - **Influence of inflow on salinity reduced in lower CRE**
    - **Effects of tidal exchange and wind on circulation**
    - **Most of the oyster habitat located ~40 km downstream from S-79**

  - **Effects of the marine parasite Dermo on oyster populations muted**
    - **High salinity & low temperature (dry season)**
    - **Low salinity & high temperature (wet season)**

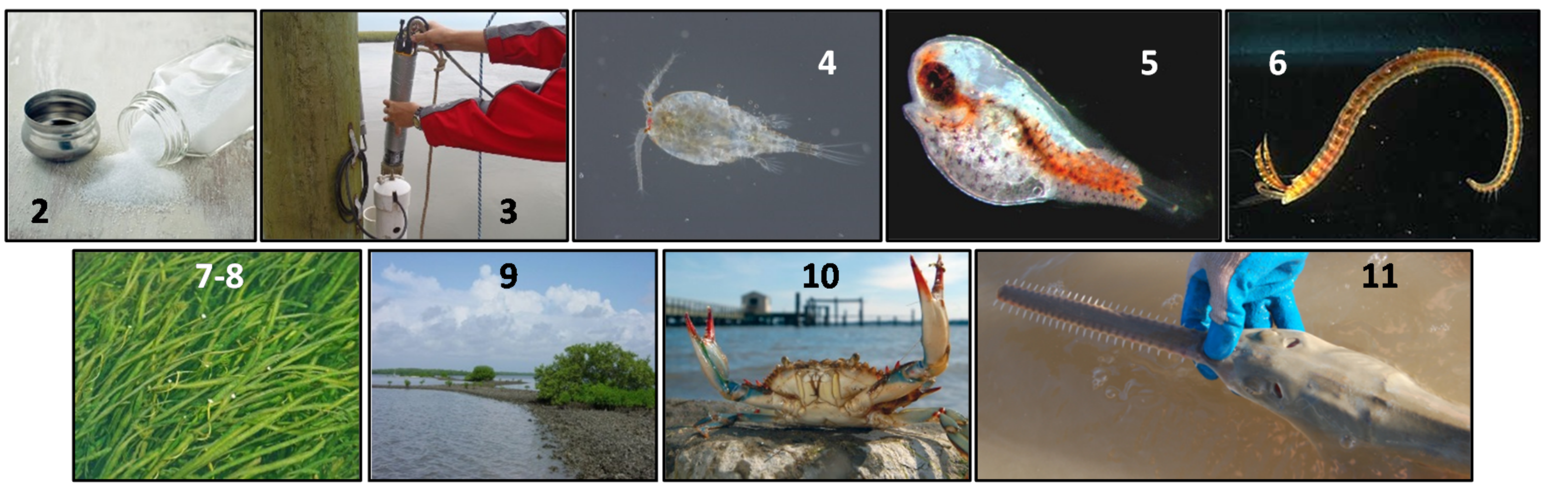
  - **Few data on the effects of marine predators with increased salinity in the CRE**

# Component Study 11:
# Relationships between freshwater inflow, salinity, and potential habitat for sawfish (*Pristis pectinata*) in the Caloosahatchee River Estuary

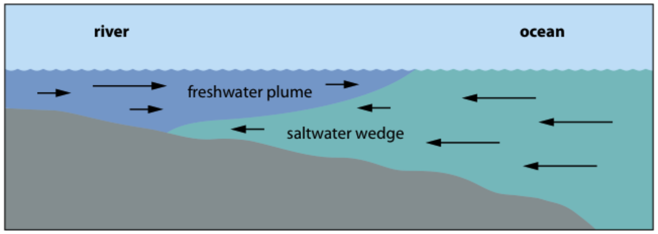
**Detong Sun and Christopher Buzzelli**
Coastal Ecosystems Section
South Florida Water Management District

# SCIENCE COMPONENTS / STUDIES

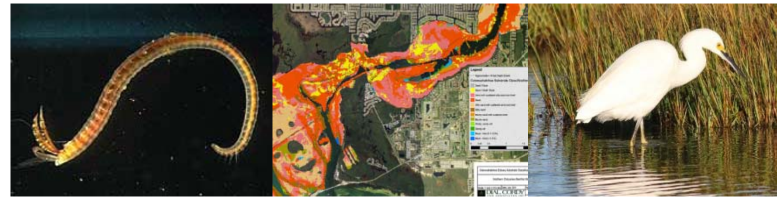
| | Component | Method |
|---|---|---|
| 1 | Hydrodynamics | Influence of alterations on hydrodynamics |
| 2 | Inflow vs. Salinity | Monthly freshwater-salinity relationships |
| 3 | Water Quality | Relationships between inflow, salinity, and water quality |
| 4 | Zooplankton | Inflow, zooplankton and habitat compression |
| 5 | Ichthyoplankton | Relationships between ichthyoplankton and inflow |
| 6 | Benthic Fauna | Macrofauna-salinity patterns relative to inflow |
| 7 | *Vallisneria* data | Empirical relationships between tape grass, S, and inflow |
| 8 | *Vallisneria* model | Model exploration of tape grass, S, light, and inflow |
| 9 | Oyster Habitat | Salinity patterns for oyster habitat in lower CRE |
| 10 | Blue Crabs | Relationships between blue crab landings, rainfall, and inflow |
| 11 | Sawfish | Dry season inflow, hydrodynamics, and habitat extent |



# INDICATORS OF ESTUARINE RESPONSE TO LOW INFLOW

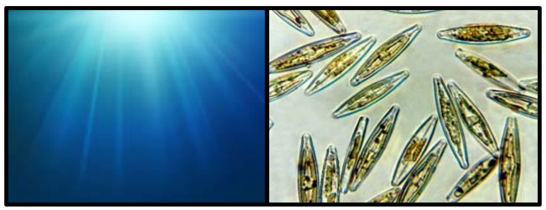



Changes in isohaline position with upstream encroachment of saltier water



Alter benthic community upon which many estuarine fauna are dependent

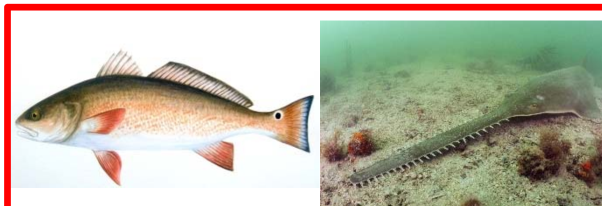
Damaging to the freshwater *Vallisneria americana* (tape grass)



Reduced flushing and enhanced light can stimulate phytoplankton in upper estuary

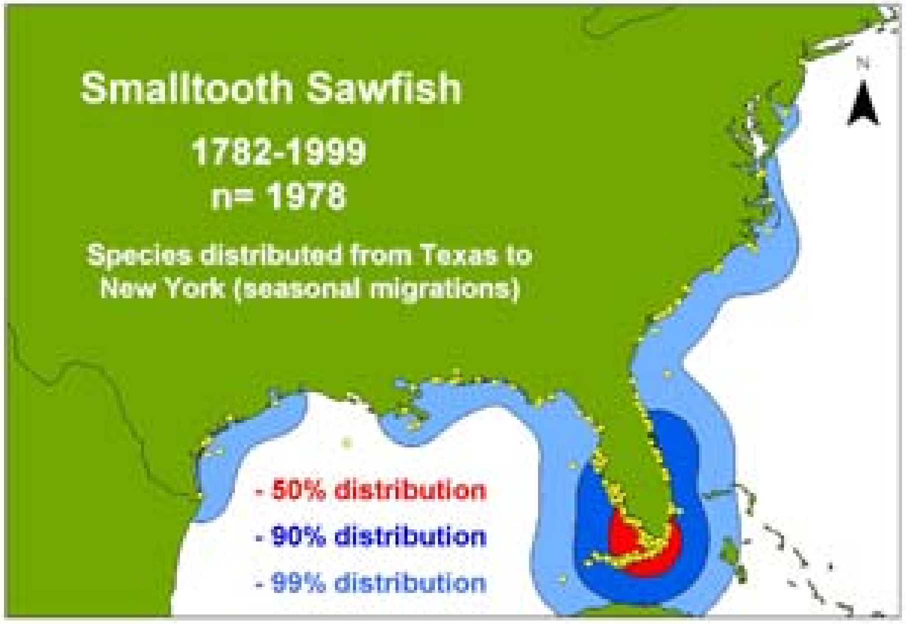
Impact physiology and habitat attributes of eastern oyster

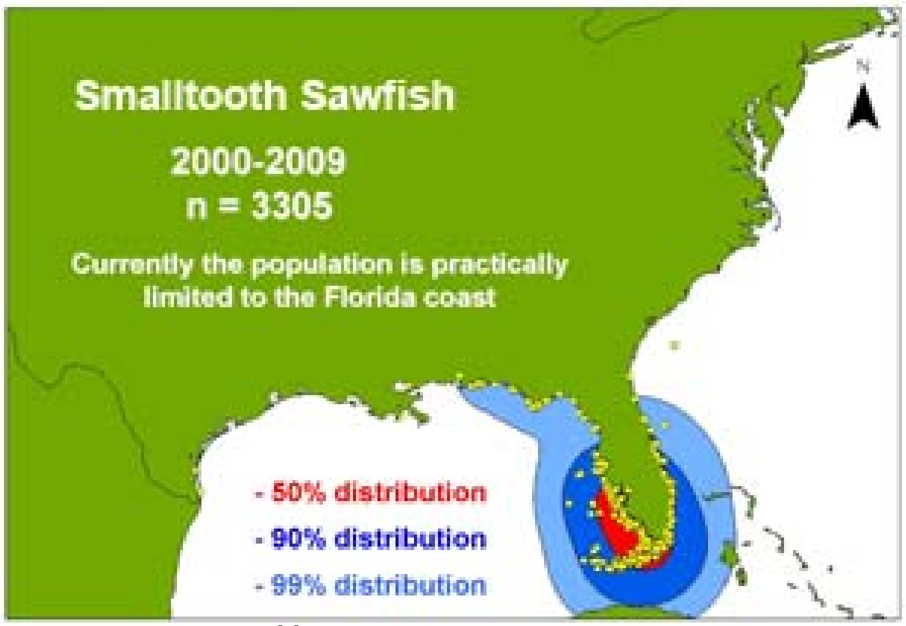
Zooplankton and ichthyoplankton assemblages move upstream but can be impinged by structure



Affect coastal fish populations dependent upon estuaries as nurseries

Negatively impact harvests of important fisheries




http://www.flmnh.ufl.edu

# SMALLTOOTH SAWFISH (*Pristis pectinata*)

- First marine fish species to receive protection under the Endangered Species Act
- World Conservation Union (IUCN) Red List as "Critically Endangered“
- Historically ranged from NY to TX
- Distribution and abundance declined due to over-fishing & habitat loss
- ~95% of the historical population
- Presently only SW Florida from Charlotte Harbor to the Dry Tortugas

# ACKNOWLEDGMENTS

**Recent studies (Poulakis, Simpfendorfer, Heupel, Colllins, Ortega et al)**

- **Little known prior to 2003**
- **CRE recognized as an essential nursery habitat for neonates and juveniles**
- **Salinity is a key driver for these fish populations**
- **Migration influenced by combination of osmotic regulation and prey resources**
- **Suite of studies to examine the distribution, location, and activity of juveniles**

CSIRO PUBLISHING
www.publish.csiro.au/journals/mfr
Marine and Freshwater Research, 2010, 61, 1–10

**Long-term presence and movement patterns of juvenile bull sharks, *Carcharhinus leucas*, in an estuarine river system**

*Michelle R. Heupel[A,D,F], Beau G. Yeiser[A], Angela B. Collins[B], Lori Ortega[C] and Colin A. Simpfendorfer[A,E]*

OPEN ACCESS Freely available online
PLoS one

**Environmental Influences on the Spatial Ecology of Juvenile Smalltooth Sawfish (*Pristis pectinata*): Results from Acoustic Monitoring**

Colin A. Simpfendorfer[1,*,¤a], Beau G. Yeiser[1¤b], Tonya R. Wiley[1¤c], Gregg R. Poulakis[2], Philip W. Stevens[2], Michelle R. Heupel[1¤d]
1 Center for Shark Research, Mote Marine Laboratory, Sarasota, Florida, United States of America, 2 Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Charlotte Harbor Field Laboratory, Port Charlotte, Florida, United States of America

Environ Biol Fish (2013) 96:763–778
DOI 10.1007/s10641-012-0070-x

**Movements of juvenile endangered smalltooth sawfish, *Pristis pectinata*, in an estuarine river system: use of non-main-stem river habitats and lagged responses to freshwater inflow-related changes**

Gregg R. Poulakis · Philip W. Stevens · Amy A. Timmers · Christopher J. Stafford · Colin A. Simpfendorfer

Environ Biol Fish (2009) 84:361–373
DOI 10.1007/s10641-009-9442-2

**Movement patterns and water quality preferences of juvenile bull sharks (*Carcharhinus leucas*) in a Florida estuary**

Lori A. Ortega · Michelle R. Heupel · Philip Van Beynen · Philip J. Motta

Estuaries and Coasts (2008) 31:1174–1183
DOI 10.1007/s12237-008-9100-5

**Spatial Distribution and Long-term Movement Patterns of Cownose Rays *Rhinoptera bonasus* Within an Estuarine River**

Angela B. Collins · Michelle R. Heupel · Colin A. Simpfendorfer

CSIRO PUBLISHING
Marine and Freshwater Research, 2011, 62, 1165–1177
www.p

**Abiotic affinities and spatiotemporal distribution of the endangered smalltooth sawfish, *Pristis pectinata*, in a south-western Florida nursery**

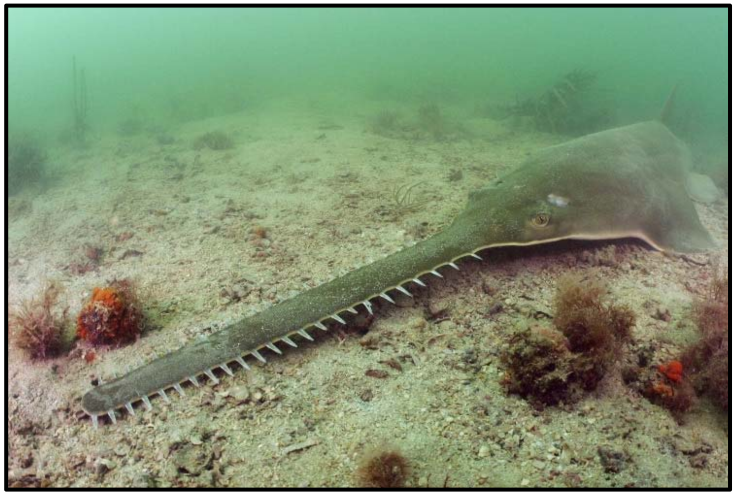
*Gregg R. Poulakis[A,B,E], Philip W. Stevens[A], Amy A. Timmers[A], Tonya R. Wiley[C] and Colin A. Simpfendorfer[D]*

# STUDY RATIONALE

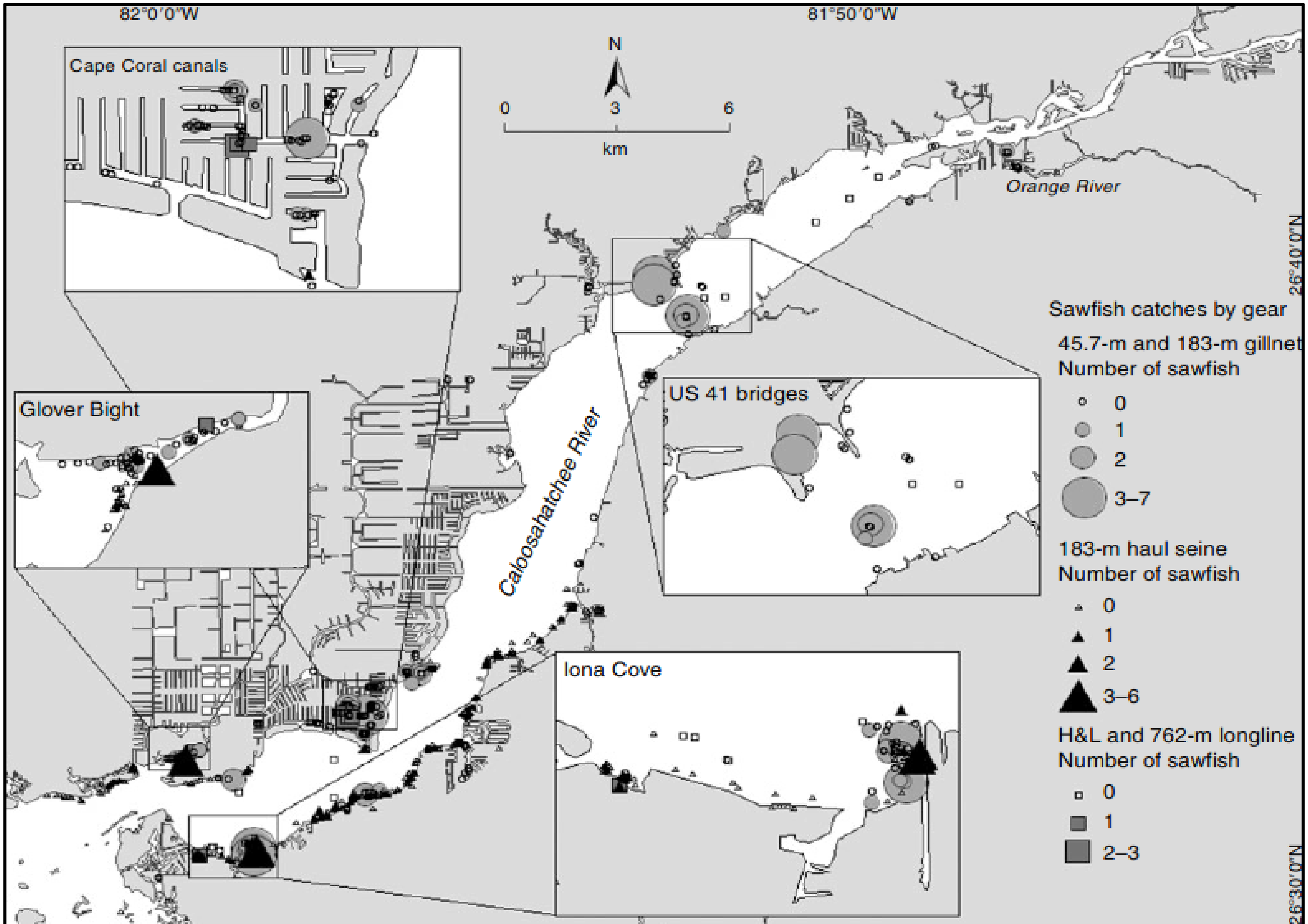
- **There are hot spots for juvenile sawfish in the CRE**
  - **Prefer salinity range of 12-27 ($S_{12\text{-}27}$) and depth $\leq$ 1.0 m; Mangrove habitat**
  - **Iona Cove and Glover Bight; Cape Coral Causeway; US 41 Bridges near Ft. Myers**

- **Increased salinity promotes upstream migration away from hot spots**
  - **Upper CRE deeper; narrower; much reduced area $\leq$ 1 m; less mangrove**
  - **Upstream migration could lead to habitat compression by S-79**
  - **Potential exposure to larger predators (bull shark salinity range 7-20)**

- **Many environmental factors that influence the distribution of juvenile sawfish**
  - **Salinity; depth and shoreline attributes; temperature; dissolved oxygen**
  - **Food availability = Not much known about diet = endangered species**



SOUTH FLORIDA WATER MANAGEMENT DISTRICT





CSIRO PUBLISHING

*Marine and Freshwater Research*, 2011, **62**, 1165–1177


**Abiotic affinities and spatiotemporal distribution of the endangered smalltooth sawfish, *Pristis pectinata*, in a south-western Florida nursery**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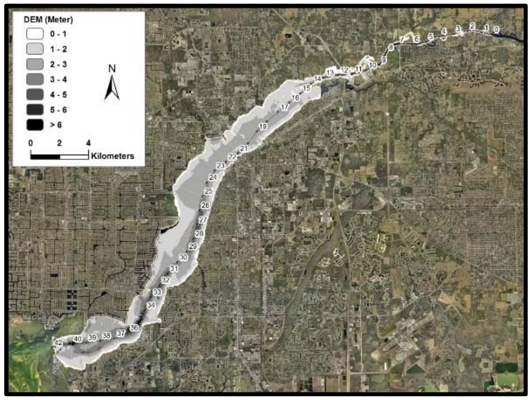
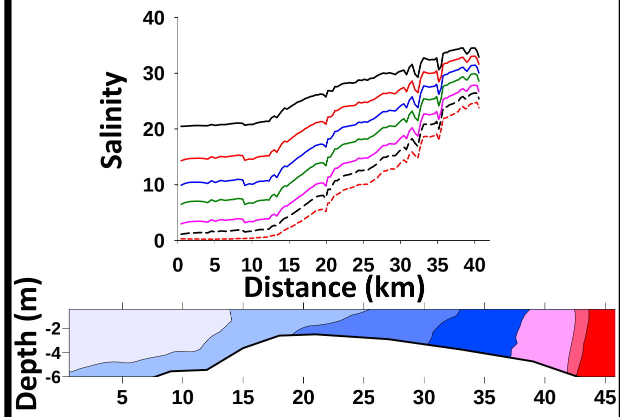
# STUDY APPROACH

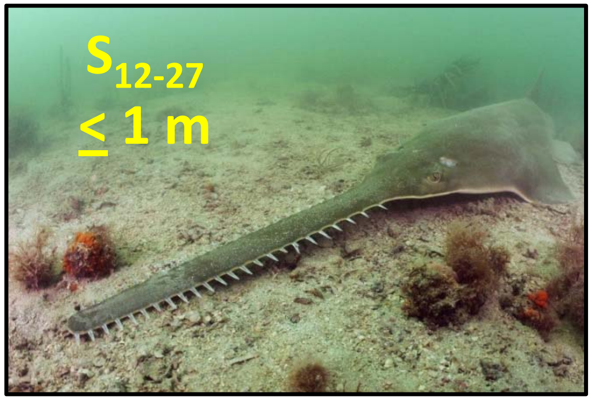
**CRE Morphology**



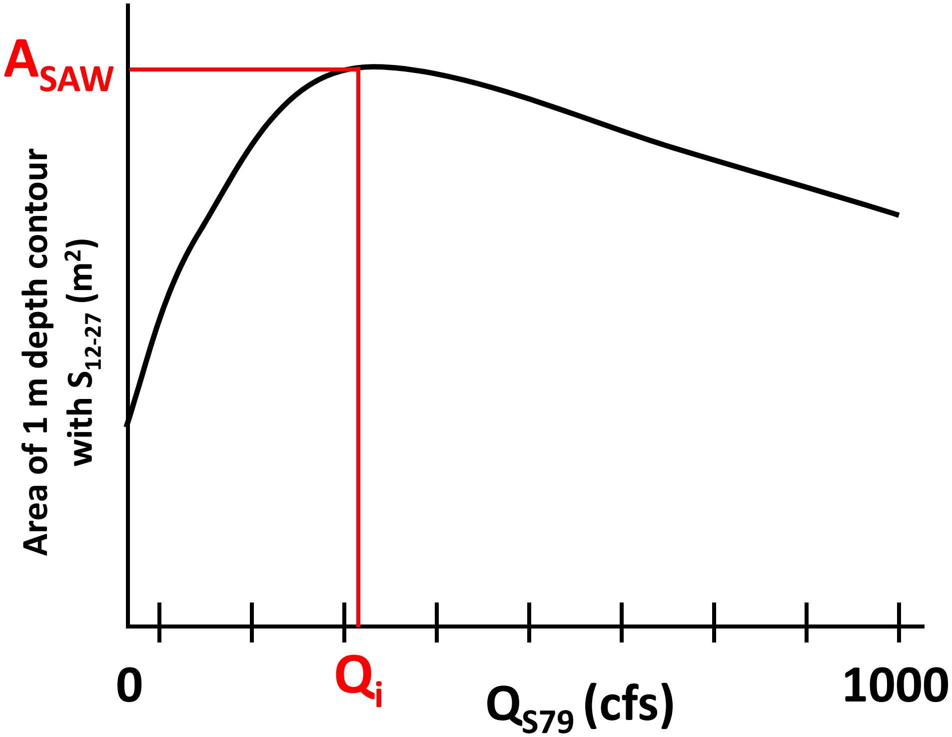

**Inflow & Salinity**




**Sawfish Habitat**

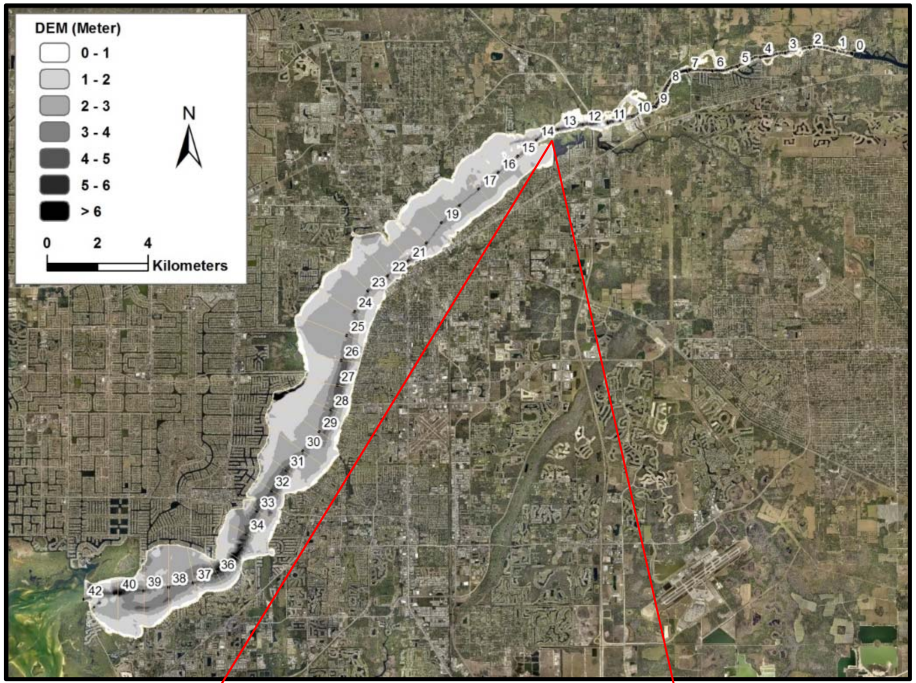



What S-79 inflow ($Q_i$) would maximize dry season sawfish habitat area ($A_{saw}$)?

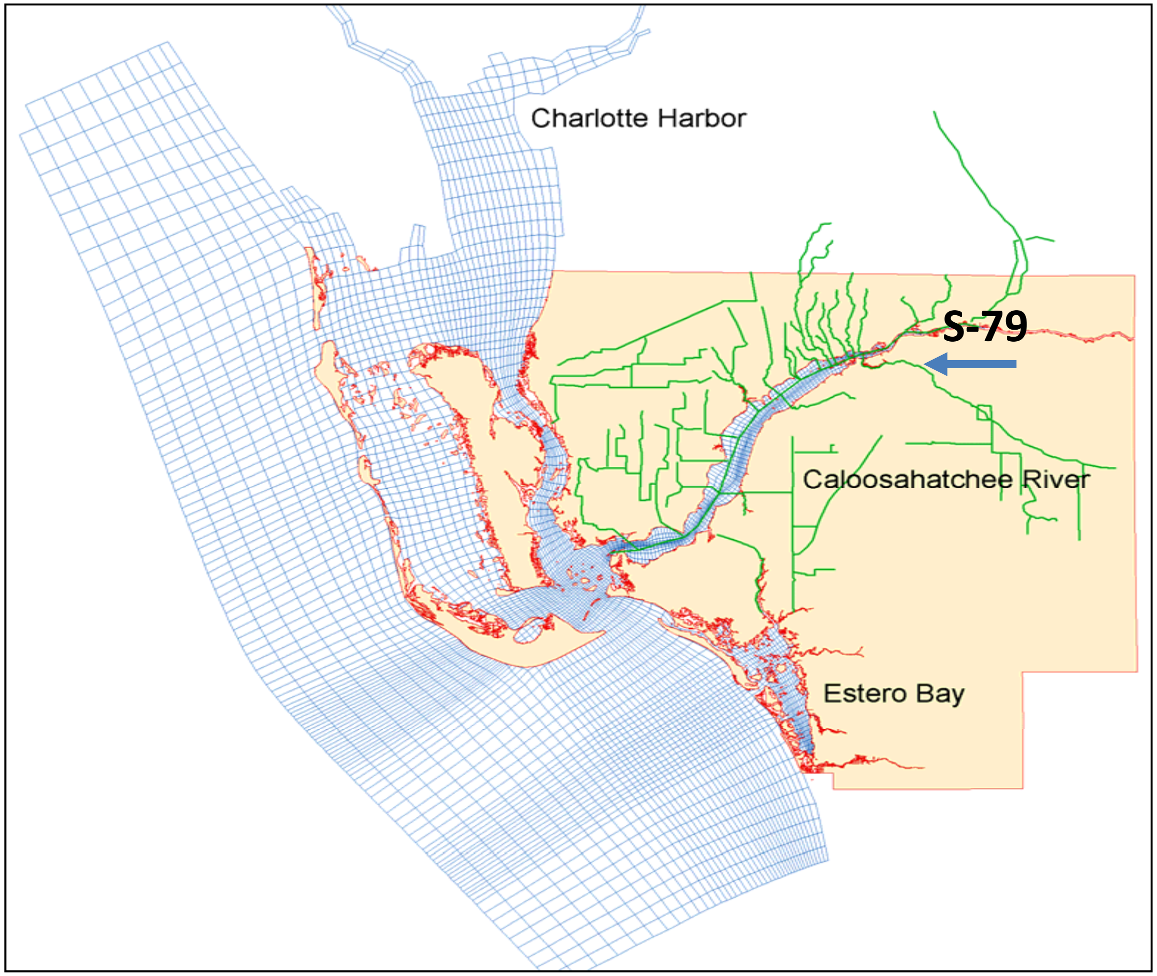


# STUDY METHODS

- **Bathymetric Analyses**
  - **Three bathymetric data sets merged to create a seamless digital elevation model (DEM)**
  - **Shoreline boundary digitized from aerial photography (S-79 to SP = 42 km)**
  - **Area (km$^2$) of the 0-1 m depth contour for each of the 42 segments**




# CURVILINEAR HYDRODYNAMIC 3D MODEL (CH3D)

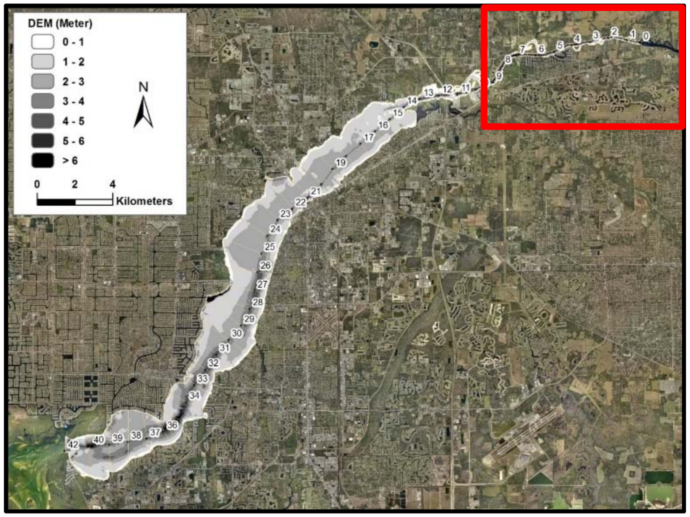


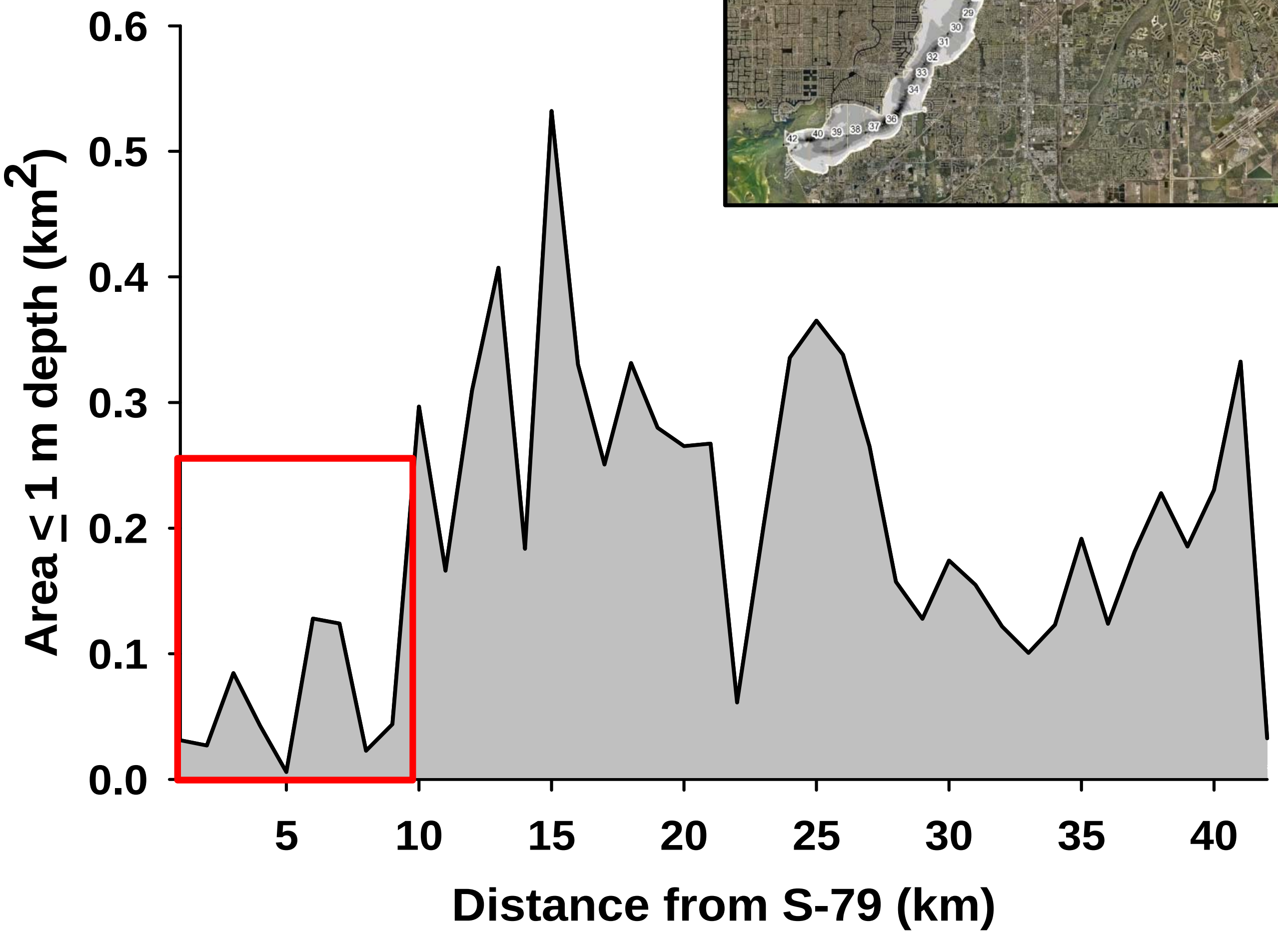

- 5300 horizontal cells
- 5 vertical layers
- Validated with > 10 years of tide, salinity data and 3 years of tidal discharge data

- WY2007 (driest year) with simulations from 1/1/2007 to 5/31/2007
- Used observed S-79 inflows from 1/1 to 2/28 as model start-up
- Introduced constant inflow rates from 3/1 to 5/31: 0, 150, 300, 450, 650, 800, 1000 cfs

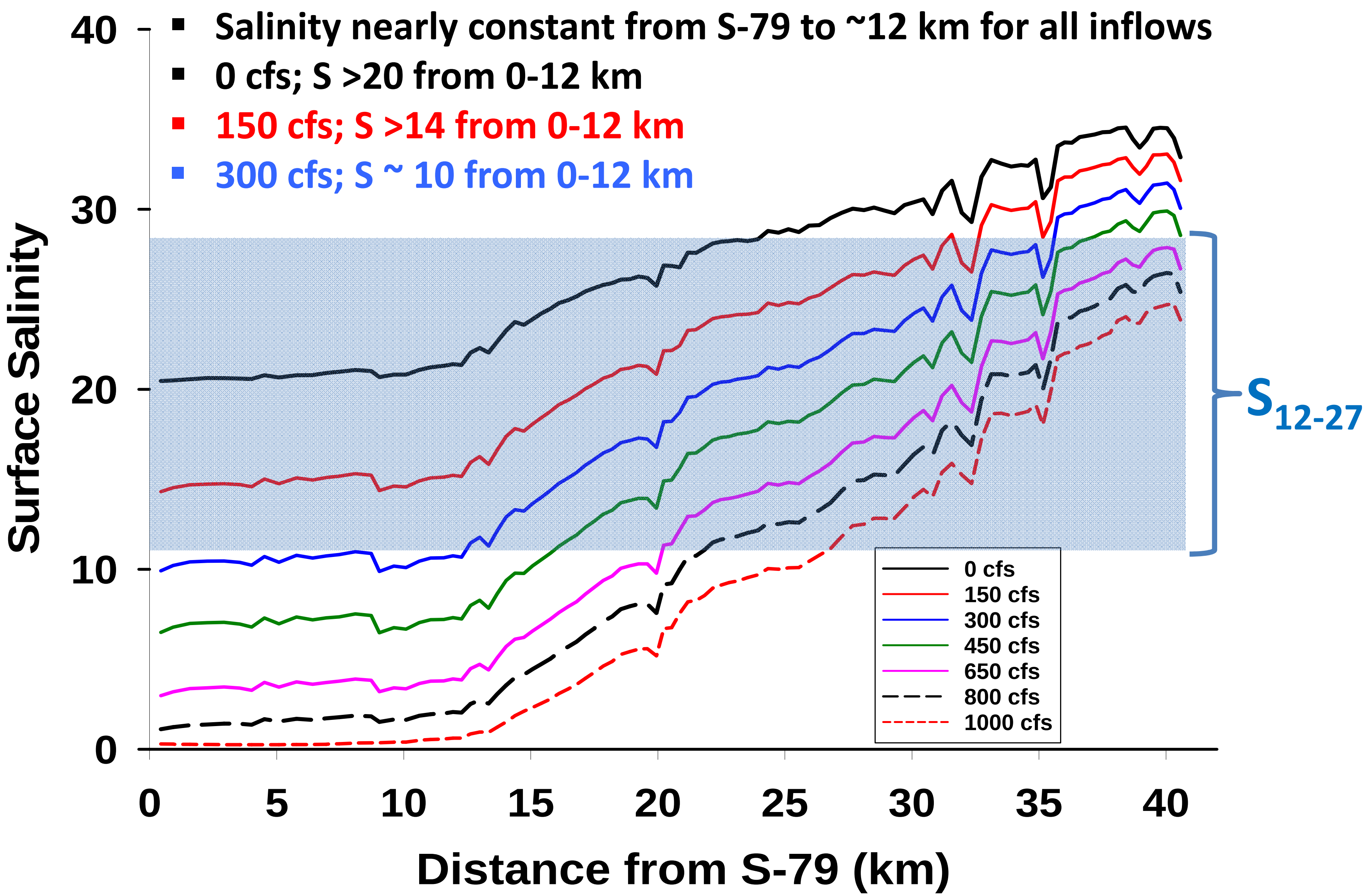
# CRE HYPSOMETRY (AREA vs DISTANCE)

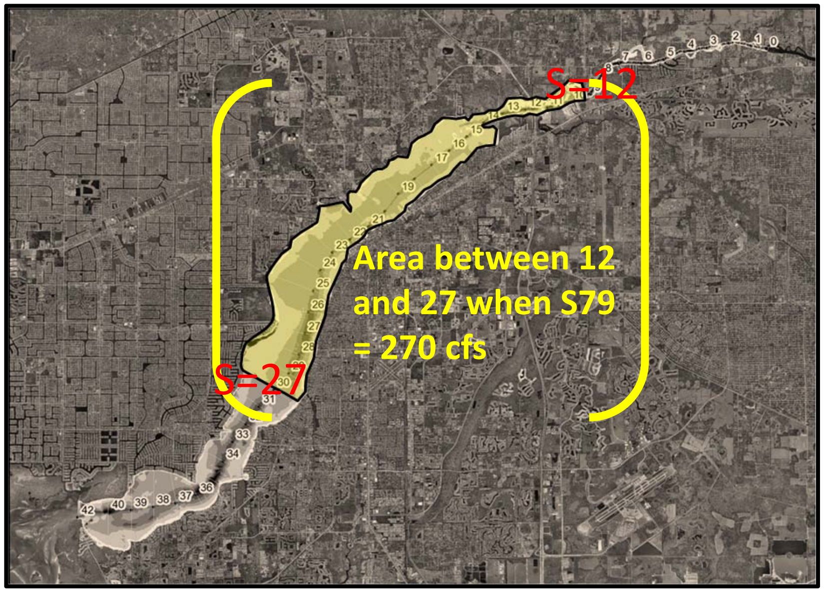
- About 58% of the CRE ≤ 1.0 m depth
- Area of 0-1 m contour: 0.01 to 0.53 km$^2$
- Much deeper area 0-10 km from S-79



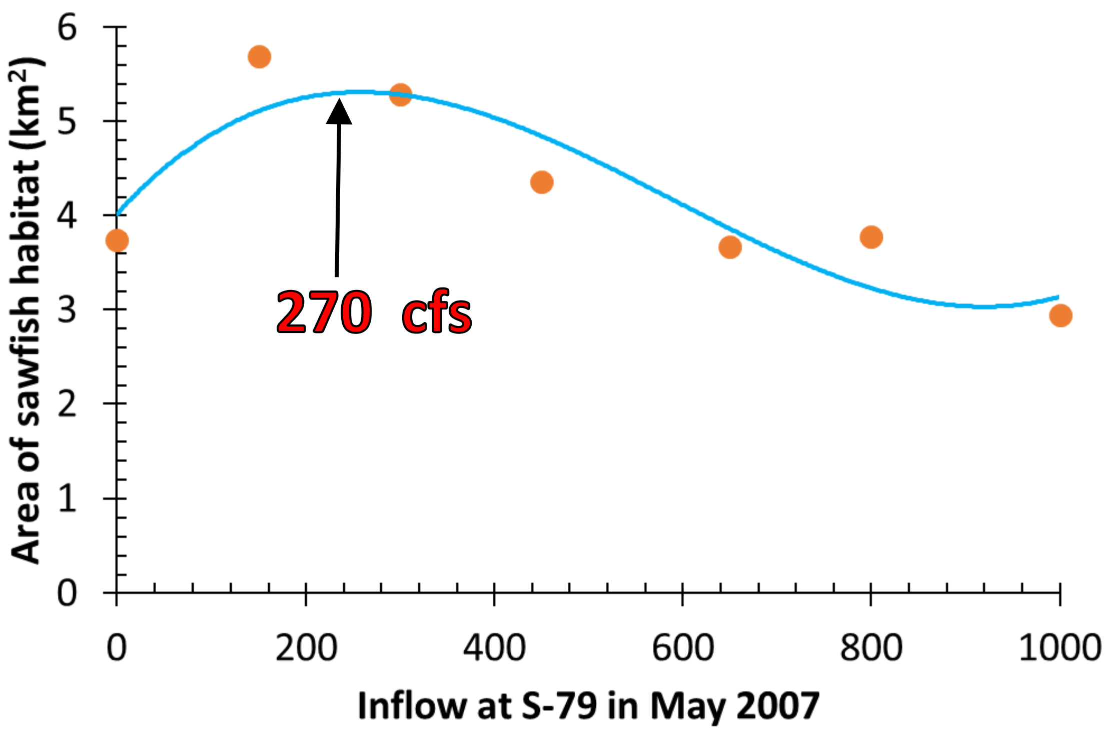
# SALINITY DISTRIBUTIONS






# INFLOW vs SAWFISH HABITAT AREA

- Polynomial relationship between $A_{saw}$ and inflow at S-79
- $A_{saw}$ = maximum of 5.35 $km^2$ when S-79 inflow rate is 270 cfs

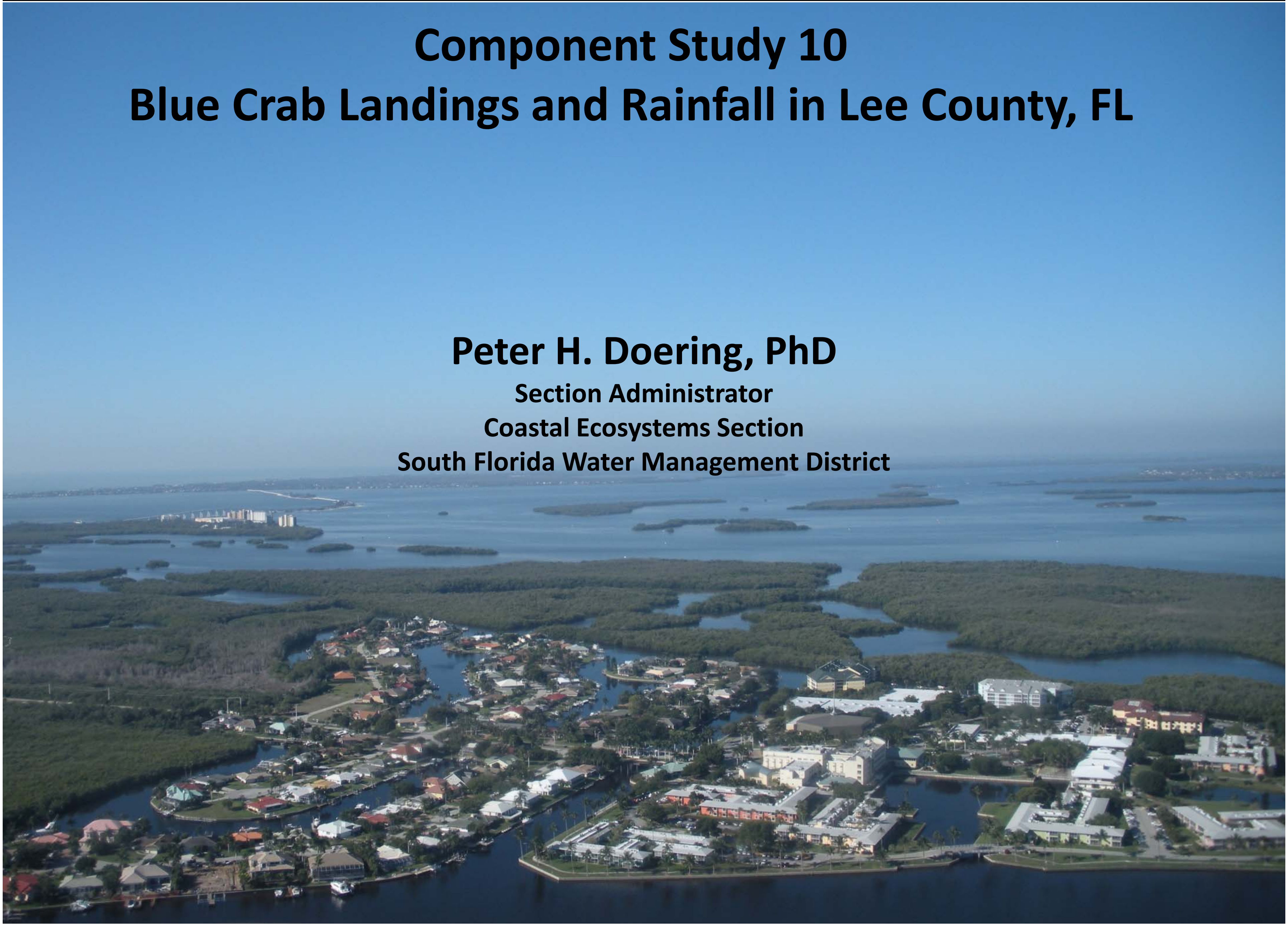


# STUDY SUMMARY

- ~95% of the historical smalltooth sawfish population gone; CRE provides essential nursery for neonates and juveniles
- Juvenile sawfish prefer salinity range of 12-27 ($S_{12\text{-}27}$) and $\leq$ 1 m depth ($A_{saw}$)
- Combined bathymetry and hydrodynamics to predict $A_{saw}$ in the dry season
- Maximum $A_{saw}$ (5.35 $km^2$) when the inflow was 270 cfs in May 2007
- 270 cfs positions $S_{12\text{-}27}$ at about 10-32 km downstream of S-79 (from above Beautiful Island to Cape Coral)
- Potential implications if S-79 < 270 cfs
    - Favorable salinity range truncated
    - Habitat compression against S-79 = increased exposure to bull sharks

# Component Study 10
# Blue Crab Landings and Rainfall in Lee County, FL

**Peter H. Doering, PhD**
Section Administrator
Coastal Ecosystems Section
South Florida Water Management District



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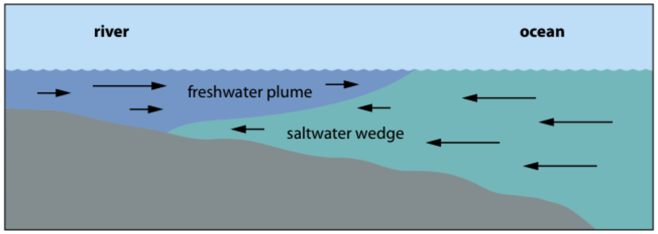


Changes in isohaline position with upstream encroachment of saltier water

Alter benthic community upon which many estuarine fauna are dependent

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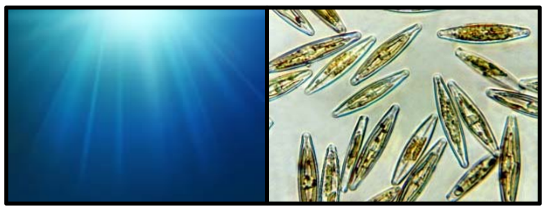

Reduced flushing and enhanced light can stimulate phytoplankton in upper estuary

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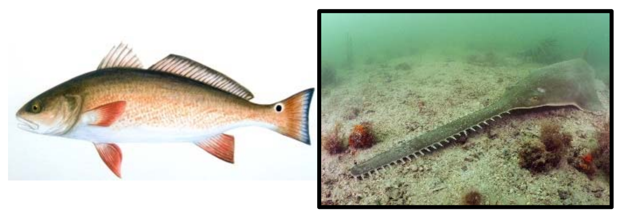

Affect coastal fish populations dependent upon estuaries as nurseries

Negatively impact harvests of important fisheries

# SCIENCE COMPONENTS / STUDIES

| | Component | Method |
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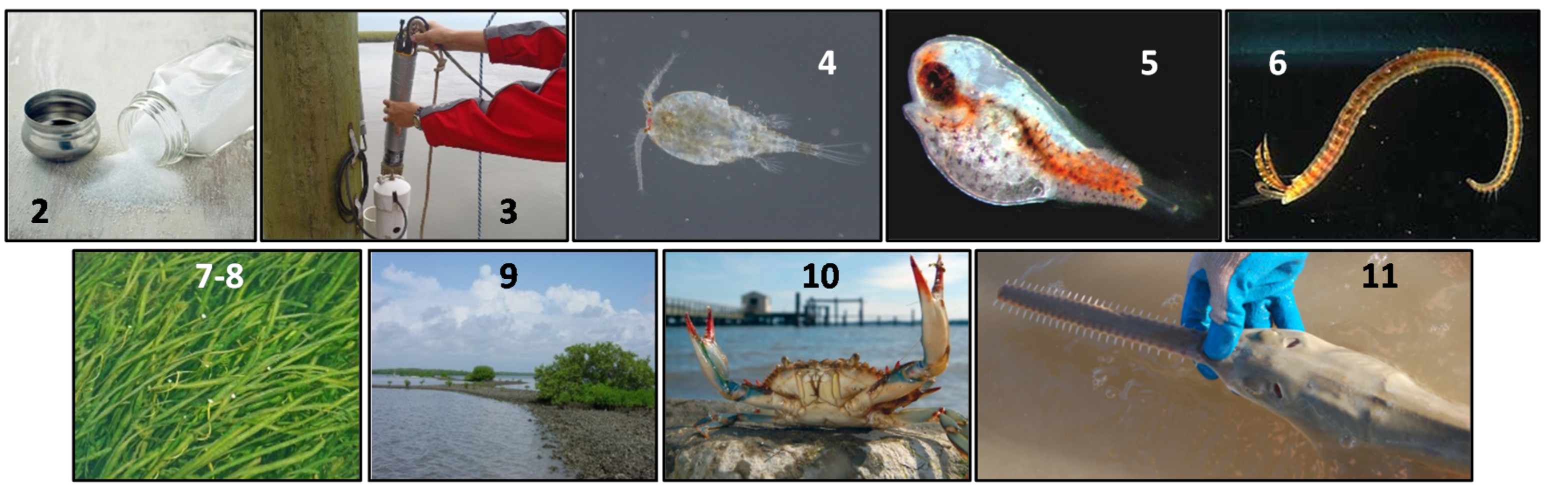


# STUDY OBJECTIVE

**To examine the relationship between blue crab landings in Lee County and selected hydrologic factors such as rainfall and discharge at the Franklin Lock and Dam (S-79) at the head of the CRE**

# BLUE CRAB FISHERY IN THE CRE

- ~180 licensed crab fishermen in Lee County (2003)
- Over 63,000 licensed traps
- Caloosahatchee is a major fishing area
- Catch records are available from the Florida Wildlife Research Institute

# ANALYSIS OF FISHERY DATA

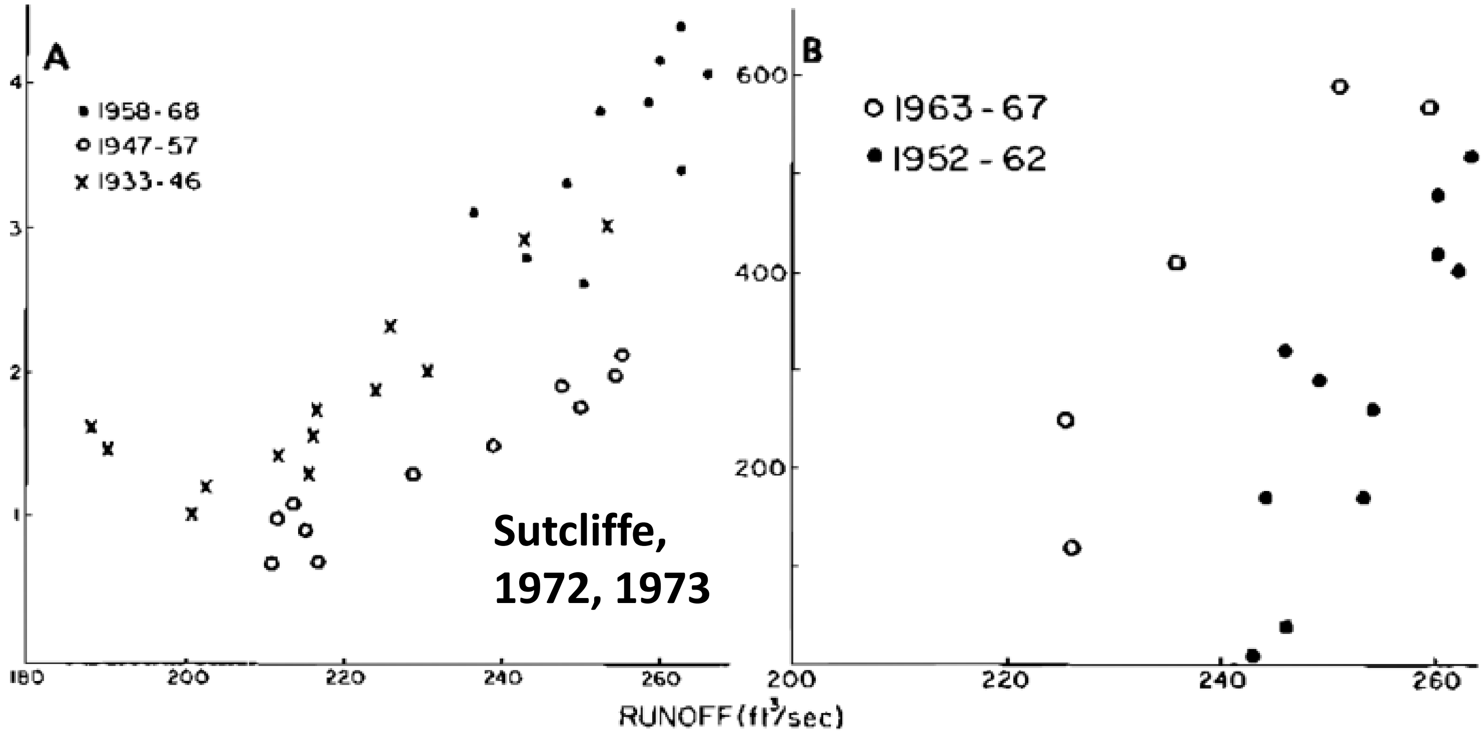



FIG. 6. (A), Halibut catch of Quebec ($\times\ 10^5$ lb) vs discharge St. Lawrence River ($\times\ 10^3 ft^3/sec$) 1933–1968 $r = .797$, $P < .001$, 10 year slip, 3-year running averages. (B), Haddock catch of Quebec ($\times\ 10^3$ lb) vs discharge St. Lawrence River ($\times\ 10^3 ft^3/sec$); 1952–1962, $r = .934$, $P = .02$; 1963–1968 $r = .773$, $P = .001$, 8 year slip, 3-year running averages.

- Annual River Discharge related to future catch of Halibut, Haddock and Lobster
- Numerous studies demonstrate relationships (shrimp, crabs, oysters, clams)
- Link between freshwater inflow and estuarine productivity and economics

# LEE COUNTY BLUE CRAB DATA

- **Monthly Landings of blue crabs from Nov 1984-Dec 2013**
- **Variables**
  - **lbs of hard shell**
  - **lbs of soft shell**
  - **number of trips**
  - **number of traps**
- **Catch per Unit Effort (CPUE) = lbs of hard shell/trap**
- **Crab POR Analyzed = WY1986-WY2013 (28 years)**

# HYDROLOGIC DATA

- Lee County Rainfall and S-79 Discharge from DBHYDRO
- Tidal Basin Discharge from rainfall-runoff model (Wan and Konyha 2015)
- Total Discharge = S-79 + Tidal Basin
- Rainfall and Discharge at S-79 POR Analyzed = WY1981-WY2013 (allow for lags)

# HYDROLOGIC & CATCH DATA SUMMARY

## Annual and seasonal (wet vs dry) rainfall in Lee County and freshwater inflow at S-79. Values are mean (standard deviation; WY1981 to WY2013

| | Annual | Wet Season | Dry Season |
|---|---|---|---|
| Lee County Rainfall (in) | 55.2 (9.2) | 42.3 (7.7) | 12.8(5.9) |
| Discharge at S-79 (cfs) | 1764 (1208) | 2294 (1413) | 1234 (1444) |
| Total Discharge (cfs) | 2267(1332) | 3055(1586) | 1480 (1599) |

## Mean annual landings (lbs/yr) of hard and soft shell blue crabs (WY1986-13)

| | Landings | CPUE |
|---|---|---|
| | lbs/yr | lbs/trap |
| Hard Shell | 1,315,808 (711,508) | 1.26 (0.35) |
| Soft Shell | 36,515 (38465) | 0.75 (0.43) |

**Soft shelled crabs comprise only 3% of catch; Analysis focused on hard crabs**

# STATISTICAL ANALYSES

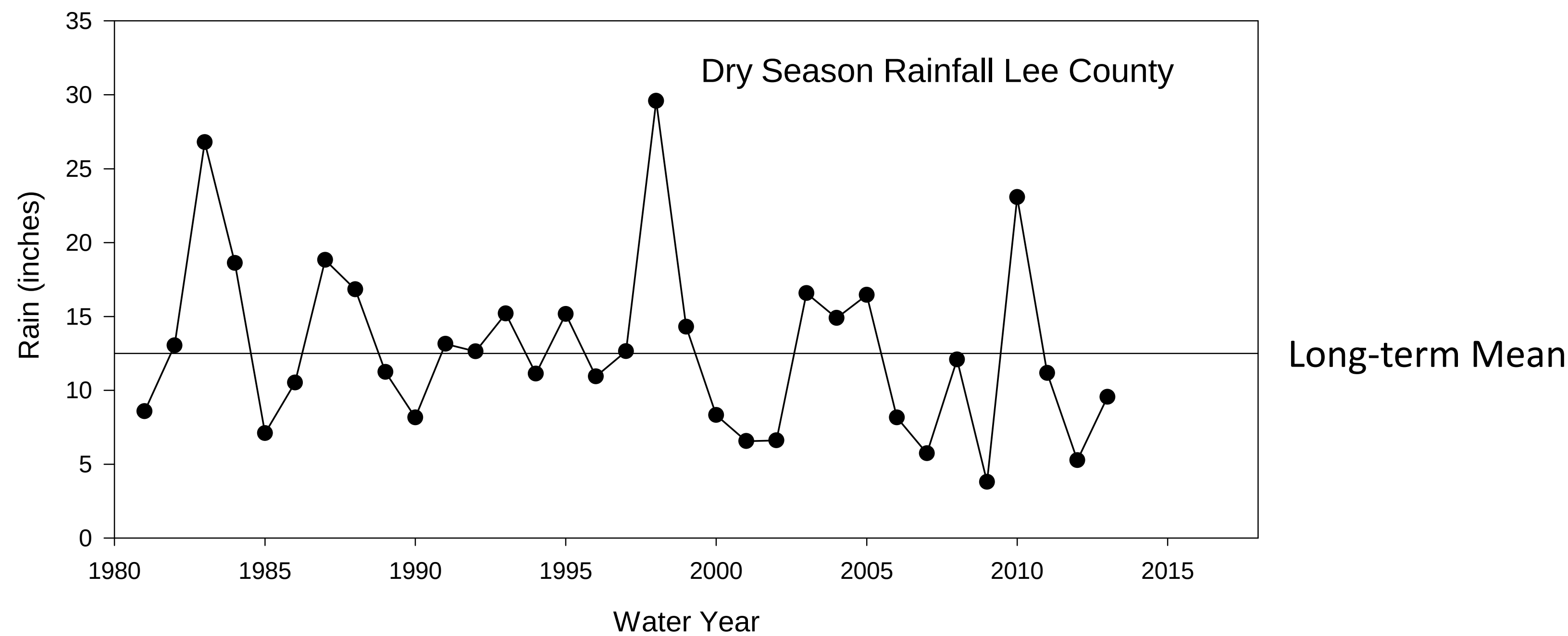
1. Correlation of unadjusted annual estimates of catch, rainfall and discharge with lags up to 5 years
2. For significant correlations, time series tested and corrected for trend and autocorrelation at lag = 1
3. Correlations re-evaluated using corrected time series
4. Relationships quantified using functional regression (Ricker 1973)
5. Spectral Analysis conducted for periodicity

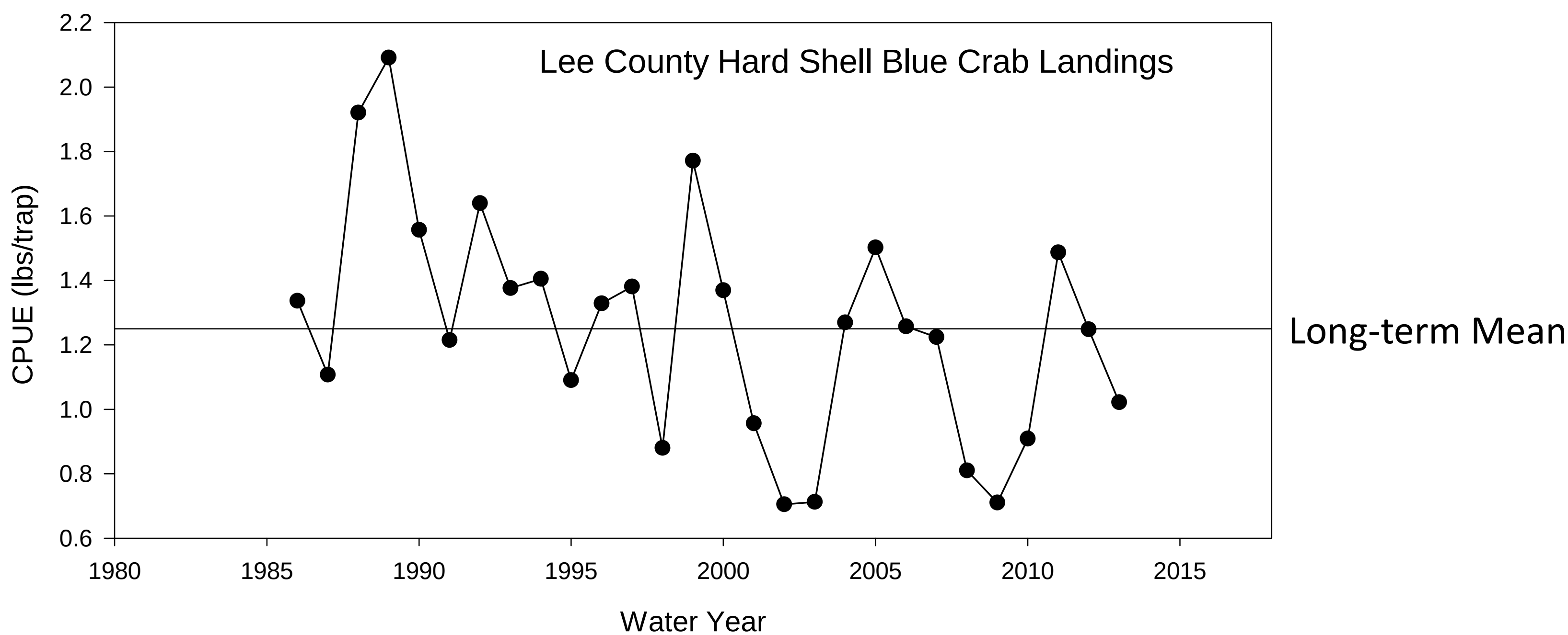
# STATISTICAL ANALYSES

| Variable | Annual CPUE |
|---|---|
| | Hard lbs/trap |
| Lee County Rainfall | |
| Annual (Lag 1) | 0.216 |
| Wet Season (Lag 1) | -0.251 |
| Dry Season (Lag 1) | 0.673** |
| | |
| Discharge at S-79 | |
| Mean Annual (Lag1) | 0.289 |
| Mean Wet Season (Lag 1) | 0.083 |
| Mean Dry Season (Lag 1) | 0.424* |
| | |
| Total Discharge S-79 + TCB | |
| Mean Annual (Lag1) | 0.293 |
| Mean Wet Season (Lag 1) | 0.058 |
| Mean Dry Season (Lag 1) | 0.450** |

**Only significant correlations between rainfall, discharge and catch were for the dry season with a lag of 1 year**

**Correlation of unadjusted hydrologic variables with unadjusted estimates of catch per unit effort. N=28 in all cases. Statistical significance: * $p < 0.05$, ** $p < 0.01$.**


Dry Season Rainfall Lee County
Rain (inches)
0
5
10
15
20
25
30
35
1980
1985
1990
1995
2000
2005
2010
2015
Water Year
Long-term Mean


Lee County Hard Shell Blue Crab Landings
CPUE (lbs/trap)
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
1980
1985
1990
1995
2000
2005
2010
2015
Water Year
Long-term Mean

# STATISTICAL ANALYSES

## Rainfall and Discharge

- No trend
- No autocorrelation at lag = 1
- No correction needed

## Hard Shelled Crab CPUE

- Long-term decreasing trend
- No autocorrelation at lag = 1

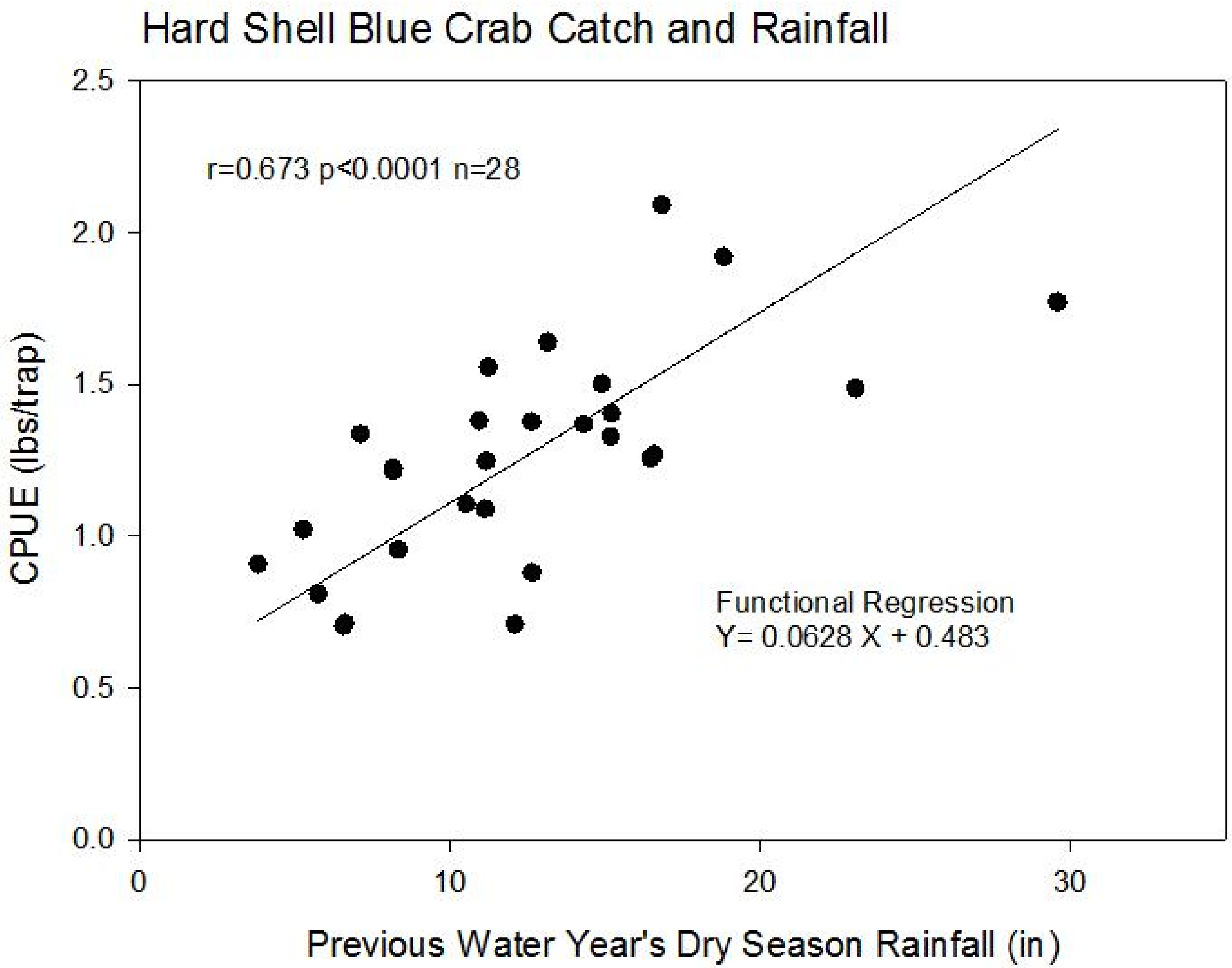
# STATISTICAL ANALYSES

| Variable | Annual CPUE |
|---|---|
| | Hard lbs/trap DT |
| **Lee County Rainfall** | |
| Total Dry Season (Lag 1) | **0.696 **** |
| | |
| **Discharge at S-79** | |
| Mean Dry Season (Lag 1) | **0.468 *** |
| | |
| **Total Discharge S-79 + TCB** | |
| Mean Dry Season (Lag 1) | **0.497**** |

**Correlation of unadjusted hydrologic variables with estimates of catch per unit effort corrected for trend N=28 in all cases**

**DT= De-trended Statistical significance: * p <0.05, ** p<0.01**

# RAINFALL & BLUE CRAB FISHERY CATCH




**Functional regression of landings of blue crabs on dry season rainfall during the previous year. Data have not been corrected for trend or autocorrelation.**

# CRE MFL CONSIDERATIONS

- Link Between Hydrology and Estuarine Productivity
- Blue Crab Catch Depends on Dry Season Rainfall in the Previous Year
- Dry Season is When Minimum Flows are Important!

# CRE MFL CONSIDERATIONS

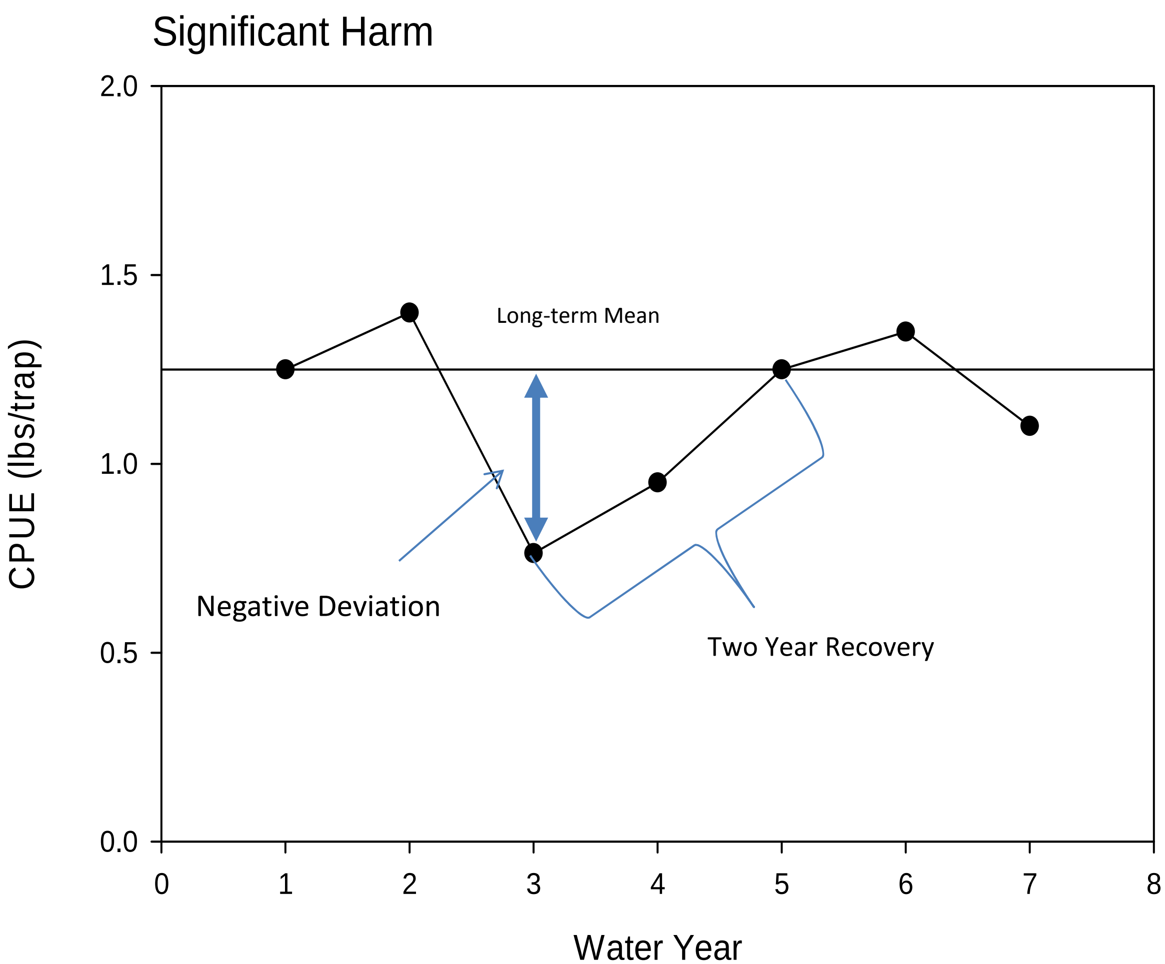
- A Minimum Flow (for a river, stream or spring) or Level (lake, aquifer) identifies the point at which further withdrawals will cause "significant harm" to the water resources or ecology of an area.

- "Significant harm" means the temporary loss of water resource functions, which result from a change in surface or ground water hydrology, that takes more than two years to recover…." (Subsection 40E-8.021(24), F.A.C.)

# LOSS OF RESOURCE FUNCTION & RECOVERY

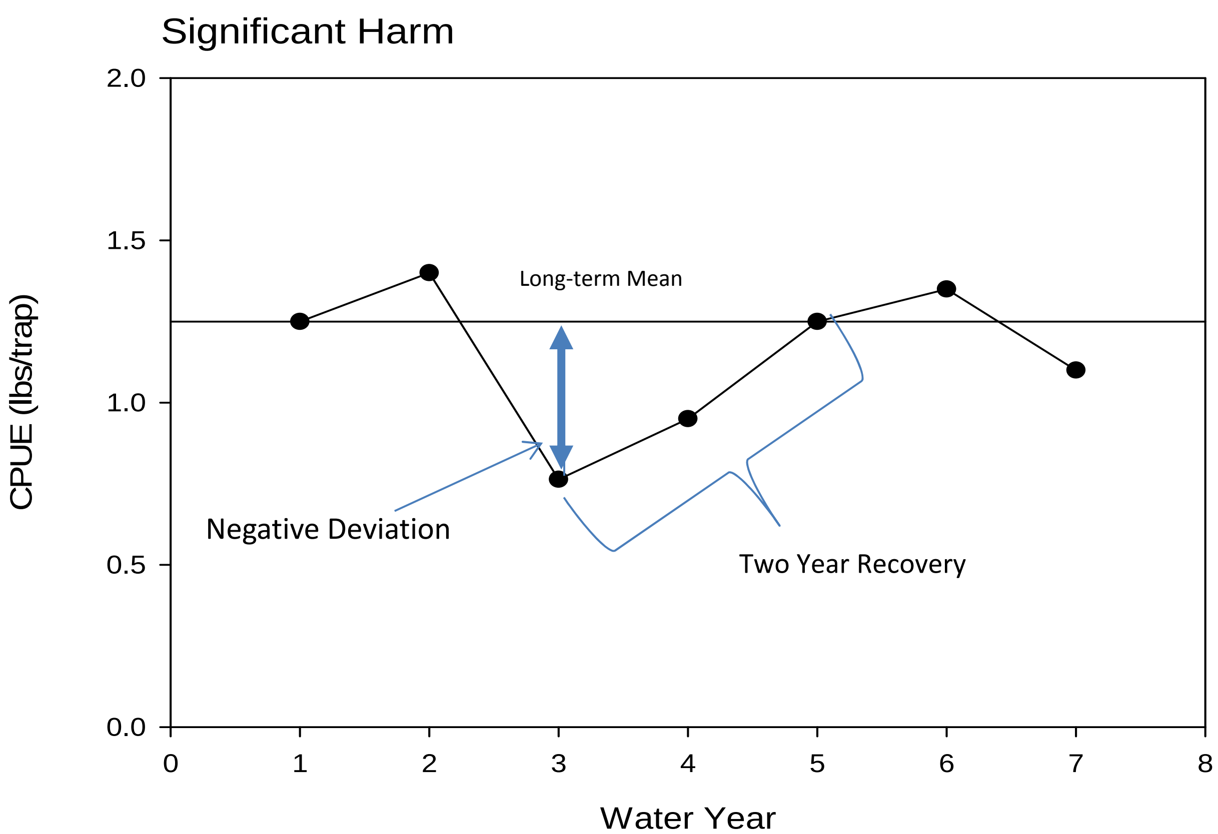
- **“Loss” and “Recover” key words in definition of significant harm**
  - **Loss of resource function suggests a negative effect**
  - **Recovery is in a positive direction**
  - **Recovery is a rate**

# LOSS OF RESOURCE FUNCTION & RECOVERY




- **Loss of Resource Function = negative deviation from the long-term mean CPUE that would recover under average dry season rainfall**
- **What is the magnitude of the deviation?**
- **What is the rainfall associated with this deviation?**
- **Estimate S-79 inflow from rainfall**

# LOSS OF RESOURCE FUNCTION & RECOVERY

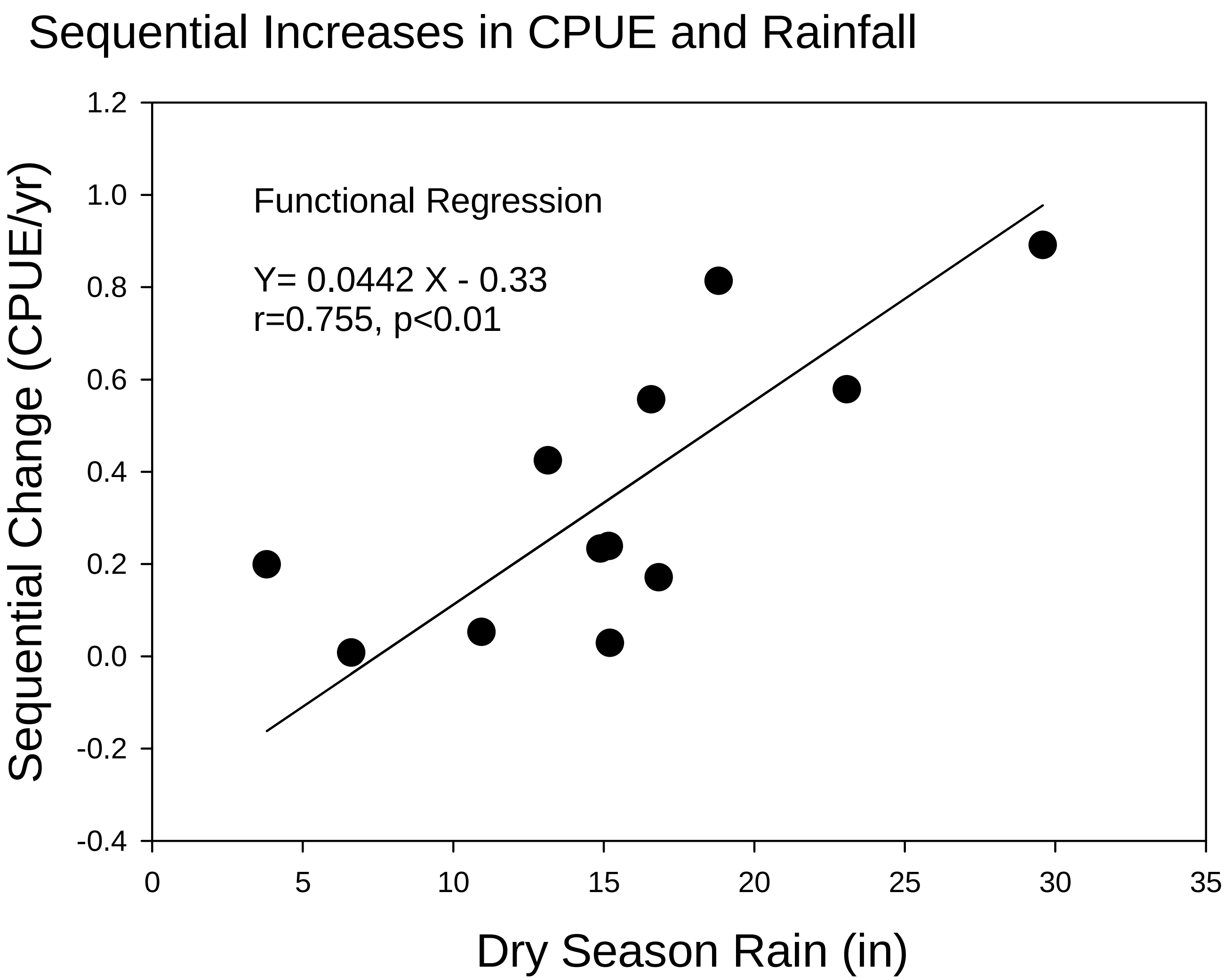



- **If period of record long enough can associate magnitude of deviation with duration of recovery**
- **Use Monte Carlo technique to generate a long-term simulated times series**

# LOSS OF RESOURCE FUNCTION & RECOVERY

- **Assume CPUE is Water Resource Function**
- **Quantify rate of recovery in CPUE as a function of hydrology**
  - **Change in CPUE sequentially, from one year to the next**
  - **Relate positive changes in CPUE to rainfall**
  - **Rainfall to flow**

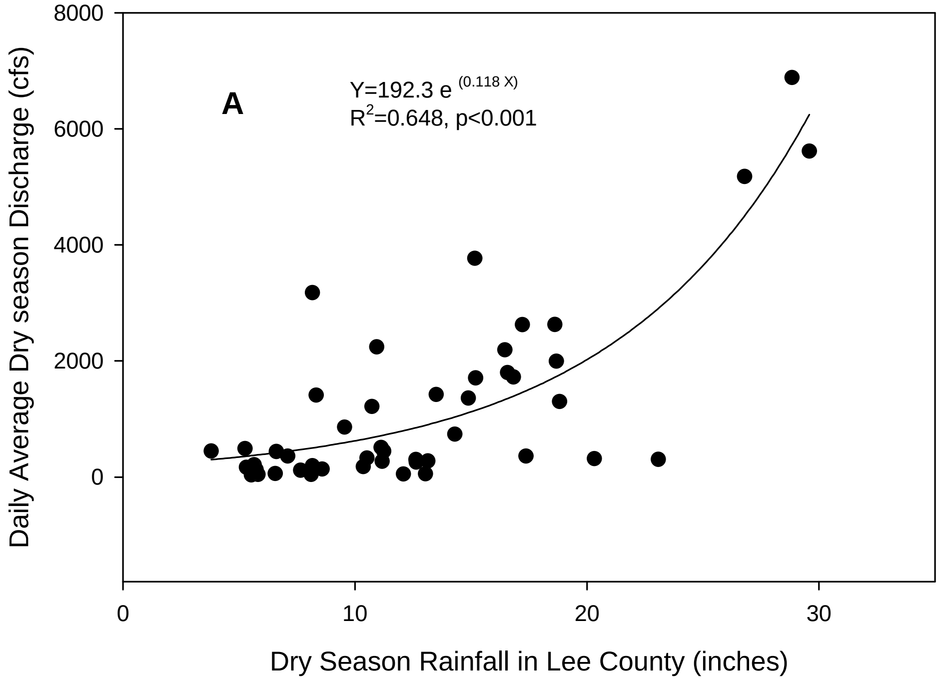
# CRE MFL CONSIDERATIONS



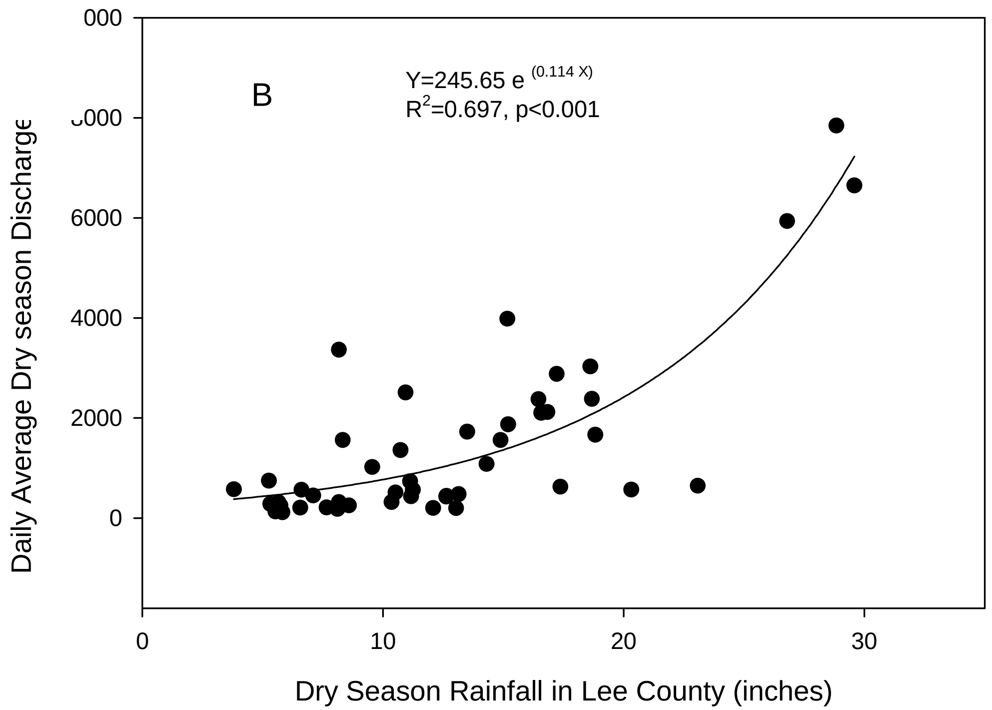

**Sequential Increases in CPUE from one year to the next and dry season rainfall in the first year**

# FRESHWATER INFLOW & RAINFALL

Discharge at S-79

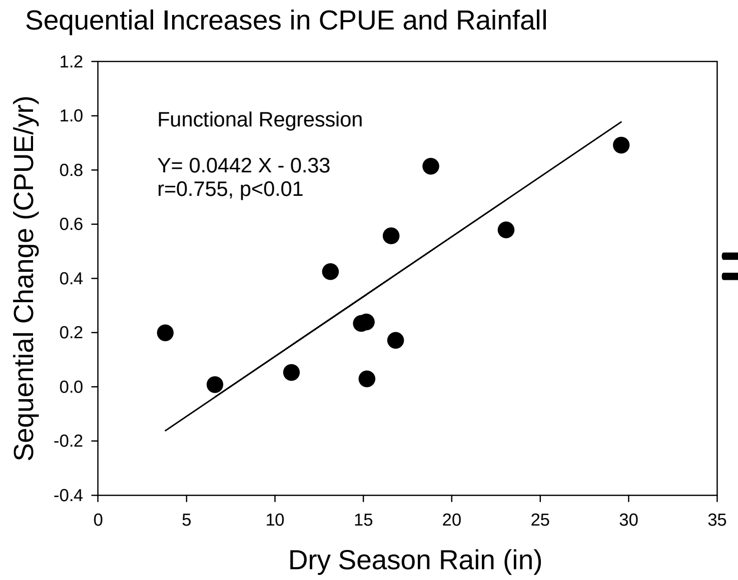



Total Discharge (S79 + Tidal Basin)



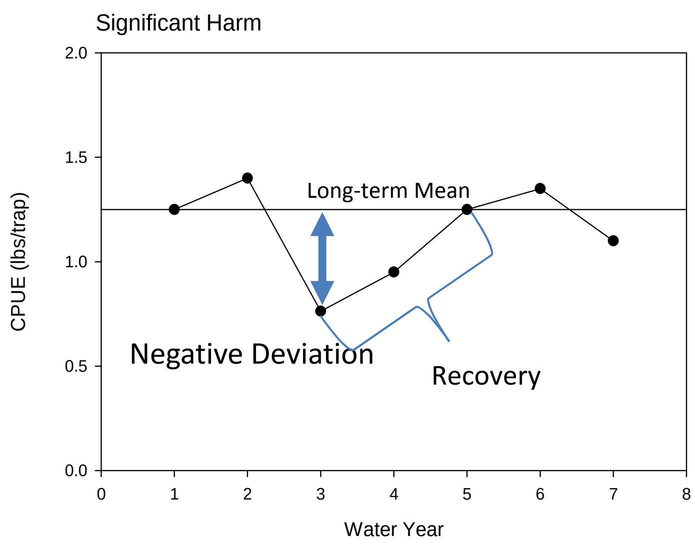
# LOSS OF RESOURCE FUNCTION & RECOVERY

**Average Dry Season Rain 12.45 in**




**= 0.22 CPUE Increase in one year**

| Years of Average Rain | Negative Deviation | CPUE 1.26 - Neg Deviation | Years of Average Rainfall to Recover to Long-term Mean |
|---|---|---|---|
| 1 | 0.22 | 1.04 | 1 |
| 2 | 0.44 | 0.82 | 2 |
| 3 | 0.66 | 0.66 | 3 |



# FRESHWATER INFLOW & RAINFALL

| Method | Years of Average Rainfall to Recover to Long-term Mean | CPUE 1.26 - Neg Deviation | Associated Rainfall (in) | Associated S-79 Discharge (cfs) | Associated Total Discharge (cfs) |
|---|---|---|---|---|---|
| | 1 | 1.04 | 8.9 | 542.8 | 675.2 |
| Regression | 2 | 0.82 | 5.4 | 360.3 | 452.9 |
| | 3 | 0.66 | 1.9 | 239.1 | 303.8 |
| | | | | | |
| Monte Carlo | 2 | 0.97 | 7.1 | 440 | 552 |
| | 3 | 0.93 | 6.4 | 407 | 512 |
| | | | | | |

# RETURN FREQUENCY

- **Spectral Analysis: showed that both rainfall and CPUE had a periodicity of 5.6 years**
- **Monte Carlo Analysis: Rainfall associated with a two year recovery had a return interval of 5.8 years**
- **Monte Carlo Analysis: Rainfall associated with a three year recovery had a return interval of 8.2 years**

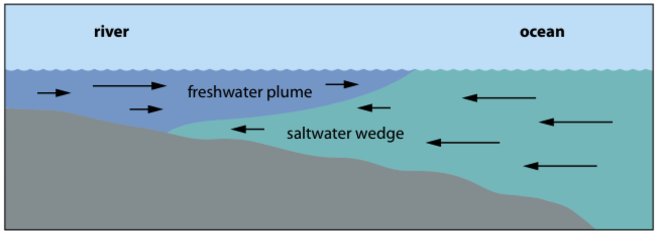
# Component Study 7: Relationships between salinity and the survival of tape grass (*Vallisneria americana*) in the Caloosahatchee River Estuary

**Christopher Buzzelli, Zhiqiang Chen, Peter Doering**

**Coastal Ecosystems Section**

**South Florida Water Management District**

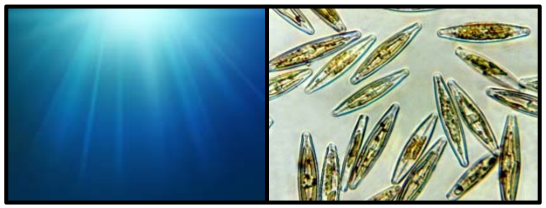
# INDICATORS OF ESTUARINE RESPONSE TO LOW INFLOW




**Changes in isohaline position with upstream encroachment of saltier water**

**Alter benthic community upon which many estuarine fauna are dependent**

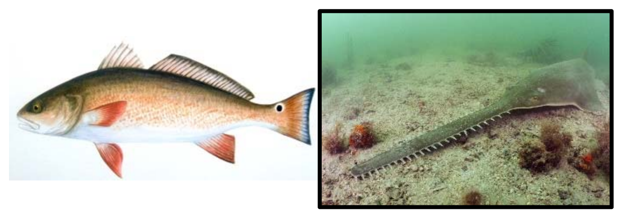
**Damaging to the freshwater *Vallisneria americana* (tape grass)**



**Reduced flushing and enhanced light can stimulate phytoplankton in upper estuary**

**Impact physiology and habitat attributes of eastern oyster**

**Zooplankton and ichthyoplankton assemblages move upstream but can be impinged by structure**

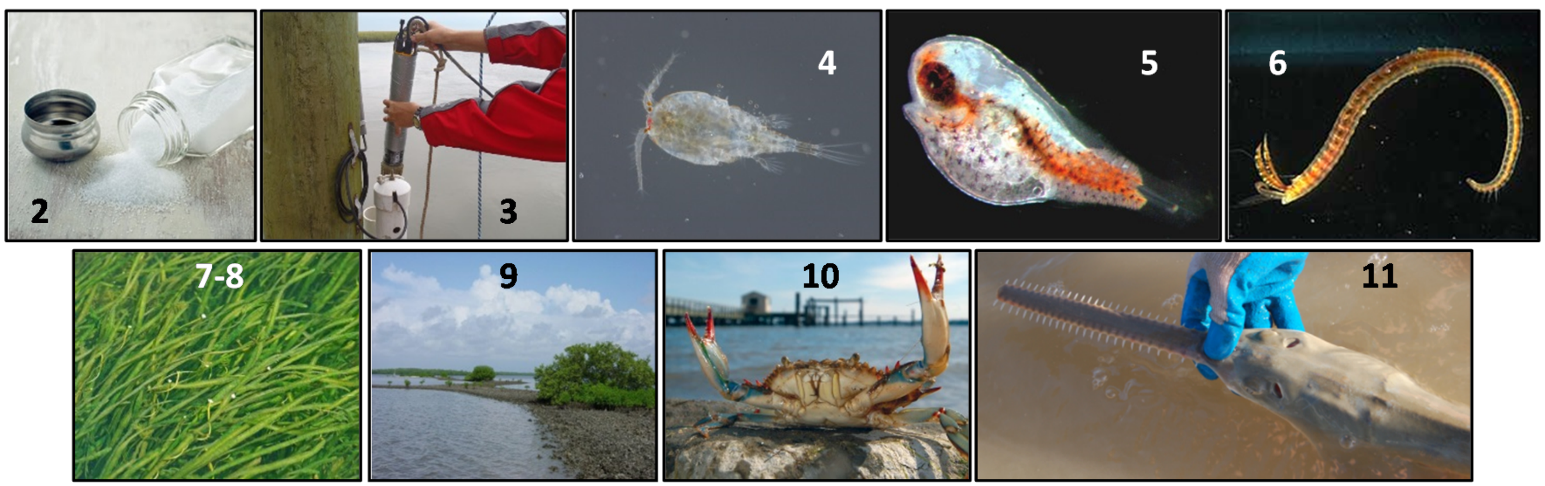


**Affect coastal fish populations dependent upon estuaries as nurseries**

**Negatively impact harvests of important fisheries**

# SCIENCE COMPONENTS / STUDIES

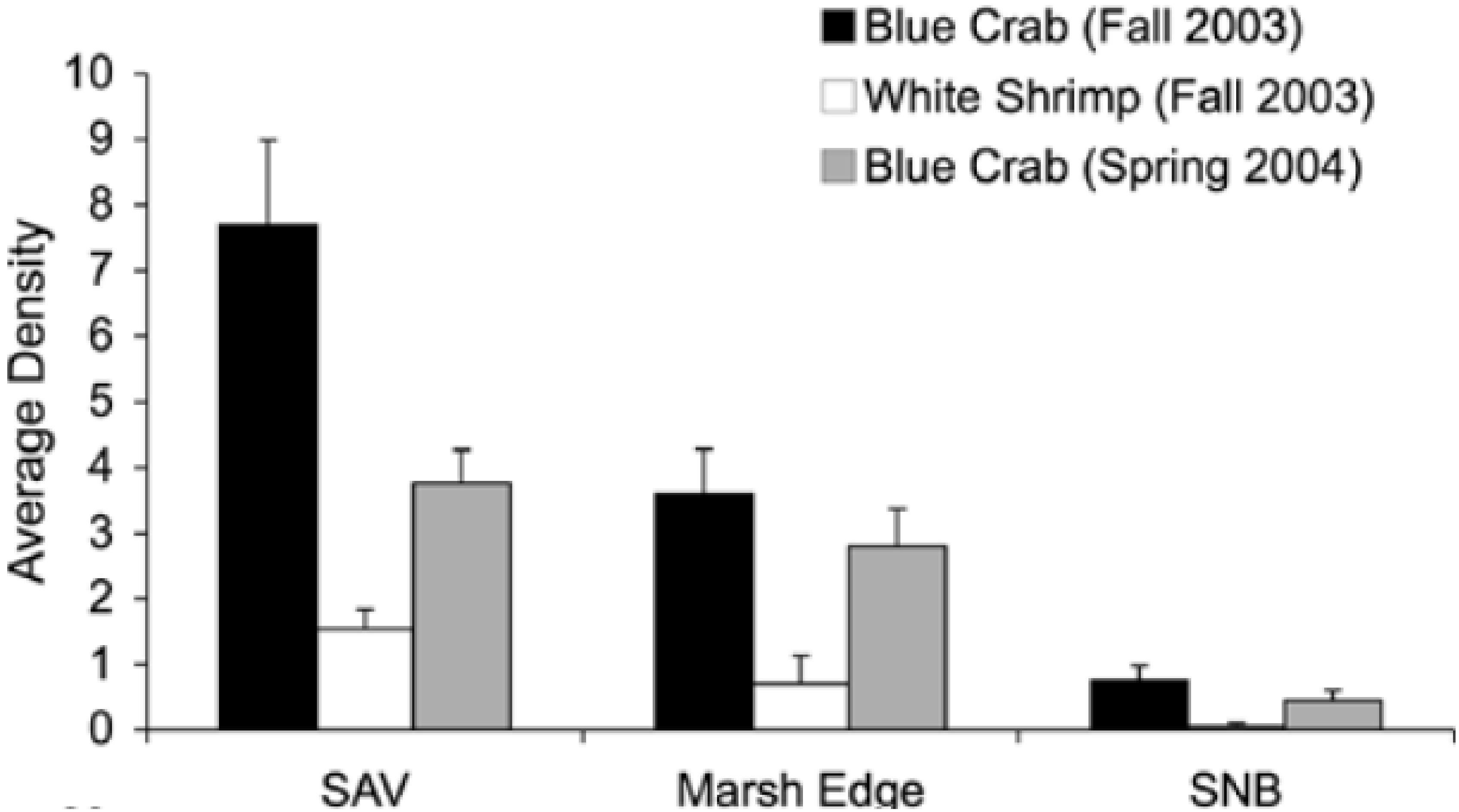
| | Component | Method |
|---|---|---|
| 1 | Hydrodynamics | Influence of alterations on hydrodynamics |
| 2 | Inflow vs. Salinity | Monthly freshwater-salinity relationships |
| 3 | Water Quality | Relationships between inflow, salinity, and water quality |
| 4 | Zooplankton | Inflow, zooplankton and habitat compression |
| 5 | Ichthyoplankton | Relationships between ichthyoplankton and inflow |
| 6 | Benthic Fauna | Macrofauna-salinity patterns relative to inflow |
| 7 | *Vallisneria* data | Empirical relationships between tape grass, S, and inflow |
| 8 | *Vallisneria* model | Model exploration of tape grass, S, light, and inflow |
| 9 | Oyster Habitat | Salinity patterns for oyster habitat in lower CRE |
| 10 | Blue Crabs | Relationships between blue crab landings, rainfall, and inflow |
| 11 | Sawfish | Dry season inflow, hydrodynamics, and habitat extent |



# RESEARCH COMPONENT RATIONALE

- *Vallisneria americana* (tape grass)
  - Freshwater species of submersed aquatic vegetation (SAV)
  - Common in many lakes, rivers, and upper reaches of estuaries
  - Perennial plant capable of clonal growth
  - S. Florida populations actively grow year round
  - Ecologically important habitat for aquatic fauna

- Estuarine tape grass survival and growth
  - Submarine light ($\geq$9% surface irradiance is best)
  - Salinity > 10 damaging to the survival of *Vallisneria*
  - Grazing by herbivores can be significant (e.g. manatees, turtles)




Estuaries and Coasts Vol. 29, No. 2, p. 297–310 April 2006

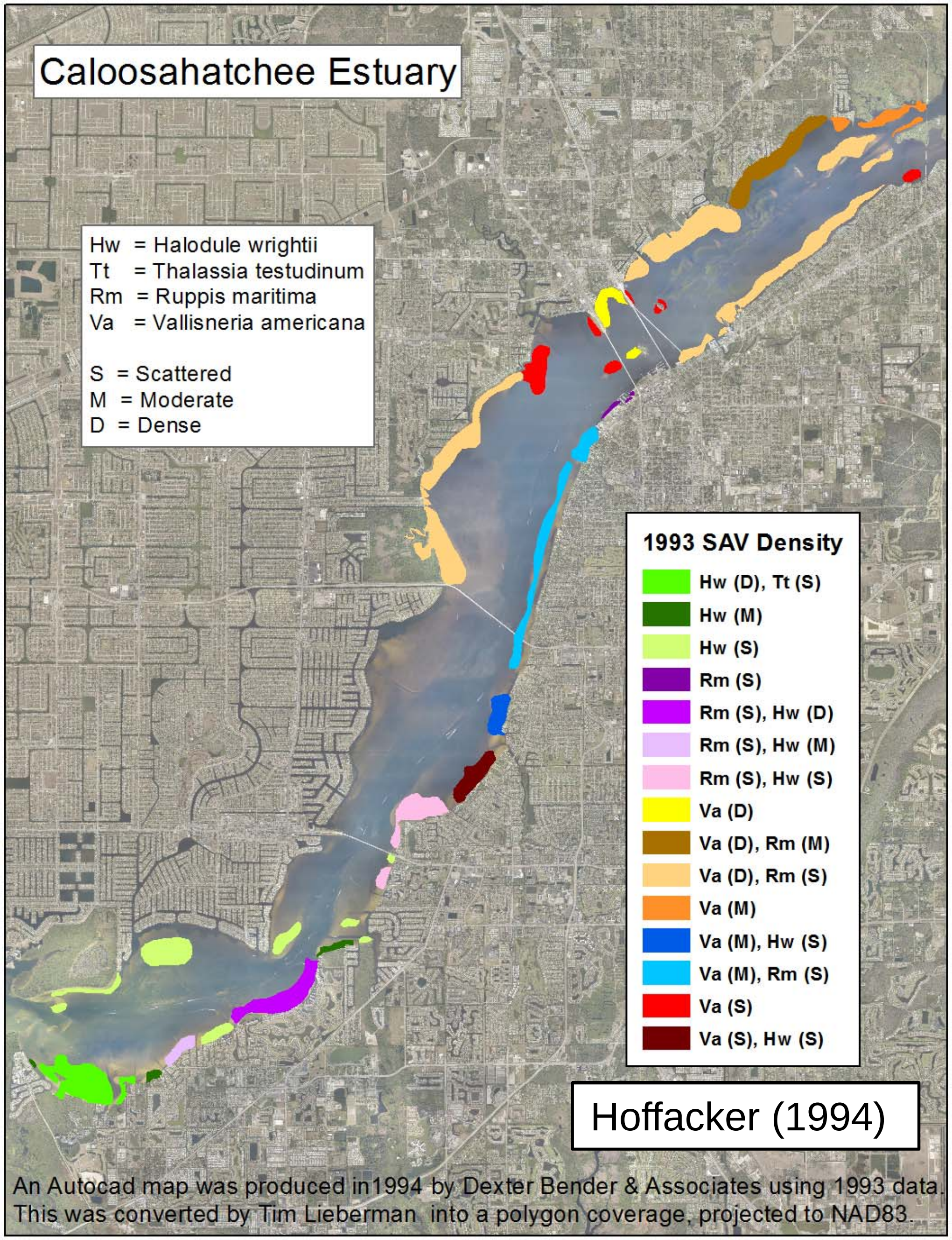
Nekton Use of *Vallisneria americana* Michx. (Wild Celery) Beds and Adjacent Habitats in Coastal Louisiana

LAWRENCE P. ROZAS[1,*] and THOMAS J. MINELLO[2]

# Vallisneria in the Caloosahatchee

- ***Vallisneria* in the CRE**
  - **Fastest growth from March to September with peak shoot density in June-July**
  - **Shoot density declines in late summer followed by flower production in Sept-Oct**
  - **Overwintering rosettes have short blades < 10 cm in length**

- ***Vallisneria* habitat in the CRE**
  - **Qualitative observations supported the presence of *Vallisneria* in the early 1960's**
  - ***Vallisneria* was present from the mid 1980's**
  - **Hoffacker (1994) visual census (dense, moderate or scattered)**
    - **July to October 1993**
    - ***Vallisneria* was dense from Beautiful Island to the Edison Bridge at Ft. Myers**
    - **Coverage extended downstream to Whiskey Creek**
  - **Dense beds of *Vallisneria* in the upper CRE from 1993-1999**
  - **Salinity $\geq$ 10 (Ft. Myers) are damaging to distribution and density of tape grass**

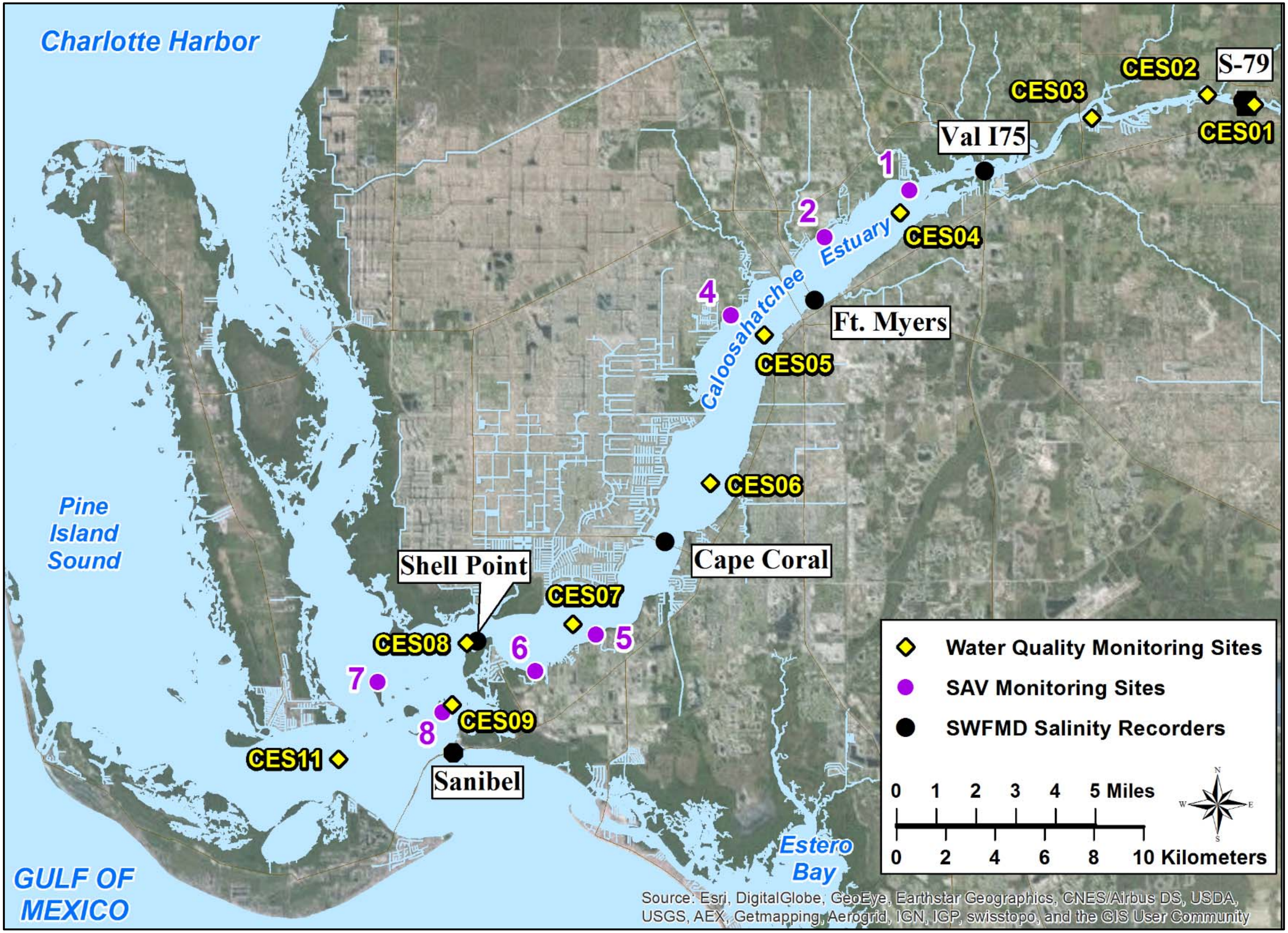

Caloosahatchee Estuary
Hw = Halodule wrightii
Tt = Thalassia testudinum
Rm = Ruppis maritima
Va = Vallisneria americana
S = Scattered
M = Moderate
D = Dense
1993 SAV Density
Hw (D), Tt (S)
Hw (M)
Hw (S)
Rm (S)
Rm (S), Hw (D)
Rm (S), Hw (M)
Rm (S), Hw (S)
Va (D)
Va (D), Rm (M)
Va (D), Rm (S)
Va (M)
Va (M), Hw (S)
Va (M), Rm (S)
Va (S)
Va (S), Hw (S)
Hoffacker (1994)
An Autocad map was produced in1994 by Dexter Bender & Associates using 1993 data.
This was converted by Tim Lieberman into a polygon coverage, projected to NAD83.

# STUDY METHODS

- **Quantitative monitoring of *Vallisneria***
    - **Started in 1998 at 4 sites**
    - **Paired, perpendicular 100 m transects at each site**
    - **5 separate, random 0.1 $m^2$ quadrats along each transect**
    - **Site 3 discontinued in 2003**
    - **Shoot densities ~monthly 1998-2007**
    - **Changed to gridded presence/absence method 2008-2015**
    - **Sites 1 and 2 used in this study; Site 4 not used (tape grass too sparse)**

- **Effects of salinity on *Vallisneria* survival - 3 approaches**
    - **Change-point analysis to determine the critical salinity for *Vallisneria***
    - **Examine relationship between the duration of high salinity and mortality**
    - **Patterns of salinity and *Vallisneria* density over two 6.5 year time periods**

- **Salinity Data**
    - **Salinity at Ft. Myers; 15 min intervals (near surface and bottom)**
    - **Average daily salinity from 5/1/1992 to 4/30/2014**
    - **Missing data (1058 of 8035 days) estimated using auto-regressive model (Qiu and Wan 2013)**


Charlotte Harbor
S-79
CES02
CES03
CES01
Val I75
1
2
CES04
Estuary
Caloosahatchee
4
Ft. Myers
CES05
CES06
Pine
Island
Sound
Cape Coral
Shell Point
CES07
CES08
6
5
7
CES09
8
CES11
Sanibel
Water Quality Monitoring Sites
SAV Monitoring Sites
SWFMD Salinity Recorders
0 1 2 3 4 5 Miles
0 2 4 6 8 10 Kilometers
Estero
Bay
GULF OF
MEXICO
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

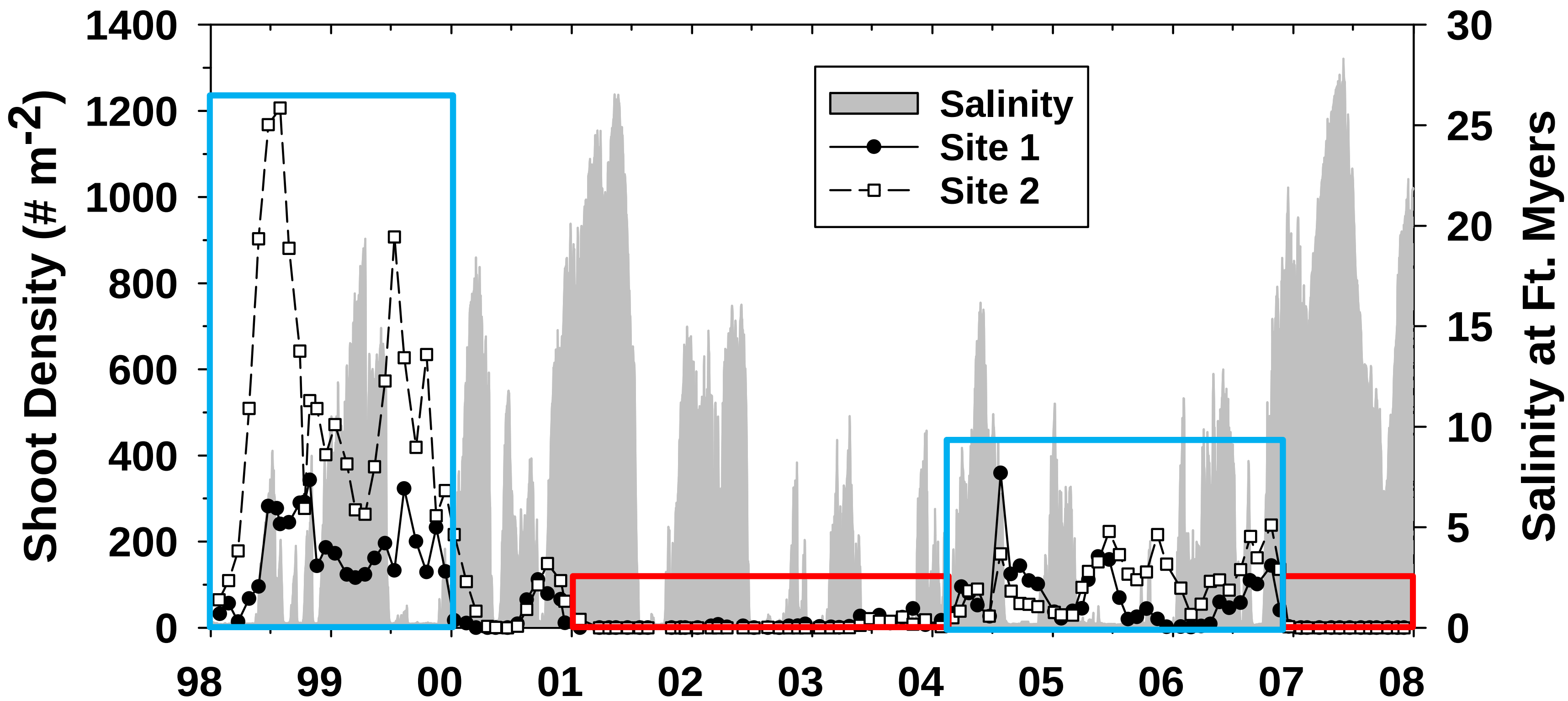
# STUDY METHODS

1. **Change Point Analyses**
   - **Successively split data into two groups to test statistical dissimilarity**
   - **Change points =max probability of difference among paired groups**

2. **Effects of salinity exposure time on *Vallisneria***
   - **30 day moving average salinity ($S_{30d}$)**
   - **Four time periods among the two sites**
   - **Shoot density on the first day as the initial condition**
   - **For each time period**
     - **Number of days where $S_{30d} \geq 10$**
     - **Percent of shoots remaining relative to initial conditions**
     - **Negative exponential curve for shoot decline with $S \geq 10$**

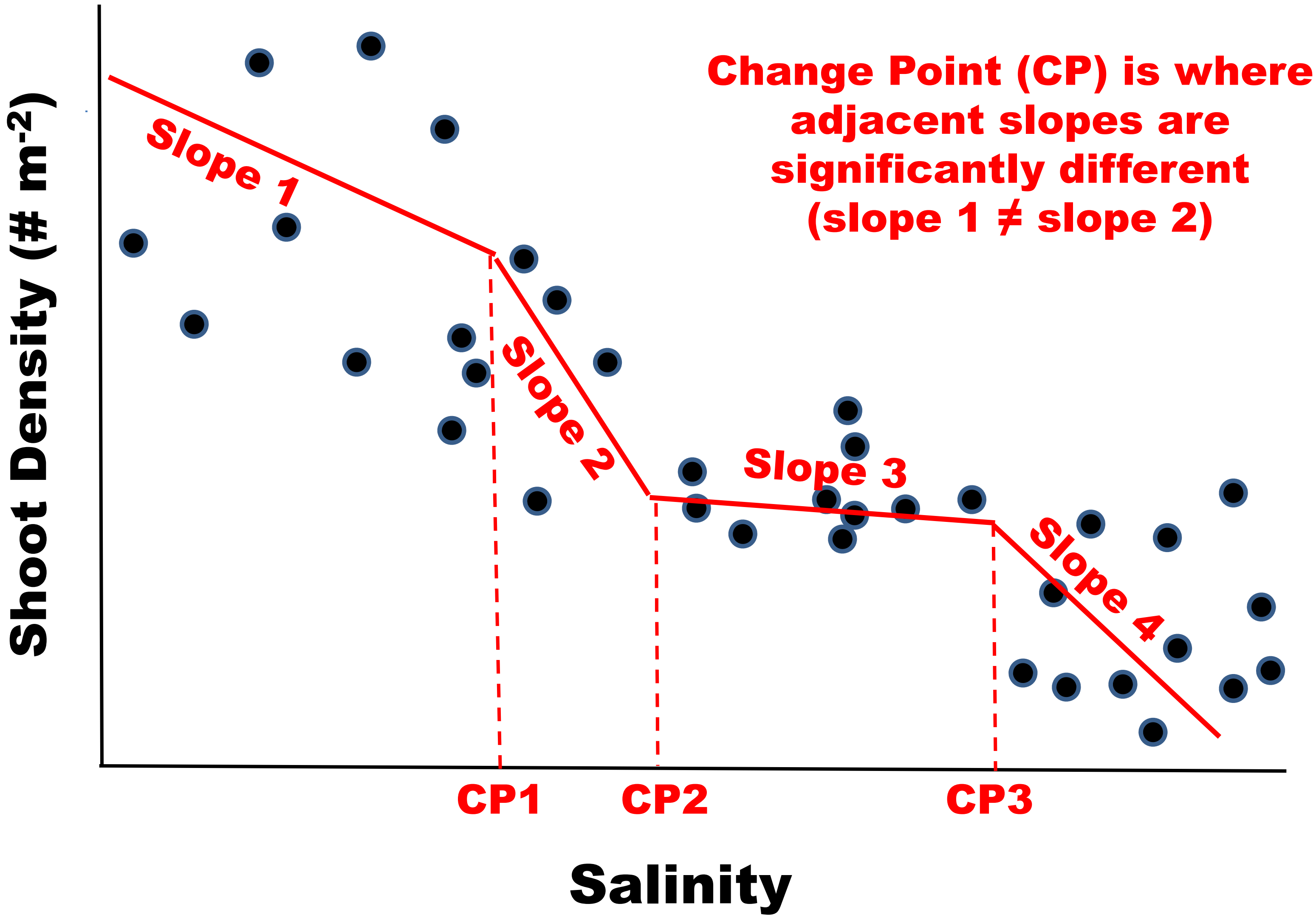
3. **Long-term Salinity and Inflow**
   - **Defined two time periods each with seven wet and six dry seasons**
     - **Period 1: 5/1/1993-10/31/1999**
     - **Period 2: 5/1/2007-10/31/2013**
     - **Salinity evaluated along with shoot densities from Site 1**
   - **Determination of suitable freshwater inflows (Period 1)**
     - **Dry season days where salinity at Ft. Myers was 9-10**
     - **S-79 inflows associated with upper salinity limit for tape grass**

# TIME SERIES OF SHOOT DENSITY & SALINITY

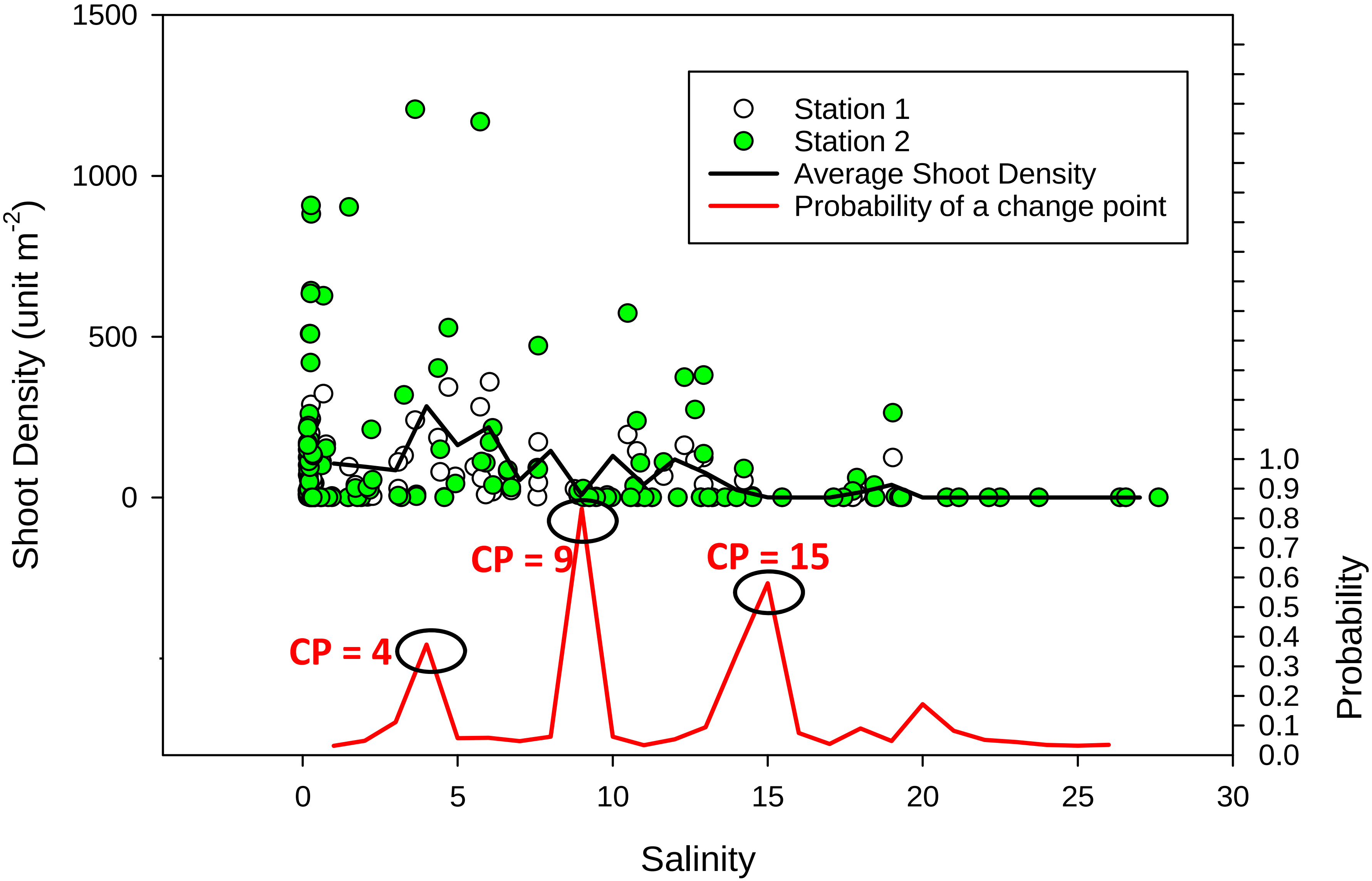



- Average shoot densities ranged 0-360 and 0-1200 shoots $m^{-2}$ at Sites 1 and 2
- Shoots were abundant from 1998-2000
- Shoot densities much reduced and similar between the two sites in 2000
- Reduced to ~0.0 from 2001-2003
- Increased slightly to 0-200 shoots $m^{-2}$ from 2004-2006
- Reduced to ~0.0 in 2007

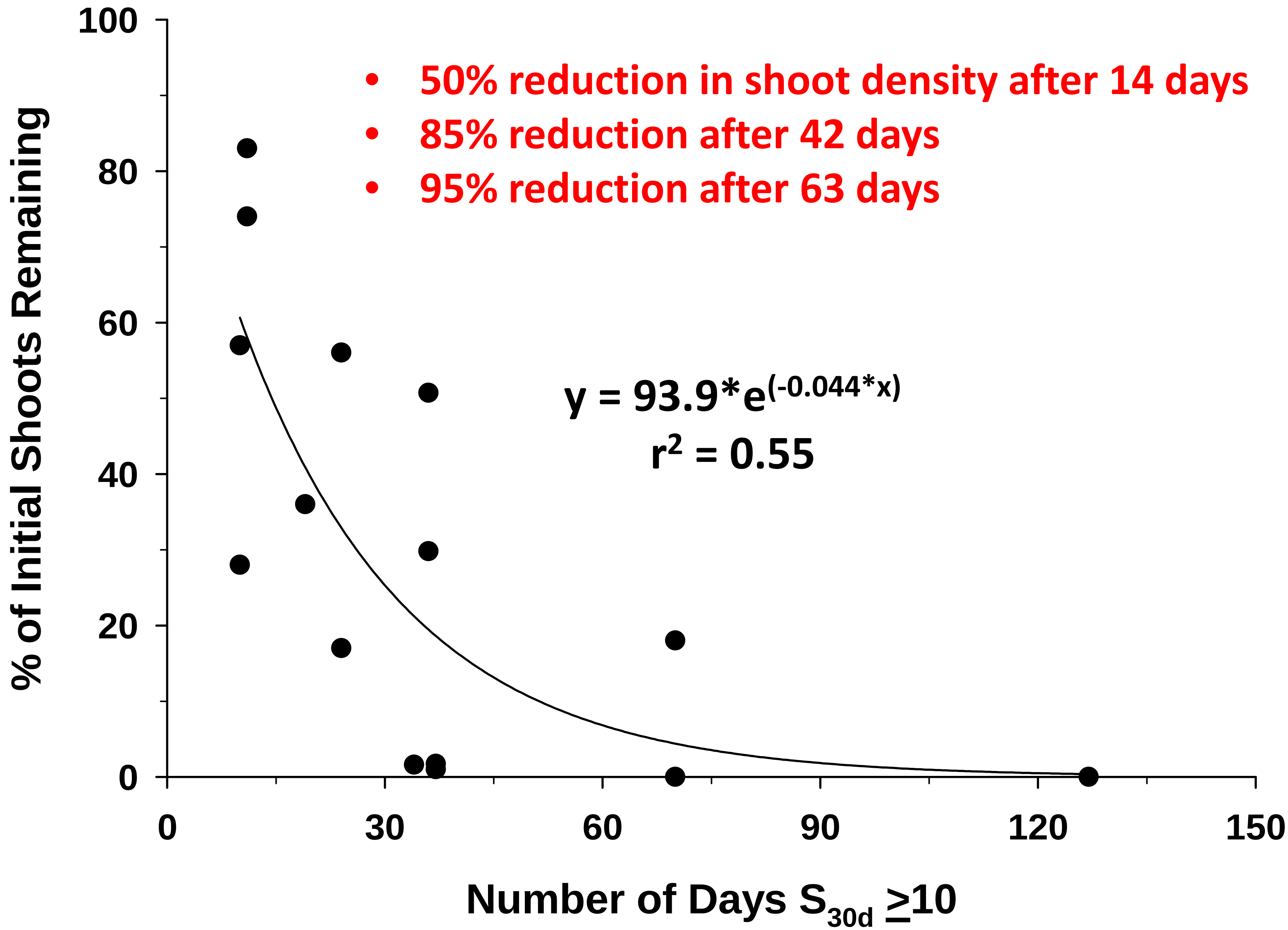
# CHANGE-POINT ANALYSIS

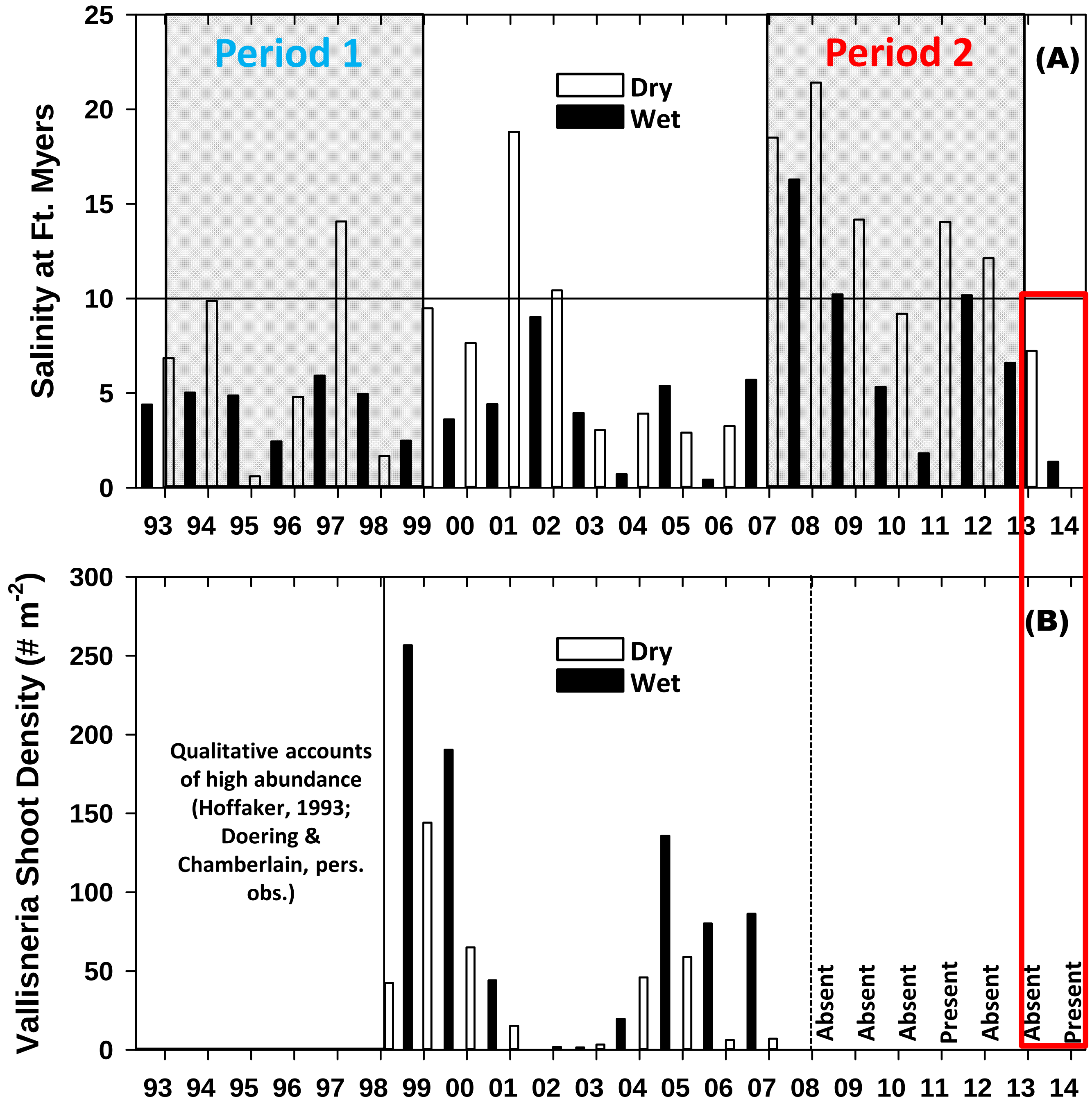


# SALINITY CHANGE-POINT ANALYSIS



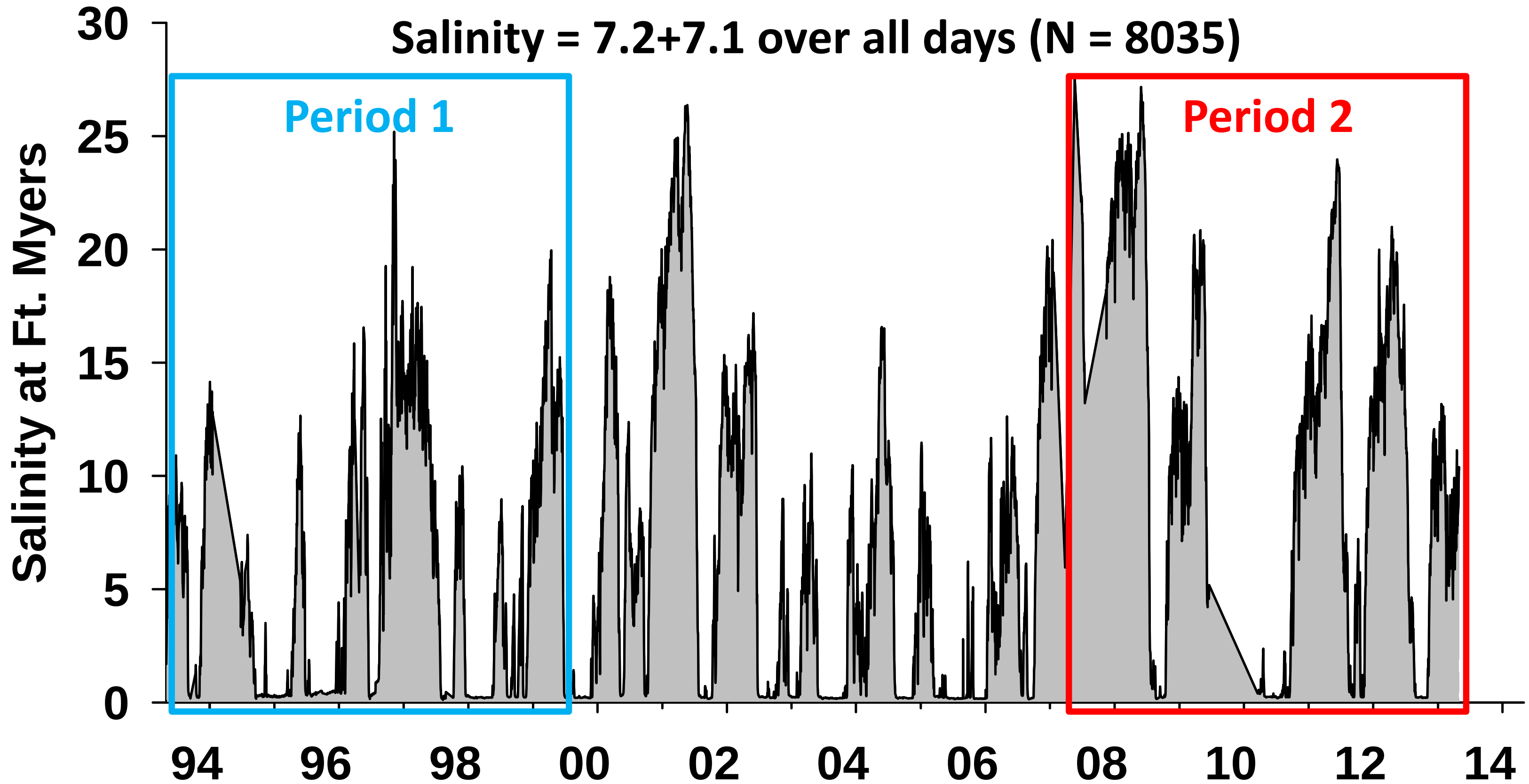
# EFFECTS OF SALINITY DURATION ON SHOOTS





Salinity at Ft. Myers
25
20
15
10
5
0
Period 1
Period 2
(A)
Dry
Wet
93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
Vallisneria Shoot Density (# m-2)
300
250
200
150
100
50
0
(B)
Dry
Wet
Qualitative accounts of high abundance (Hoffaker, 1993; Doering & Chamberlain, pers. obs.)
Absent
Absent
Absent
Present
Absent
Absent
Present
93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14

# SALINITY TIME SERIES AT FT. MYERS

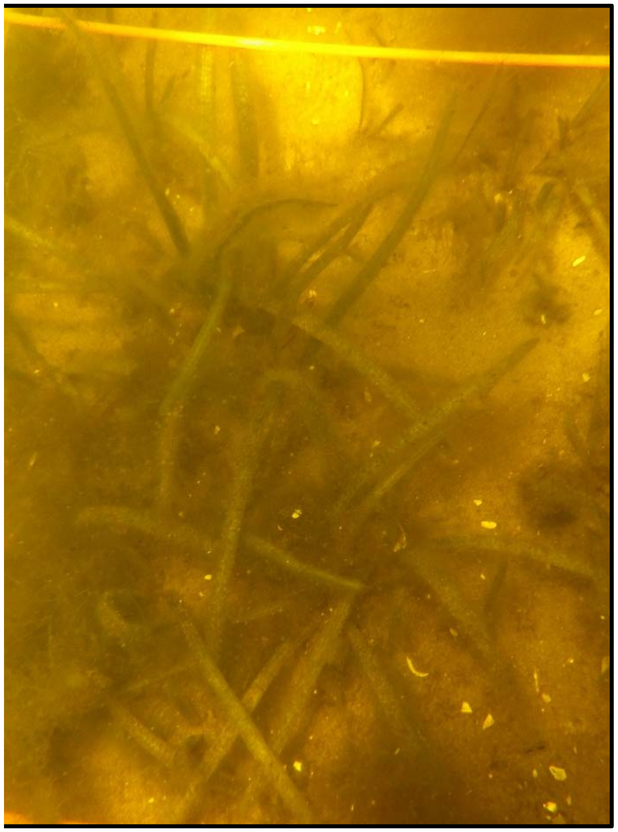



**Period 1**
5.5±5.4 (N = 2375)
Season average ≥ 10
Dry 1997

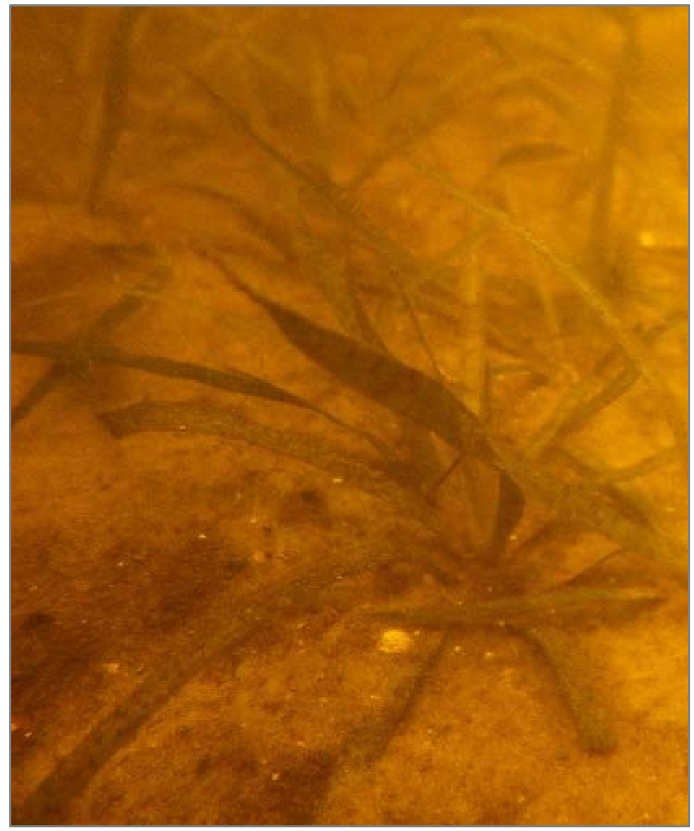
**Period 2**
10.0±8.0 (N = 2376)
Season average ≥ 10
4 of 6 dry seasons
3 of 7 wet seasons

S-79 dry season inflow rate 545±774 cfs for salinity of 9-10 at Ft. Myers

# June 2015



# May 2016



# STUDY SUMMARY

- **Significant differences in salinity between Period 1 Period 2**
  - **Period 1 (1993-1999)**
    - ***Vallisneria* beds dense and widespread**
    - **Salinity was ~5 as seasonal average salinity rarely exceeded 10**
    - **S-79 inflows 545±774 cfs for dry season salinity of 9-10 at Ft. Myers**
  - **Period 2 (2007-2013)**
    - ***Vallisneria* was virtually absent (sporadic shoots)**
    - **40% reduction in freshwater inflow to the upstream estuary**
    - **Salinity was ≥10 in multiple wet and dry seasons**

- **Repeated, drought-induced stress in 2001 and 2007-08 harmful to tape grass**

- **~50% of shoots lost if salinity at Ft. Myers is ≥10 for 14 consecutive days**

- **Loss of mature shoots inhibits the potential to re-establish viable habitat through vegetative and reproductive growth**

- **Tape grass coverage and density increasing with S < 10 since 2013**

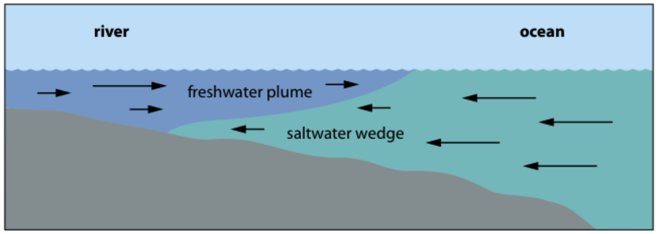
# Component Study 8: Development and Application of a Simulation Model for Tape Grass (*Vallisneria americana*) in the Caloosahatchee River Estuary

**Christopher Buzzelli, Peter Doering, Yongshan Wan**

**Coastal Ecosystems Section**

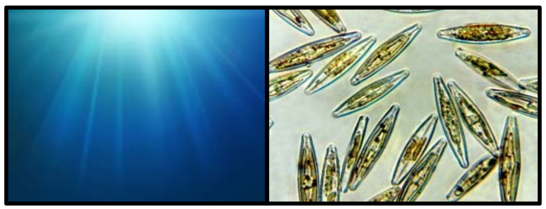
**South Florida Water Management District**

# INDICATORS OF ESTUARINE RESPONSE TO LOW INFLOW




Changes in isohaline position with upstream encroachment of saltier water

Alter benthic community upon which many estuarine fauna are dependent

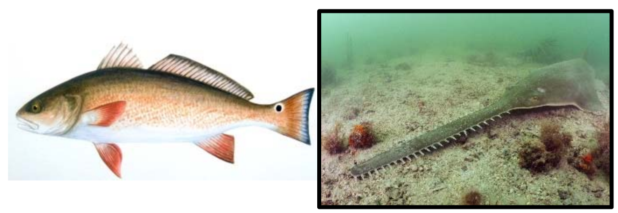


Reduced flushing and enhanced light can stimulate phytoplankton in upper estuary

Damaging to the freshwater *Vallisneria americana* (tape grass)

Impact physiology and habitat attributes of eastern oyster

Zooplankton and ichthyoplankton assemblages move upstream but can be impinged by structure



Affect coastal fish populations dependent upon estuaries as nurseries

Negatively impact harvests of important fisheries

# SCIENCE COMPONENTS / STUDIES

| | Component | Method |
|---|---|---|
| 1 | Hydrodynamics | Influence of alterations on hydrodynamics |
| 2 | Inflow vs. Salinity | Monthly freshwater-salinity relationships |
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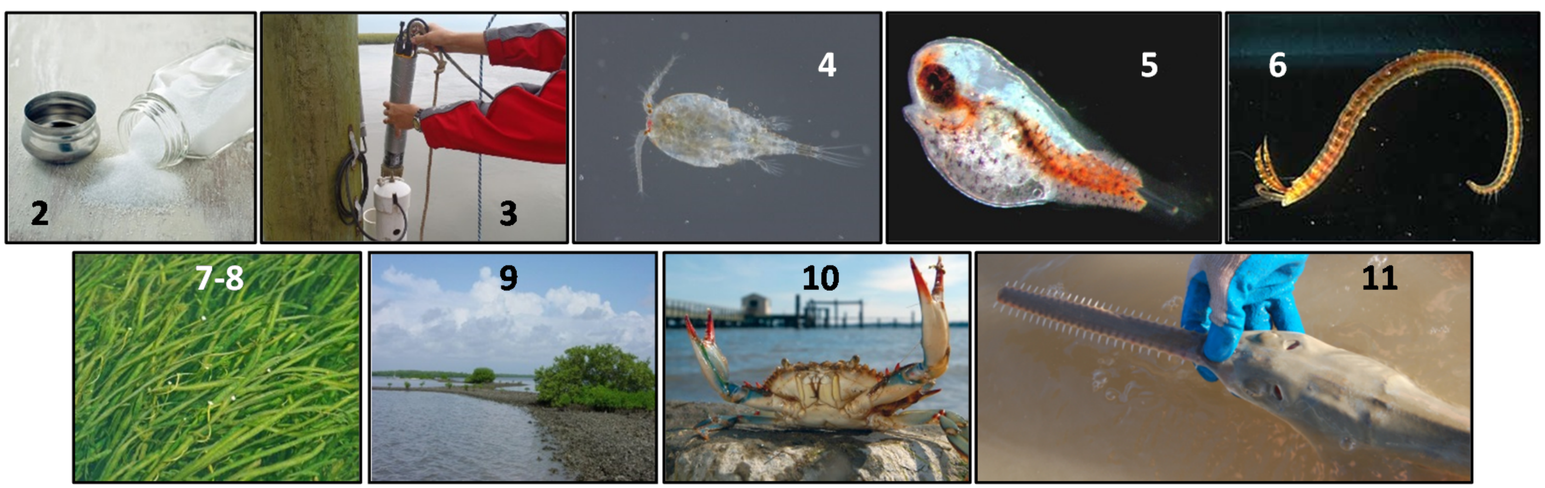


# RESEARCH COMPONENT RATIONALE

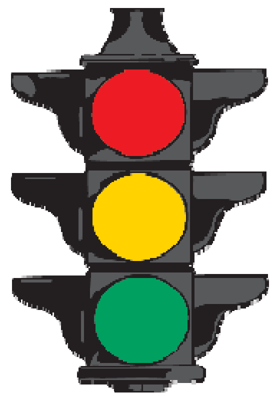
- ***Vallisneria americana*** **(tape grass)**
  - **Freshwater species of submersed aquatic vegetation (SAV)**
  - **Common in many lakes, rivers, and upper reaches of estuaries**
  - **Perennial plant capable of clonal growth through below-ground stolons**
  - **S. Florida populations actively grow year round**
  - **Ecologically important habitat for aquatic fauna**

- **Estuarine tape grass survival and growth**
  1. **Submarine light ($\geq$9% surface irradiance)**
  2. **Salinity > 10 damaging to the survival of *Vallisneria***
  3. **Grazing by herbivores can be significant**

# VALLISNERIA AS AN INDICATOR

- Application of *Vallisneria* in a resource-based approach to water management is very unique in estuarine science and possible because:
  - Most of the inflow is regulated through S-79
  - Low inflow in the dry season increases salinity throughout the estuary
  - Historically, tape grass habitat is an important resource
  - Acute sensitivity to salinity fluctuations

- Importance of modeling study
  - Model is platform to improved understanding from days-decades
  - Integrated a variety of information (laboratory, field, mesocosm, monitoring)
  - Simulate the responses to multiple, non-linear drivers (S, T, I)
  - Evaluate historic conditions that promoted or inhibited survival and growth
  - Estimate inflows which are supportive for tape grass survival
  - Quantify performance of freshwater management alternatives

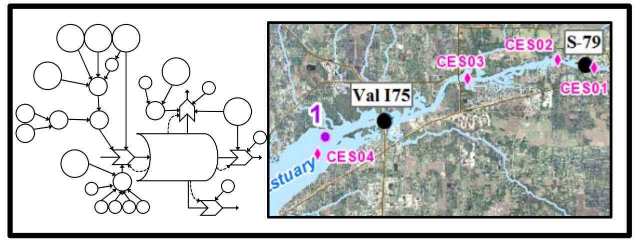


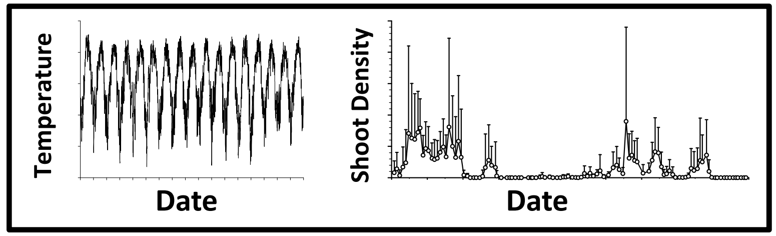
# ECOLOGICAL MODELING PROCESS

**Refinement of modeling approach**

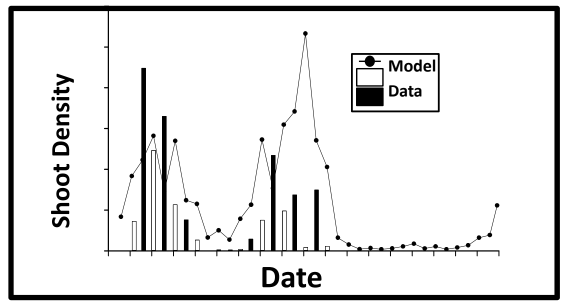
- **Ecological Question**
- **Conceptualization**
- **Data acquisition & processing**
- **Equations, calibration, testing**
- **Verification**
- **Application**

**How does tape grass respond to variable salinity?**



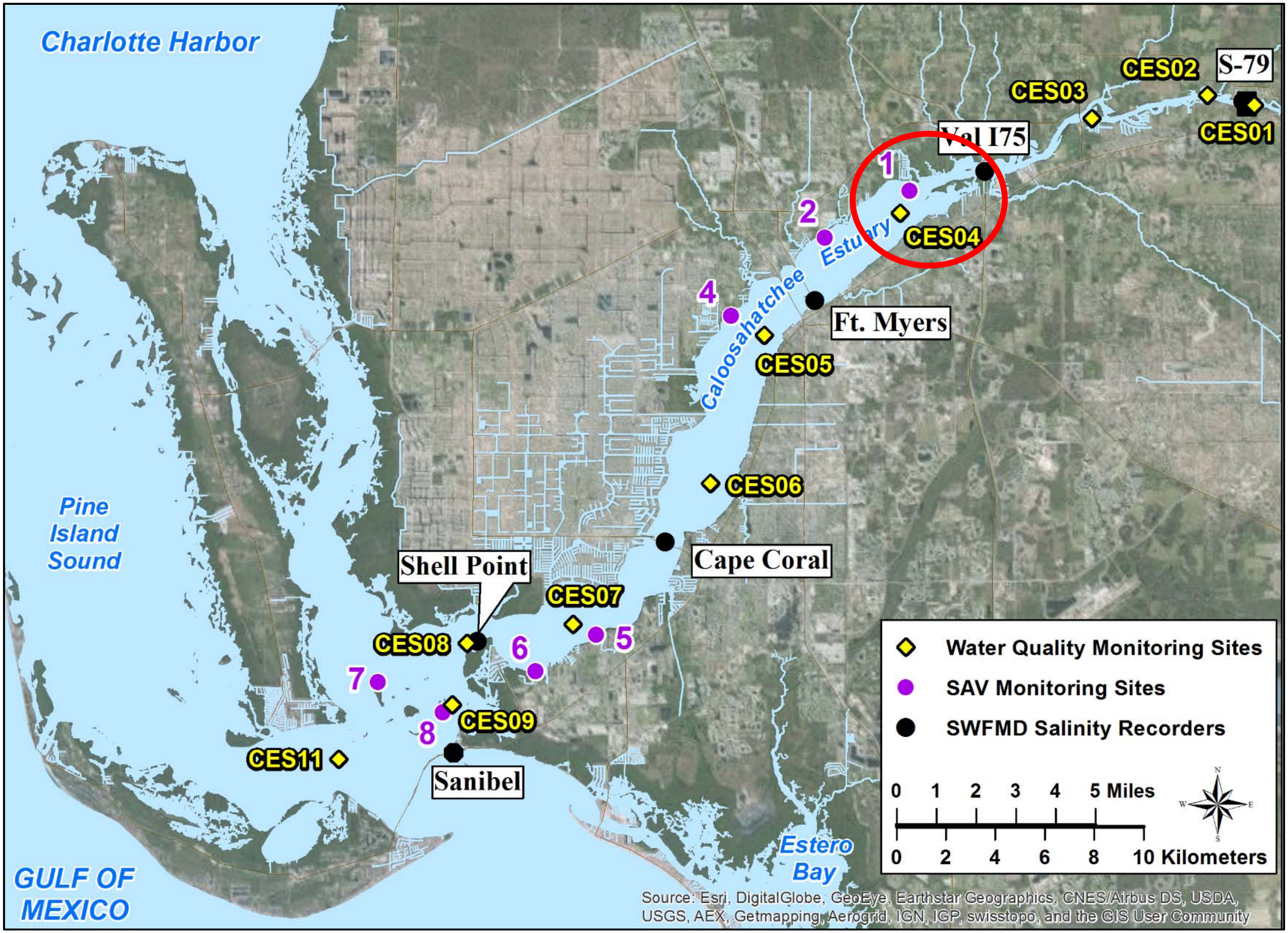

$$G_{shoot} = P_m *[\frac{I_z}{(I_k + I_z)}]* fS_{gross} * fT_{shoot} *[\frac{C_{shoot}}{C_{\max}}]*C_{shoot}$$



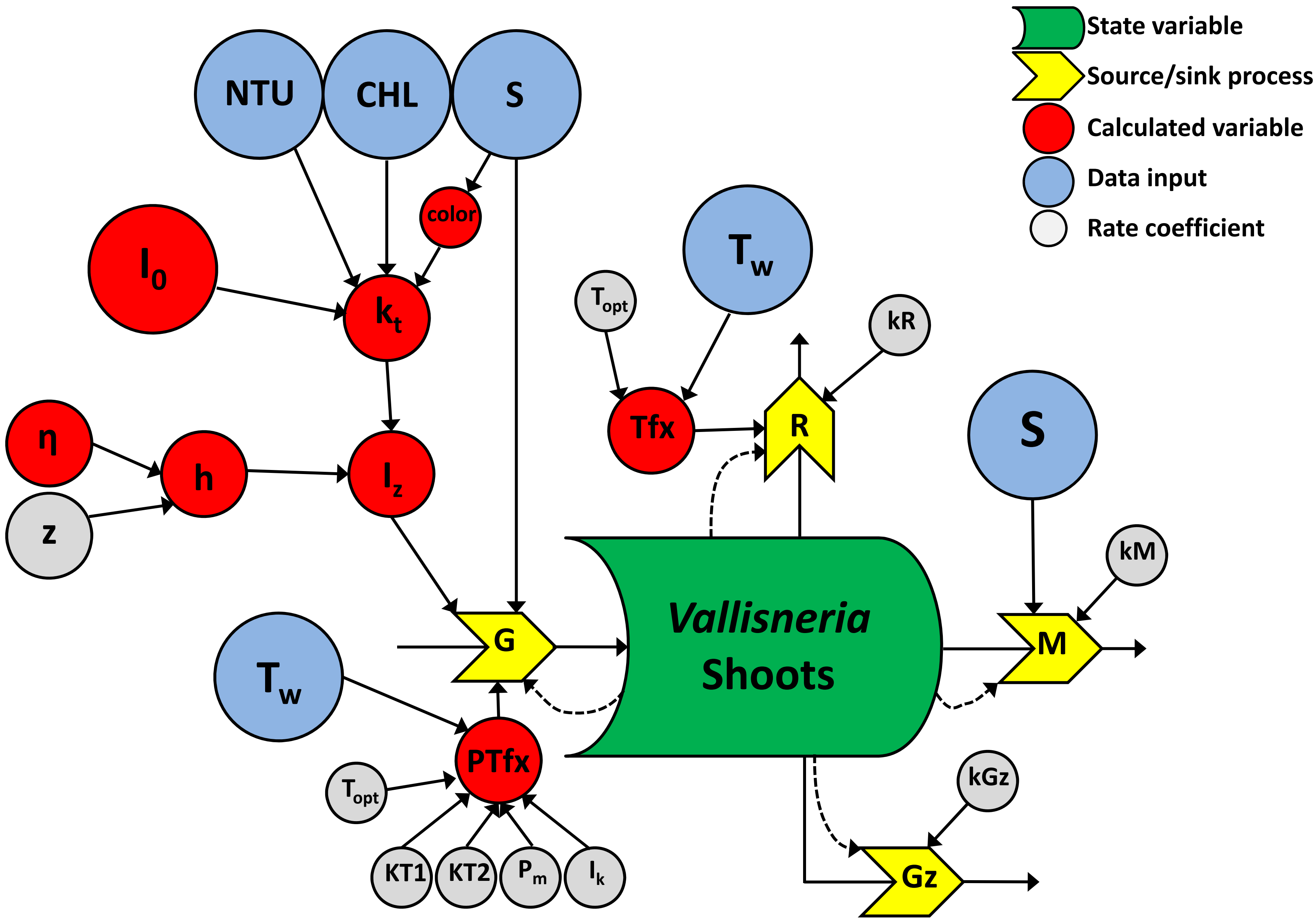

**Quantify salinity and inflows associated with mortality**

# ECOLOGICAL MODELING PROCESS

## How does tape grass respond to variable salinity?


Charlotte Harbor
S-79
CES02
CES03
CES01
Val I75
1
2
CES04
Caloosahatchee Estuary
4
Ft. Myers
CES05
Pine Island Sound
CES06
Cape Coral
Shell Point
CES07
CES08
6
5
7
CES09
8
CES11
Sanibel
Water Quality Monitoring Sites
SAV Monitoring Sites
SWFMD Salinity Recorders
0 1 2 3 4 5 Miles
0 2 4 6 8 10 Kilometers
Estero Bay
GULF OF MEXICO
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

# TAPE GRASS CONCEPTUAL MODEL



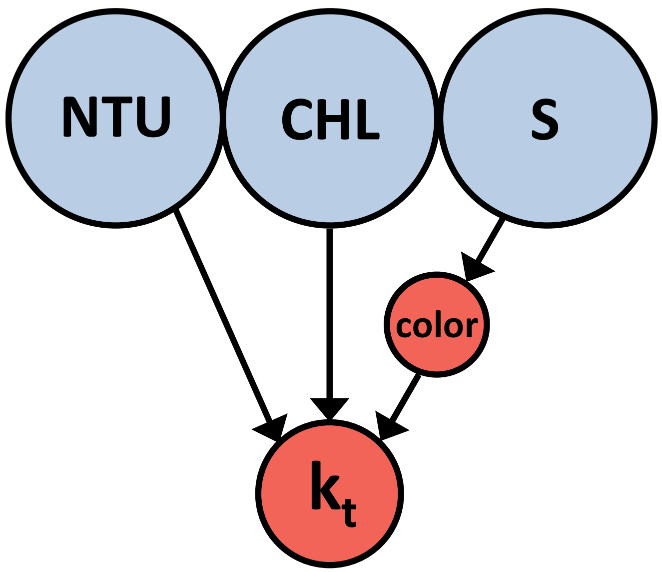
# RESEARCH COMPONENT METHODS

- Model developed to represent changes in shoot biomass (gdw $m^{-2}$) at Site 1
  - 1997-2014; 18 y; 216 months; 6574 days
  - First year (1997) used to stabilize the model (results = 1998-2014)
  - Output on daily, monthly, seasonal, annual, and inter-annual time scales

- Model Drivers
  - Water temperature at Ft. Myers from 1997-2014 ($T_w$)
    - Missing temperature data estimated using an interpolation method
    - Influences rates of gross production and respiration
  - Salinity (S)
    - Daily salinity at SAV monitoring Site 1 from 1997-2014 ($S_{val1}$)
    - Predicted using auto-regressive method
    - S effects on shoots
      - Range of 0-10
        - Increased S = decreased rate of gross production
        - Increased S = increased rate of mortality
      - S >10
        - Rate of gross production = 0.0
        - Rate of mortality = maximum

# RESEARCH COMPONENT METHODS

- Irradiance (I)
  - Surface ($I_0$) and photoperiod calculated daily
  - Surface light attenuation
    - Water depth (hourly using water level coefficients for Ft. Myers)
    - Total extinction coefficient ($k_{total}$ or $k_t$)
      - Color (negative exponential relationship with salinity)
      - Chlorophyll *a* (CHL; mg $m^{-3}$; monthly from station CES04)
      - Turbidity (NTU; monthly from station CES04)
    - Calculate percentage of surface irradiance at the bottom ($\%I_0$)



# TAPE GRASS MODEL EQUATIONS

**Change in biomass (g m$^{-2}$ d$^{-1}$)**

$$\frac{dC_{shoot}}{dt} = G_{shoot} + N_{shoot} - R_{shoot} - M_{shoot} - Gz_{Sshoot}$$

**Gross Production (g d$^{-1}$)**

$$G_{shoot} = P_m * [\frac{I_z}{(I_k + I_z)}] * fS_{gross} * fT_{shoot} * [\frac{C_{shoot}}{C_{\max}}] * C_{shoot}$$

**Temperature Effect (unitless)**

$$fT_{shoot} = IF(T_w > T_{opt}) e^{-kT2*(T_{opt} - T)^2}$$

$$fT_{shoot} = IF(T_w \le T_{opt}) e^{-kT1*(T - T_{opt})^2}$$

**New shoots (g m$^{-2}$ d$^{-1}$)**

$$N_{shoot} = C_{shoot} * kN$$

**Respiration (g m$^{-2}$ d$^{-1}$)**

$$R_{shoot} = C_{shoot} * [kR * e^{KtB(T_w - T_{opt})}]$$

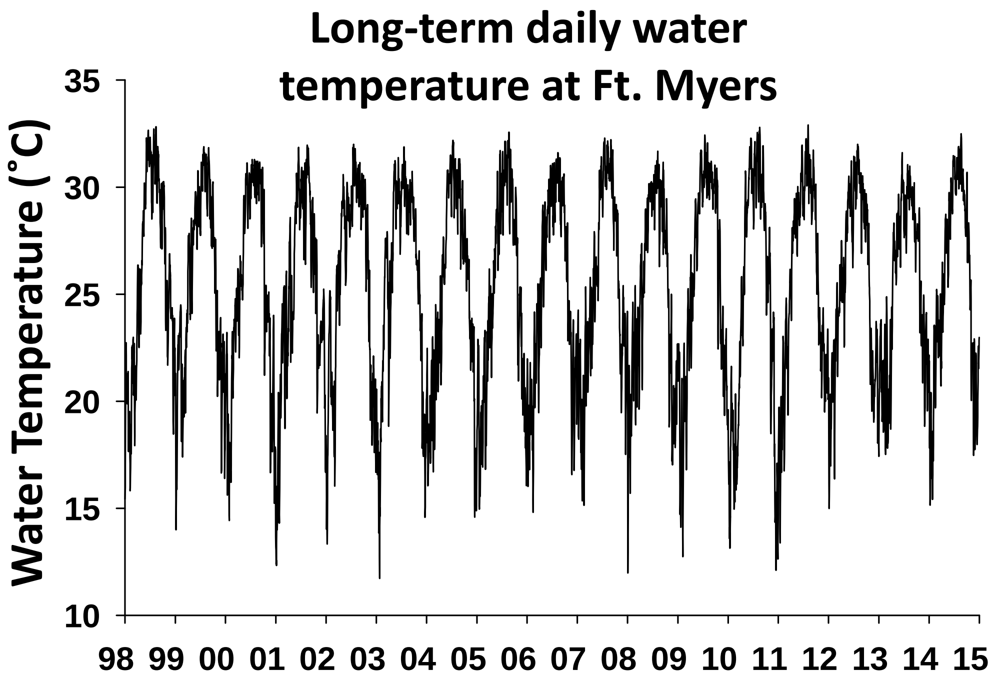
**Mortality (g m$^{-2}$ d$^{-1}$)**

$$M_{shoot} = C_{shoot} * kS_{loss} * fS_{loss}$$

**Grazing (g m$^{-2}$ d$^{-1}$)**

$$Gz_{shoot} = kGz * C_{shoot}^{\ 2}$$

# TAPE GRASS MODEL - TEMPERATURE

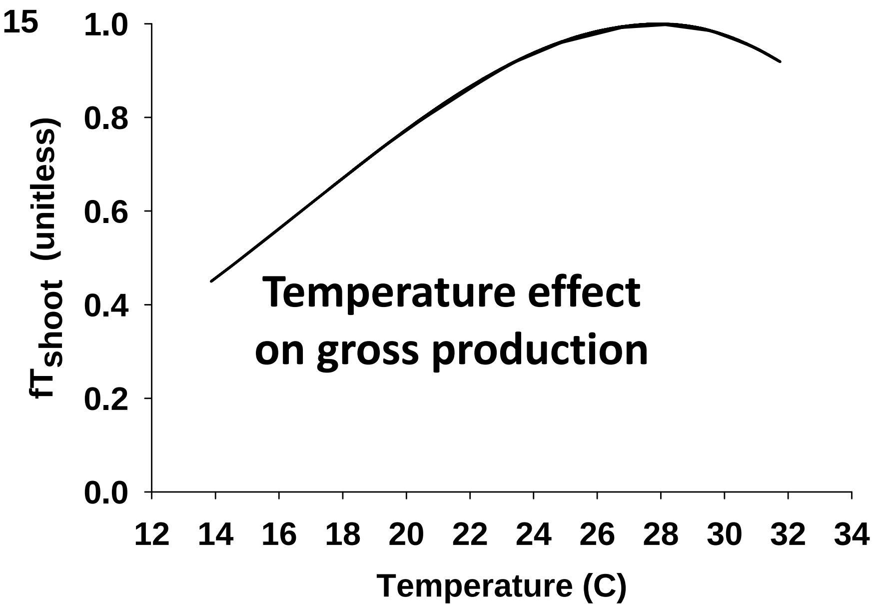



Wetlands Ecol Manage
DOI 10.1007/s11273-014-9354-6

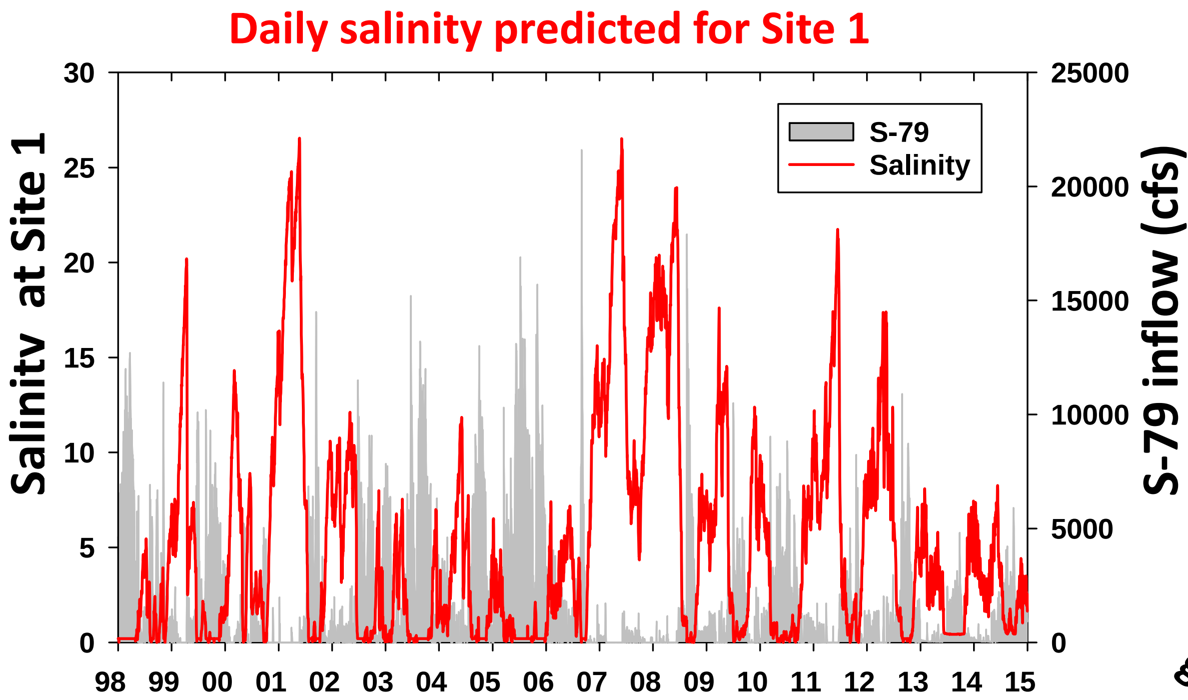
ORIGINAL PAPER

**Effects of temperature on growth of *Vallisneria americana* in a sub-tropical estuarine environment**

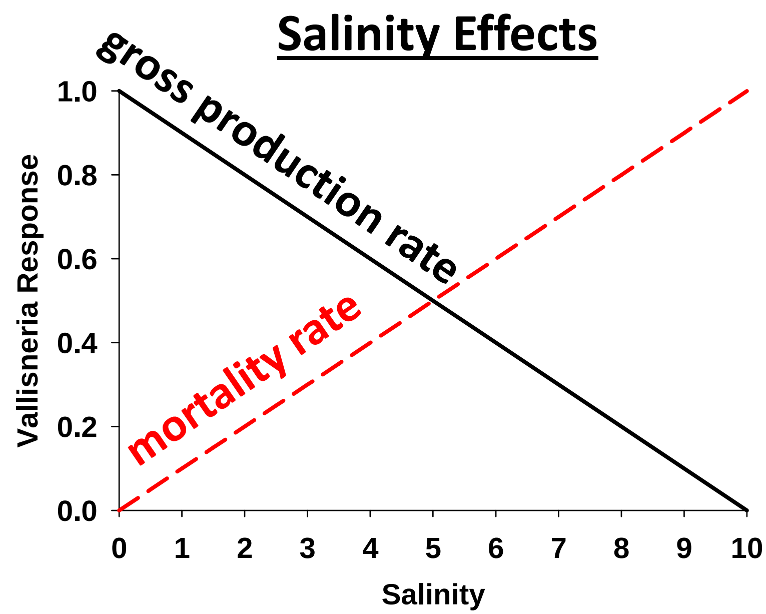
**Richard D. Bartleson · Melody J. Hunt · Peter H. Doering**



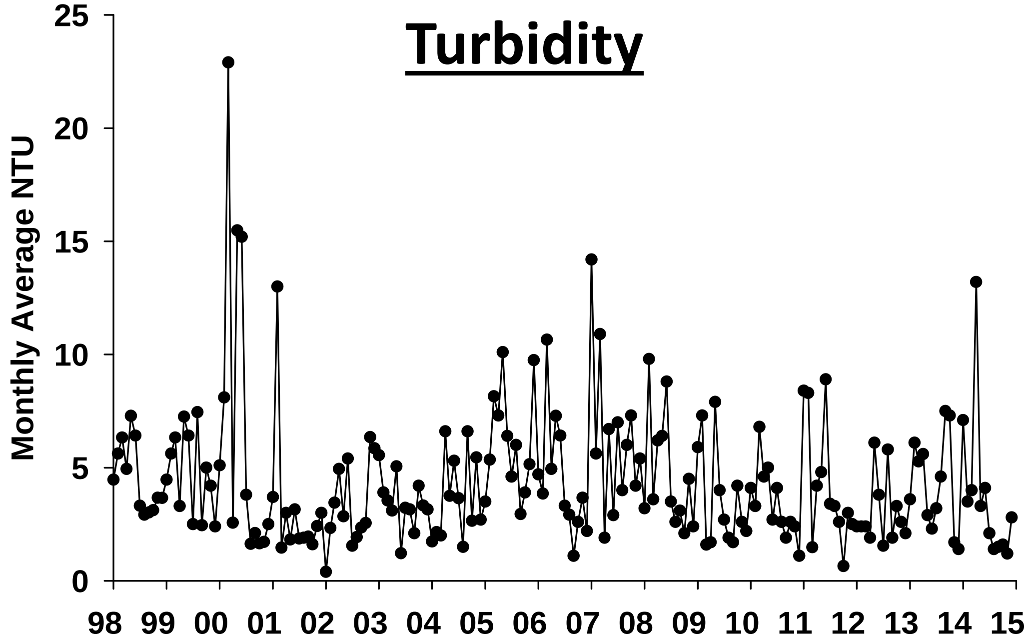
# TAPE GRASS MODEL - SALINITY

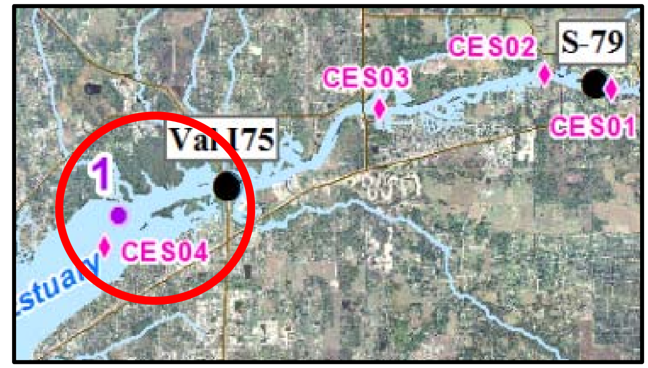


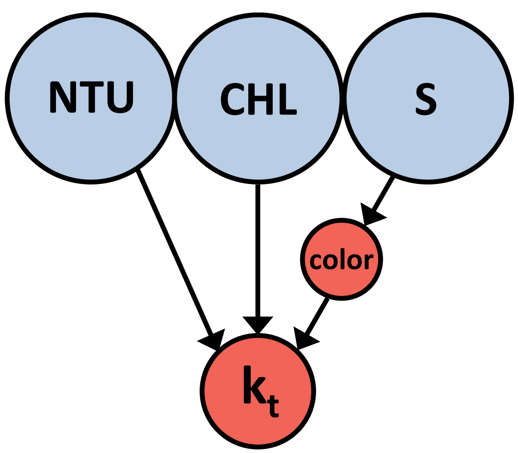

- Salinity range of 0-10
  - Increased S = decreased rate of gross production
  - Increased S = increased rate of mortality
- S >10
  - Rate of gross production = 0.0
  - Rate of mortality = maximum

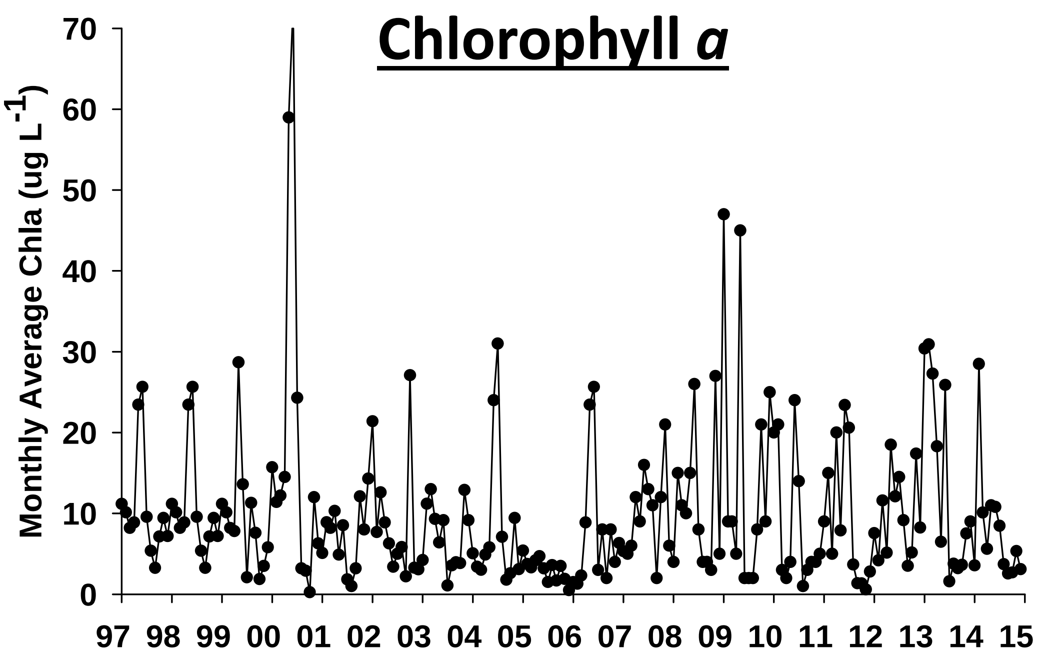


# MONTHLY DATA FOR LIGHT (CES04)

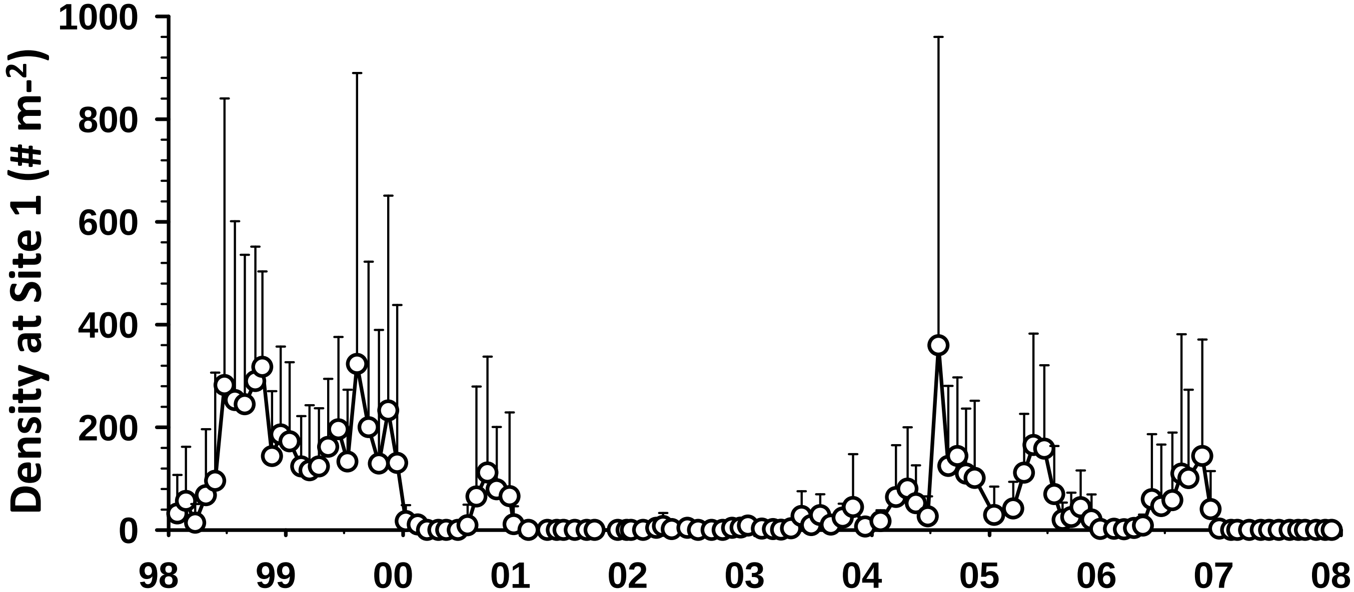


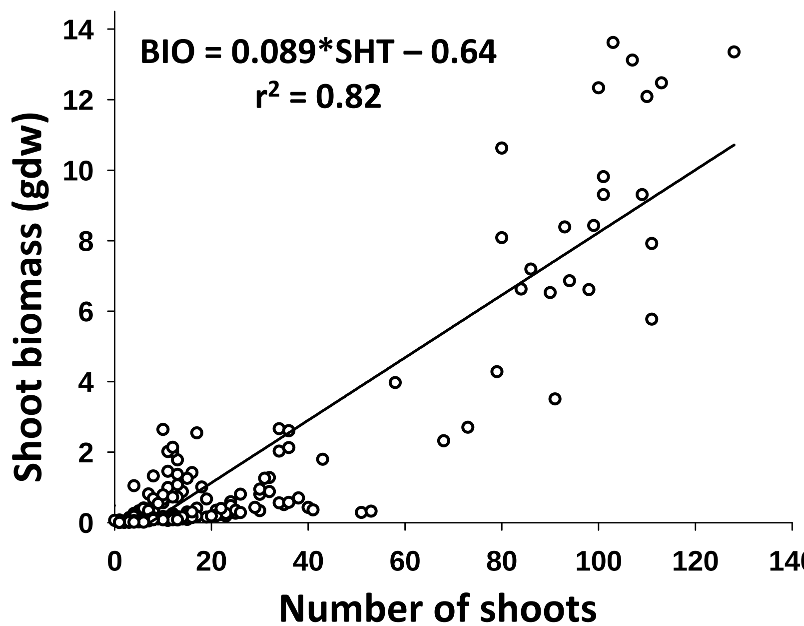



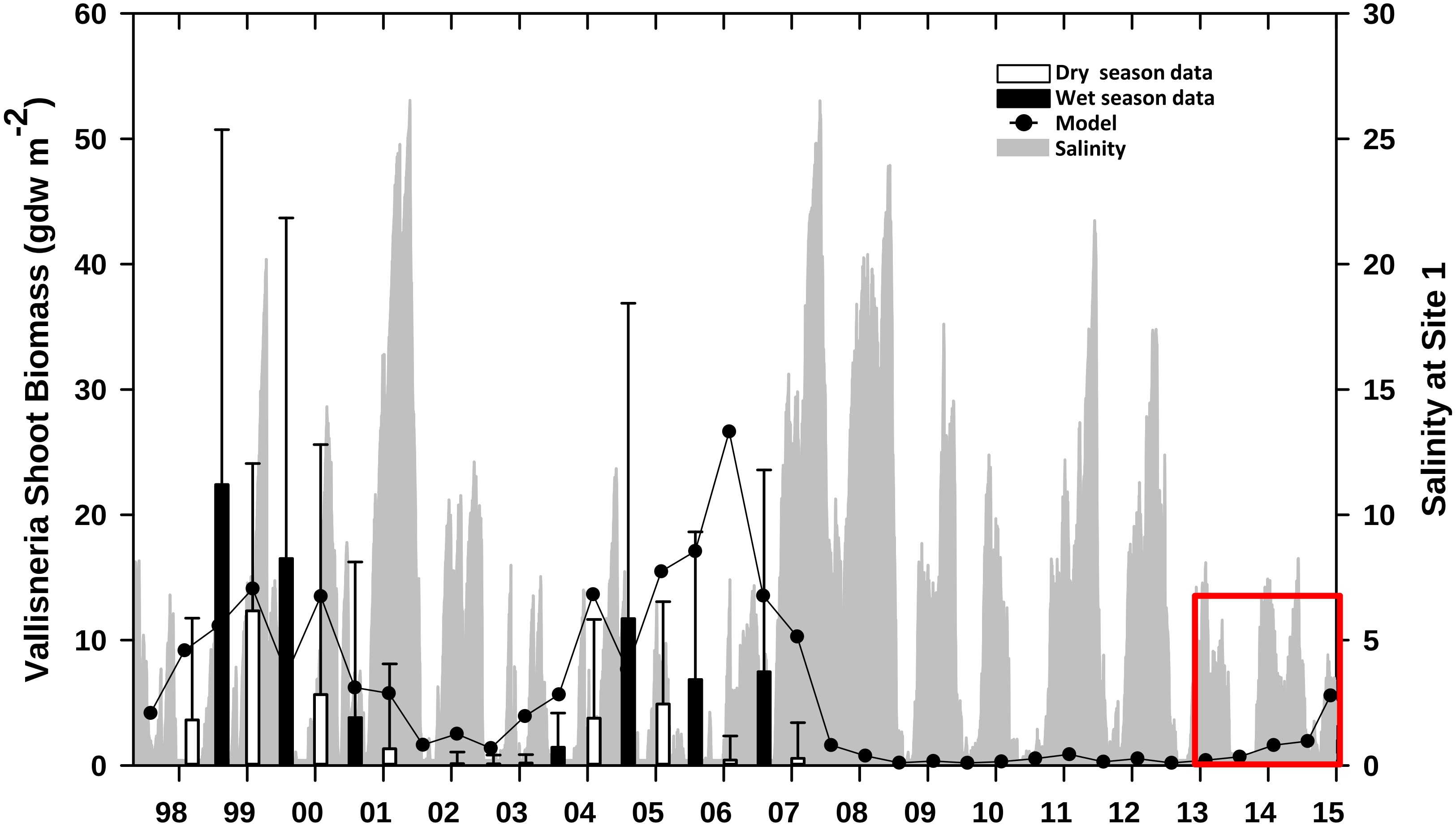
# SHOOT DENSITY & BIOMASS CONVERSION







# TAPE GRASS DATA vs. MODEL



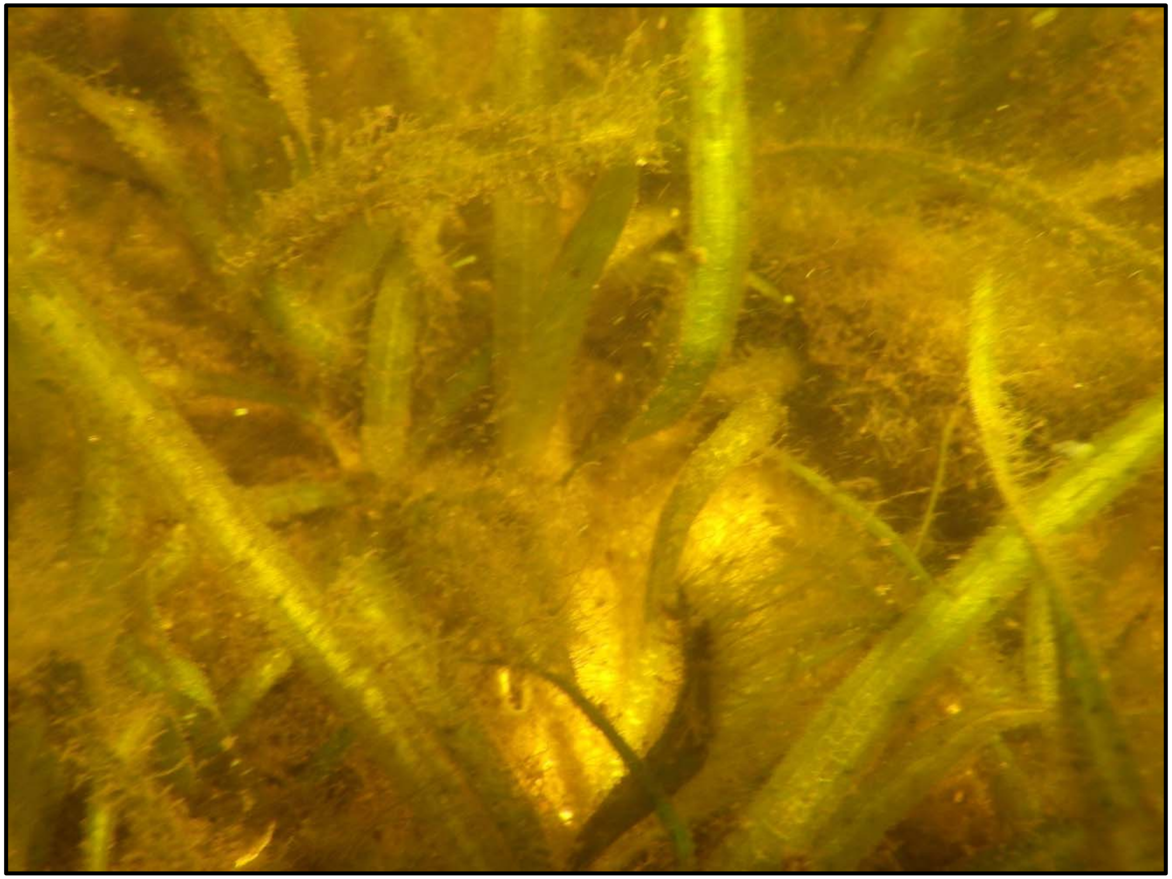

## Intra-annual

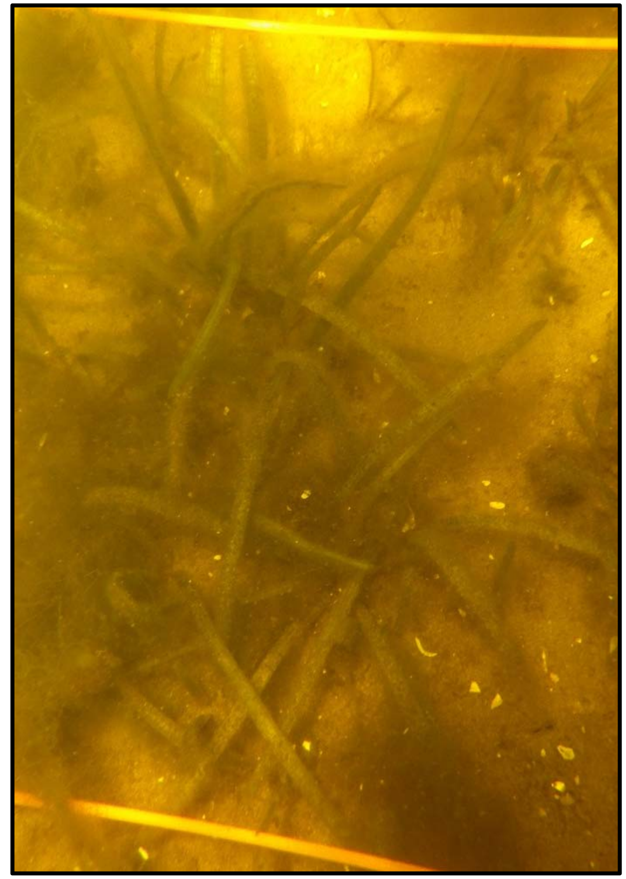
- **Biomass increases: Usually 4-6 months of wet season starting in June or July**
- **Biomass decreases: 6-8 months of dry season extending into May-June**

## Inter-annual

- **Salinity conditions occur approximately two years at a time**
- **Low salinity 1998-1999; Increased salinity 2001 and 2007-2008; Low salinity 2013-2014**

# TAPE GRASS AT SITE 1 – JUNE 2015





# TAPE GRASS MODEL – DRY SEASONS

| WY | $Q_{S79}$ (cfs) Avg±SD | $S_{val1}$ Avg±SD | T Avg±SD | $\%I_0$ Avg±SD | $C_{shoot}$ Avg±SD |
|---|---|---|---|---|---|
| 1998 | 5596±3655 | 1.2±1.9 | 21.3±2.5 | 3.3±1.4 | 9.2±2.8 |
| 1999 | 737±1606 | 7.7±5.6 | 22.8±3.0 | 8.0±5.4 | 14.1±3.1 |
| 2000 | 1412±1766 | 5.5±4.6 | 21.7±2.9 | 4.3±2.5 | 13.5±3.4 |
| 2001 | 61±269 | 16.6±5.3 | 21.1±3.9 | 15.7±6.2 | 5.8±1.7 |
| 2002 | 440±462 | 7.4±2.4 | 22.5±3.5 | 7.6±2.9 | 2.5±0.4 |
| 2003 | 1809±1948 | 2.7±2.4 | 21.7±3.9 | 4.9±2.4 | 3.9±0.9 |
| 2004 | 1358±1360 | 2.8±2.0 | 21.1±2.9 | 5.3±1.7 | 13.6±1.7 |
| 2005 | 2212±1991 | 1.8±1.5 | 21.1±3.0 | 4.2±1.0 | 15.5±1.8 |
| 2006 | 3273±3552 | 2.0±1.8 | 21.7±3.1 | 3.5±1.0 | 26.6±5.3 |
| 2007 | 128±262 | 14.7±3.9 | 21.5±2.4 | 11.9±2.9 | 10.3±4.6 |
| 2008 | 52±151 | 16.5±2.2 | 22.2±2.7 | 11.4±3.5 | 0.8±0.3 |
| 2009 | 426±340 | 8.1±3.1 | 20.9±3.0 | 7.5±5.9 | 0.3±0.1 |
| 2010 | 1117±1448 | 5.6±3.7 | 20.4±3.3 | 5.9±2.6 | 0.3±0.1 |
| 2011 | 268±371 | 8.7±2.2 | 21.2±4.4 | 7.0±2.8 | 0.9±0.3 |
| 2012 | 488±695 | 8.2±3.9 | 22.4±2.5 | 8.4±3.3 | 0.5±0.2 |
| 2013 | 371±534 | 4.0±1.6 | 21.7±2.6 | 4.0±2.6 | 0.4±0.1 |
| 2014 | 168±145 | 4.0±1.5 | 22.2±2.8 | 4.6±1.4 | 1.6±0.2 |
| Total | 1172±1117 | 6.9±2.9 | 21.6±3.1 | 6.9±2.9 | 7.1±1.6 |

# SUMMARY

- **Salinity and light modulate the survival and growth of tape grass**
  - **Productive in 1998-2000 and 2004-2006 with low salinity and light (3-8%)**
  - **Mortality in 2001 and 2007-2008 with high salinity and light (11-15%)**
  - **Photosynthetic capacity inhibited by salinity (French & Moore, 2003)**

- **Intra-annual time scales**
  - **Biomass increases**
    - **Usually 4-6 months of wet season starting in June or July**
    - **Salinity values ranging from ~1.0 to 2.0**
  - **Biomass decreases**
    - **6-8 months of dry season extending into May-June**
    - **Freshwater input near end of dry season good for tape grass**

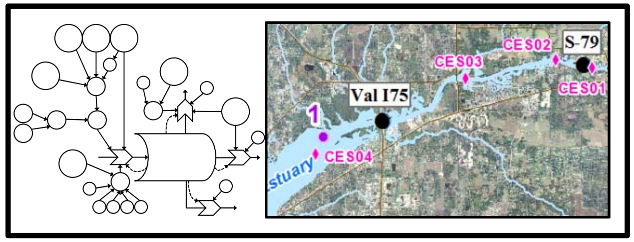
- **Inter-annual time scales**
  - **Salinity conditions occur approximately two years at a time**
  - **Salinity patterns from 1998-1999 promoted maximum *Vallisneria* shoot biomass**
  - **Increased salinity in 2007-2008 led to substantial loss of shoots**
  - **Emergence of *Vallisneria* in 2014 as $S_{val1}$ was ~4.0 in 2013-2014**

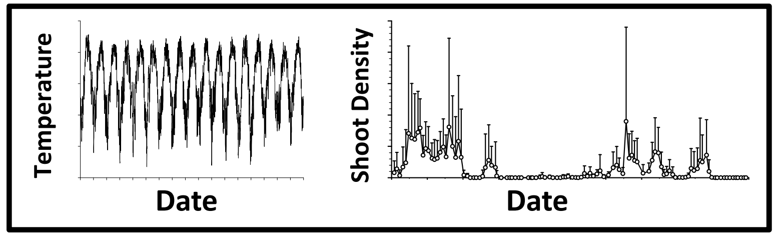
# ECOLOGICAL MODELING PROCESS

Refinement of modeling approach

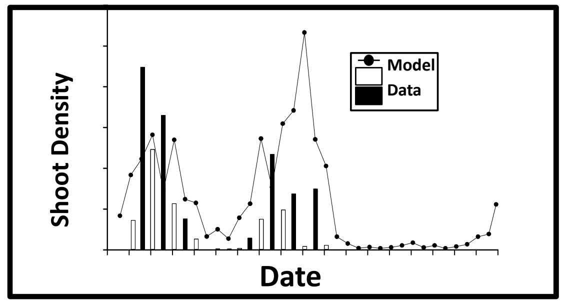
- Ecological Question
- Conceptualization
- Data acquisition & processing
- Equations, calibration, testing
- Verification
- Application

**How does tape grass respond to variable salinity?**




$$G_{shoot} = P_m * [\frac{I_z}{(I_k + I_z)}] * fS_{gross} * fT_{shoot} * [\frac{C_{shoot}}{C_{max}}] * C_{shoot}$$




**Quantify salinity and inflows associated with mortality**

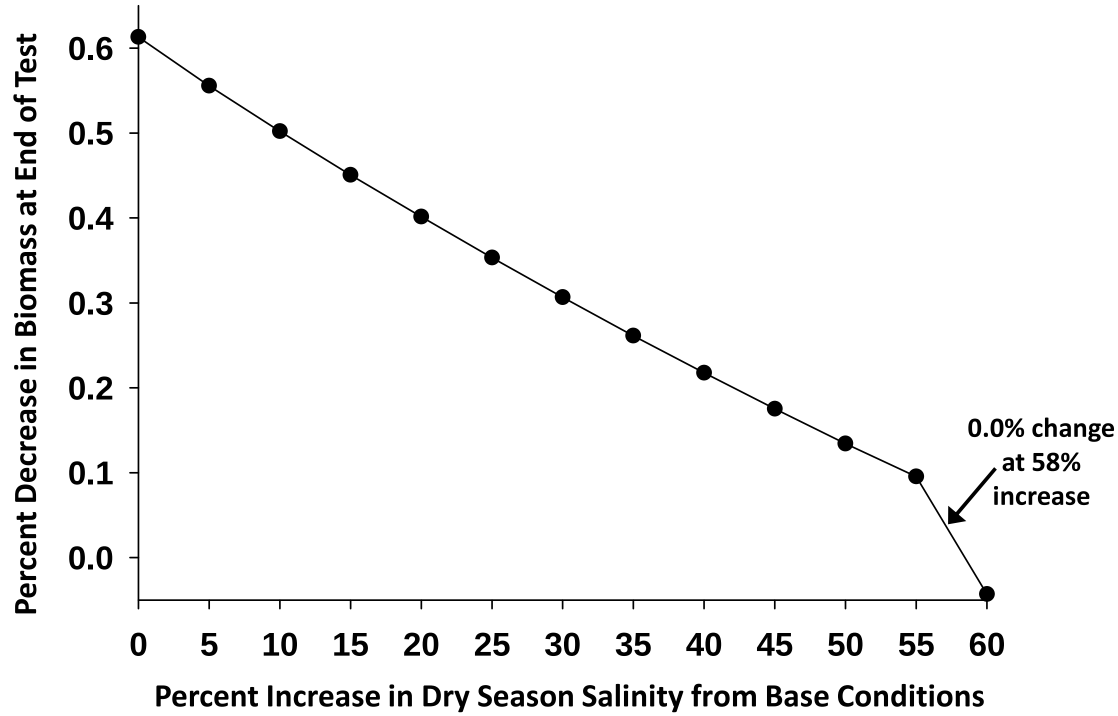
# TAPE GRASS MODEL EXPERIMENT

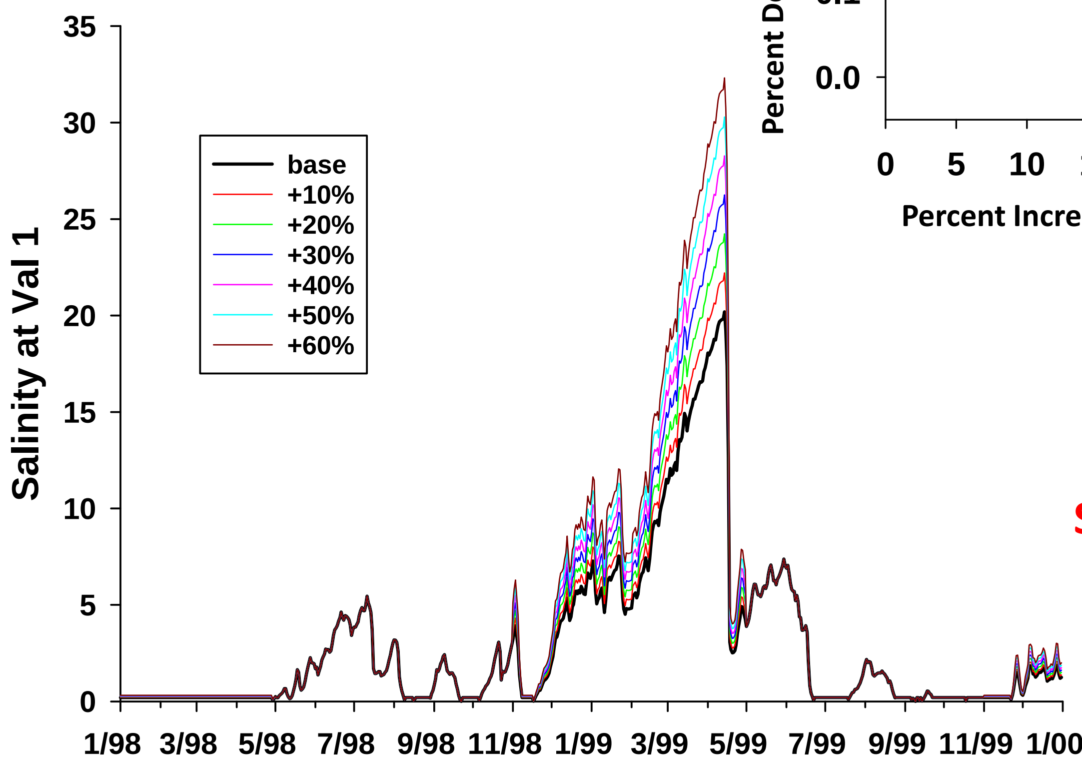
- **8 year experimental model**
  - **Loop favorable environmental conditions from 1/1/1998 to 12/31/1999**
  - **2 y x 4 loops = 8 y experimental model**
  - **Net increase in shoot biomass at the end of each 2 y interval**

- **Dry season salinity and tape grass mortality**
  - **Salinities for each day of the dry season (Nov-Apr) increased at 5% intervals**
  - **5-75% over 16 model tests (base model + 15 increased salinity tests)**
  - **Net annual decrease in shoot biomass = net mortality**
  - **Calculate salinity associated with net mortality (1999 base + %change)**
  - **Use calculated salinity to evaluate inflows**

- **Salinity (Ft. Myers) and Inflow (S-79)**
  - **5/1/1993 and 4/30/2013**
  - **Inflow-salinity relationships for 14 WY's (Component 2)**
  - **Calculate S-79 inflow associated with target salinity for each WY**
  - **Range, average, and standard deviation in calculated inflows**

# TAPE GRASS MODEL EXPERIMENT



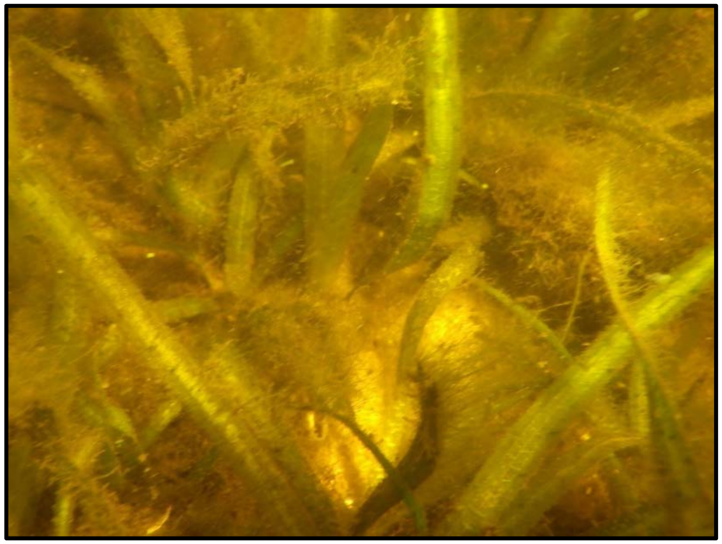

**Annual net mortality with 58% increased salinity**

$$S_{mort} = (S_{dryWY99}) + (S_{dryWY99}*0.58) = 12$$

# SUMMARY – PART 2

- **Salinity, mortality, and freshwater inflow from experimental loop model**
  - **A 58% increase in dry season salinity resulted in net annual mortality**
  - **Salinity = 12 (58% greater than dry season value in WY1999)**

- **Salinity (Ft. Myers) and Inflow (S-79)**
  - **5/1/1993 and 4/30/2013**
  - **Inflows associated with $S_{FtM}$ = 12 ranged from 15-629 cfs; 342±180 cfs**
  - **Other estimates:**
    - **Doering et al. 2002 293 cfs**
    - **Tape grass MFL Component 7 545±774 cfs**

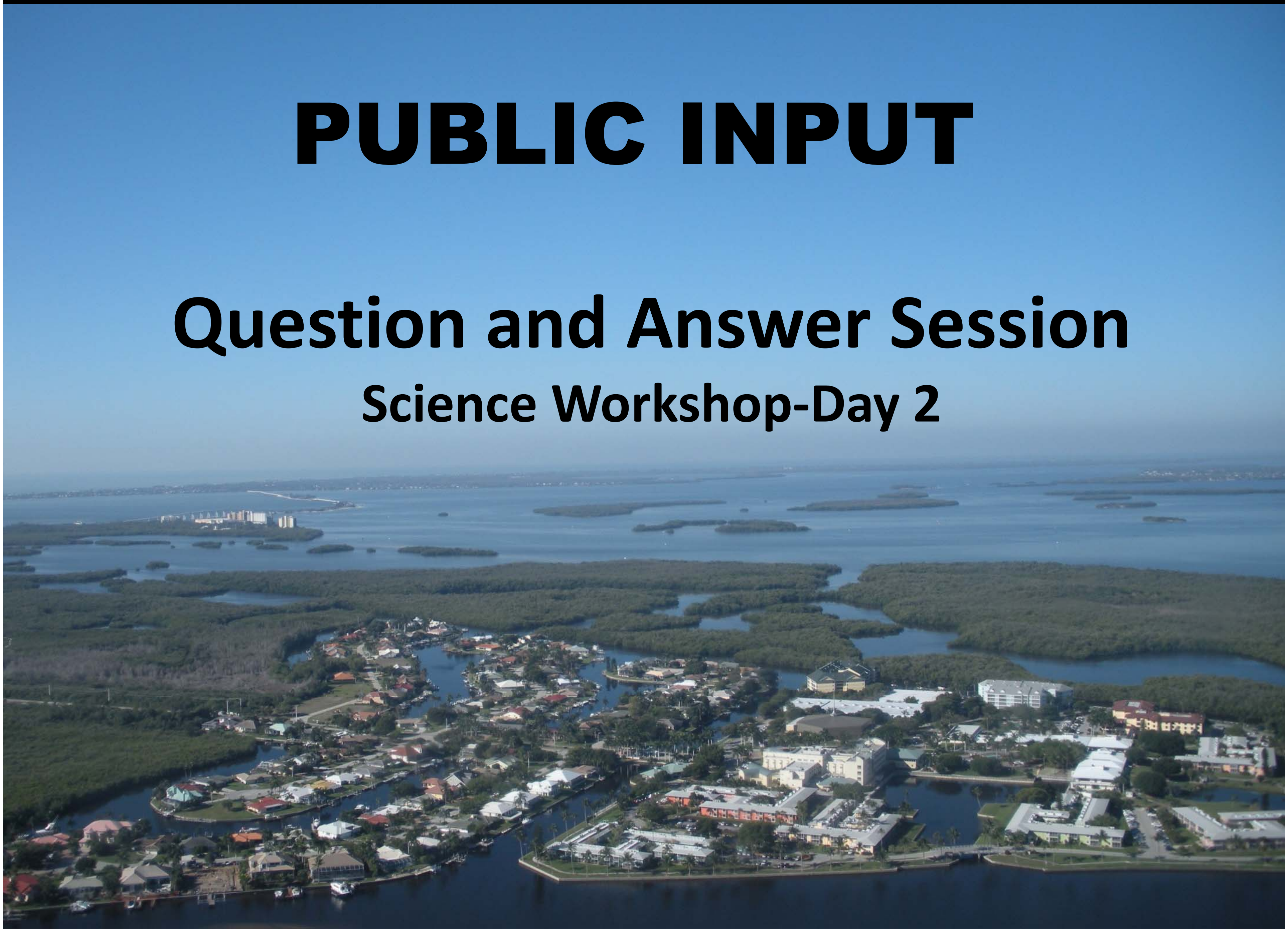


S O U T H   F L O R I D A   W A T E R   M A N A G E M E N T   D I S T R I C T

# PUBLIC INPUT

## Question and Answer Session

### Science Workshop-Day 2



# NEXT STEPS

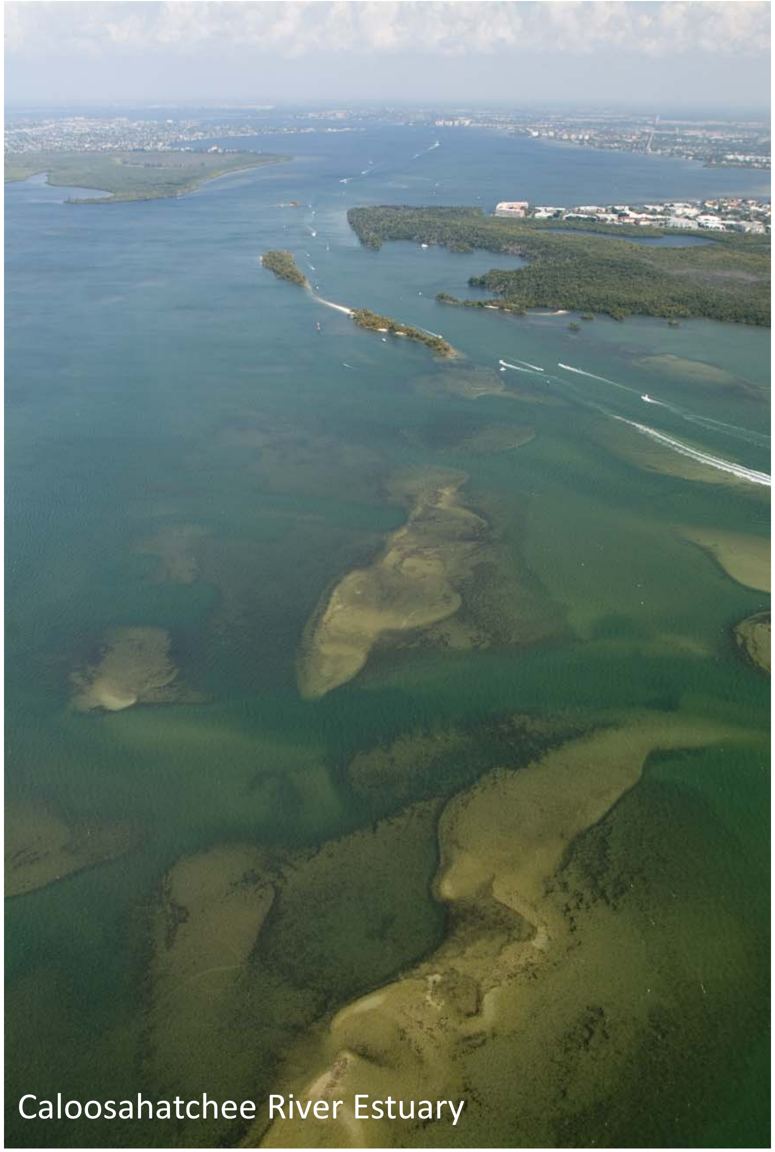
**Don Medellin, Principal Scientist**

## Caloosahatchee River and Estuary Science Symposium

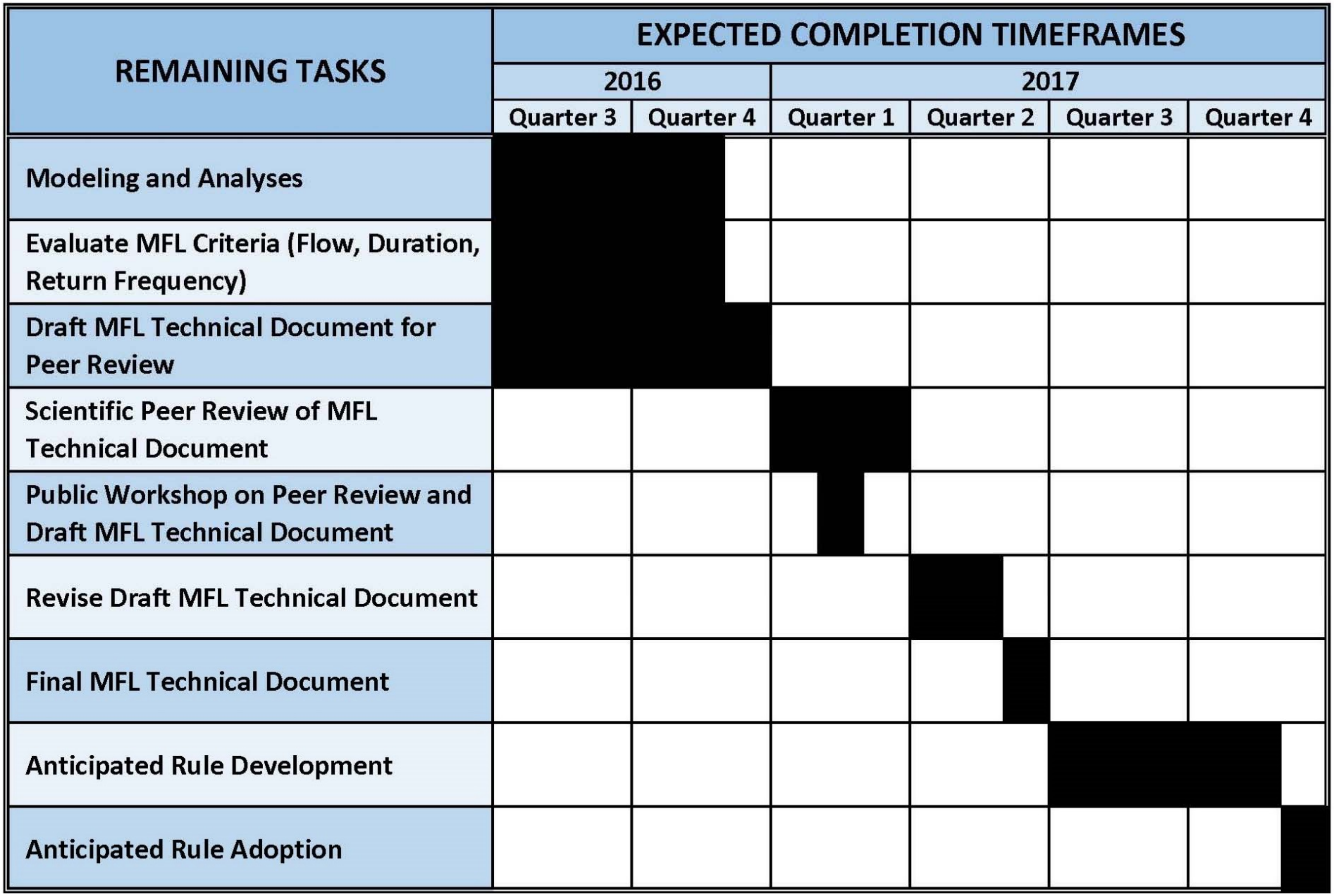
**September 15, 2016**

# Next Steps

- Receive feedback from stakeholders during the public comment period
  - 30 days prior to symposium
  - 30 days remaining – Oct. 14th
- Incorporate additional science information, where appropriate, from stakeholders after the public comment period
- Finalize the Science Document

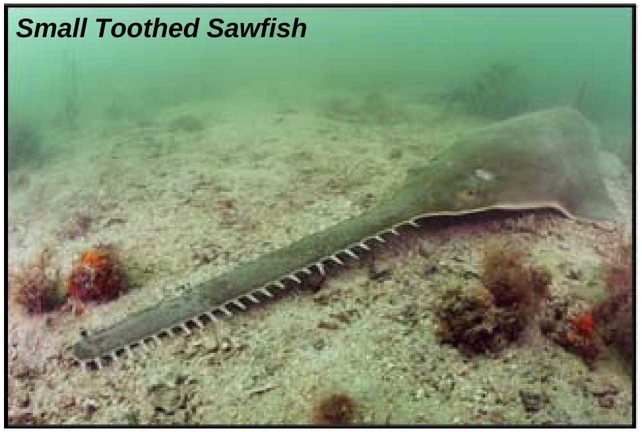

Caloosahatchee River Estuary

# Caloosahatchee MFL Re-evaluation Schedule



# Public Input

- SFWMD's web site provides information for your review: http://www.sfwmd.gov/MFLs
- ***Draft Science Document: "Assessment of the Responses of the Caloosahatchee River Estuary to Low Freshwater Inflow in the Dry Season"***
  - Science Summary and 11 Component Studies
- Public comments on the Draft Science Document are requested to be **submitted by October 14, 2016**
  - *Submit written comments to Don Medellin, Coastal Ecosystems Section dmedelli@sfwmd.gov*





Caloosahatchee River Estuary