Benthic Flux Projects:

In Support of the Northern Everglades River Watershed Research & Water Quality Monitoring Program – Caloosahatchee River Watershed

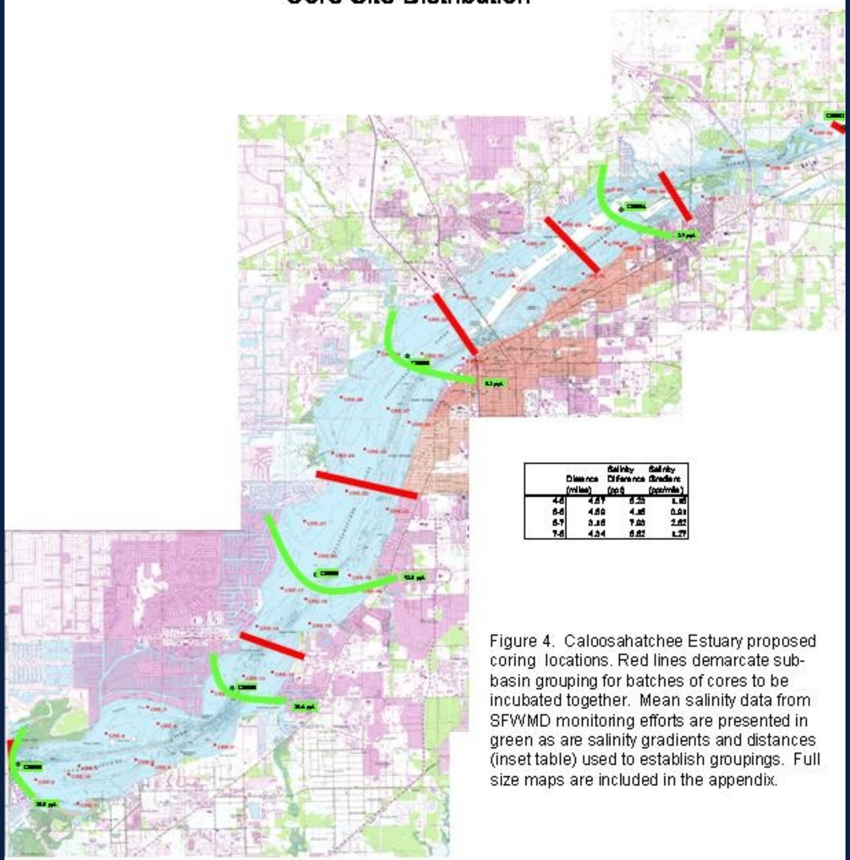
January 23, 2008

The Characterization and Quantification of Benthic Nutrient Fluxes in the Caloosahatchee River and Estuary

- Objectives
  - Provide estimates representative of system-wide benthic nutrient (Nitrogen and Phosphorus) flux rates in support of the development of a RW Research and Water Quality Monitoring Plan under the RWPP for the CRE system;
  - Identify "hot spots" of benthic nutrient flux loading to the CRE, which will serve as the focus of future research and monitoring efforts to determine temporal and event-based variation of nutrient fluxes in, and load reductions to, the CRE;
  - Provide data in support of current and future water quality modeling efforts.

50 Sites for SYSTEMWIDE Core Incubation of Benthic Nutrient Fluxes in the CRE

Caloosahatchee River Estuary
Core Site Distribution



	Distance (miles)	Salinity Difference (ppt)	Salinity Gradient (ppt/mile)
4-5	4.87	6.33	1.30
5-6	4.59	4.26	0.91
6-7	3.16	7.03	2.22
7-8	4.34	6.62	1.27

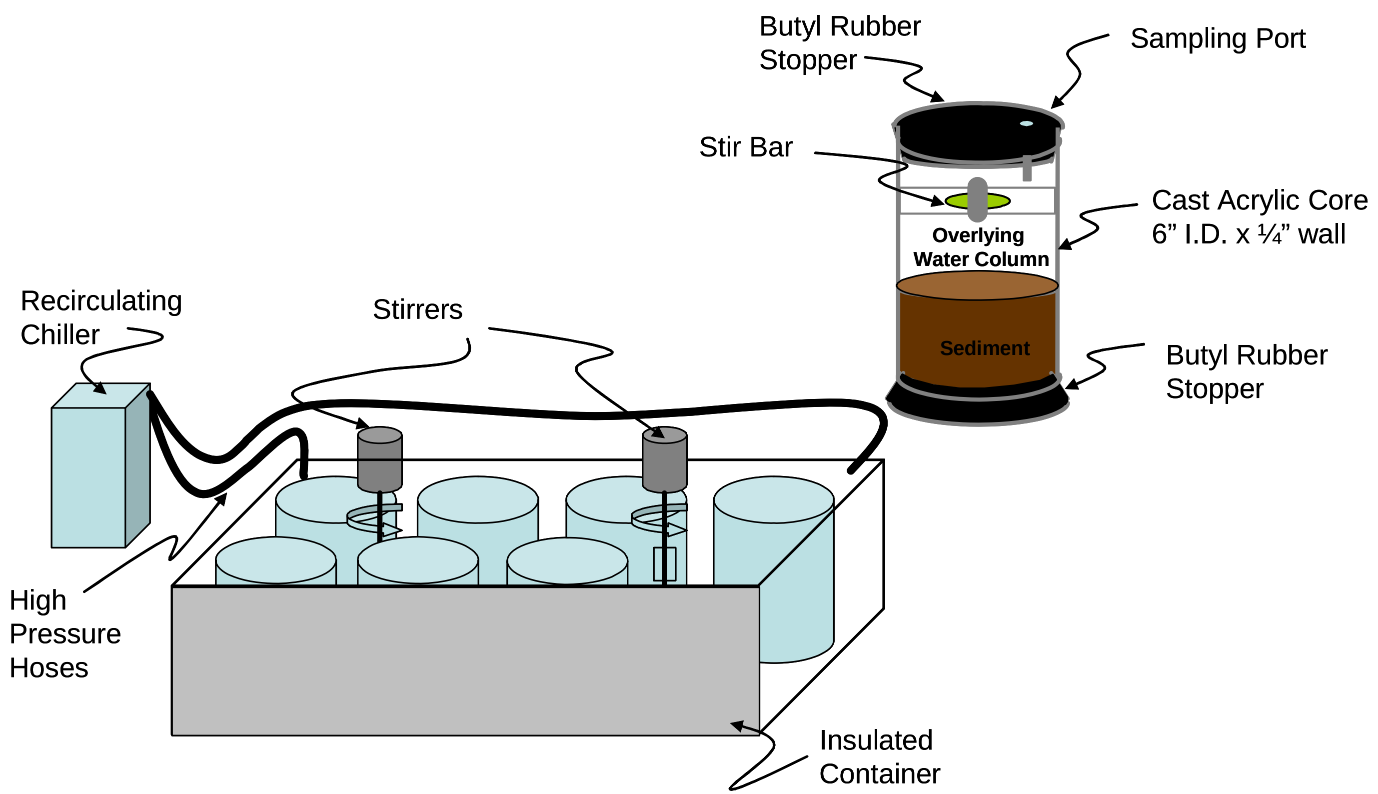
Figure 4. Caloosahatchee Estuary proposed coring locations. Red lines demarcate sub-basin grouping for batches of cores to be incubated together. Mean salinity data from SFWMD monitoring efforts are presented in green as are salinity gradients and distances (inset table) used to establish groupings. Full size maps are included in the appendix.

6 regions based on:

- Bathymetry
- Salinity

Sediment Cores: Incubation Diagram

Schematic of Sediment Flux Setup



Sample Water Column Phase

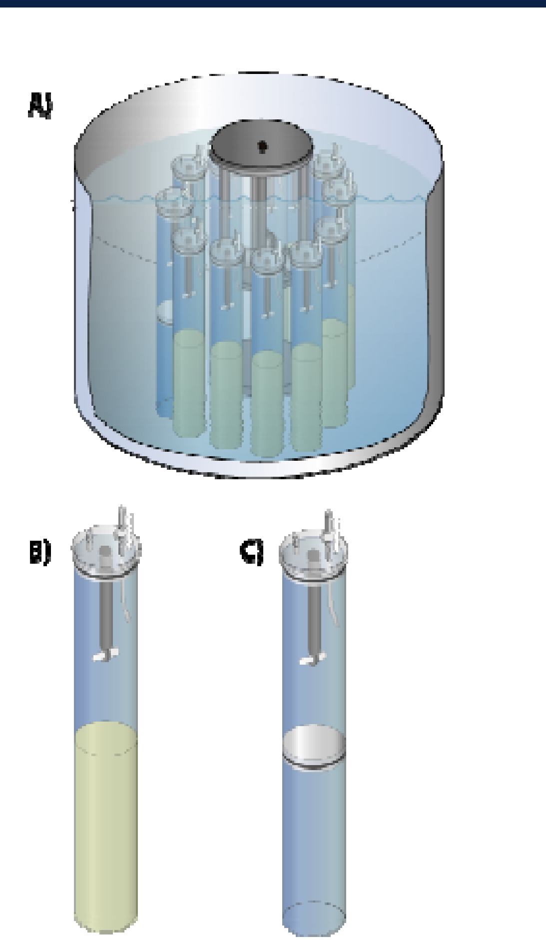
Change in N and P over time = Flux Rate

An Assessment of Processes Controlling Benthic Nutrient Fluxes in the Caloosahatchee River and Estuary and the St. Lucie River and Estuary

- Objectives
  - Determine the rates of benthic nutrient fluxes and environmental factors controlling these rates in the CRE and SLRE (i.e. groundwater vs. diffusion);
  - Identify the methodology (i.e. *in situ* vs. remote remote cores) needed to ensure the accurate measurement of benthic nutrient fluxes for application in future research and monitoring efforts to determine temporal and event based variation in support for current and future WQ modeling efforts;
  - Provide current data for comparison/verification of questionably high benthic nutrient fluxes previously measured in the SLRE system (2000-2001).

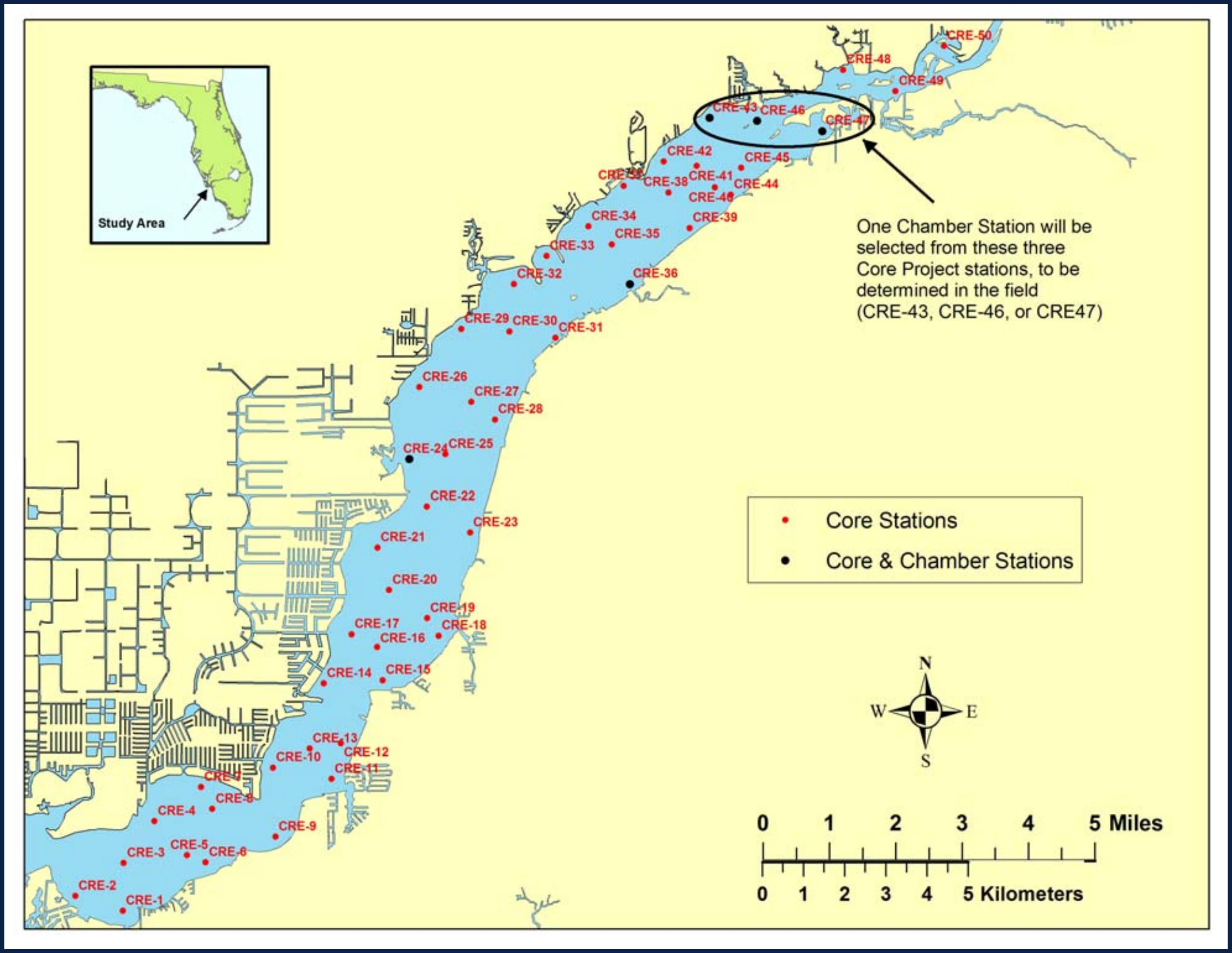
Sediment Chambers/Cores: Incubation Diagram

Remotely Incubated Cores



In Situ Chambers

Proposed Sites for Chamber and Core Incubations of Benthic Nutrient Fluxes in the CRE



Parameters:

In Situ Water Column	Incubation Water Column	Incubation Pore Water	Core Sediment Surface
Dissolved Oxygen	Dissolved Oxygen	Dissolved Oxygen	Chlorophyll *a*
Dissolved Silica	Dissolved Silica	Dissolved Silica	CPN
NH_4	NH_4	NH_4	Grain Size
NO_x	NO_x	NO_x	
DIP	DIP	DIP	
DON	DON	DON	
DOP	DOP	DOP	
TN	N_2		
TP			
Depth			
Temperature			
Salinity			
PAR (Sediment Surface)			
Chlorophyll *a*			

- Homogenous water column
- Light and Dark Incubations
- Water Column DO maintained above 50% saturation throughout

Products:

1. **Flux Rates of N and P at 50 (4) locations within the CRE: Identify sediments as sources or sinks for N and P on two (2) scales:**
   - **Locally (source "hot spots")**
   - **Regionally (i.e. systemwide)**
   - ❖ **Representative of fluxes during the dry season in a drought year**
2. **Provide a map of sediment type (fine, medium, coarse) – insight into distributions of benthic flora and fauna (e.g. potential oyster habitat)**
3. **Identify future sediment flux monitoring needs**
   - **spatial heterogeneity (how many sites needed)**
   - **importance of sediment inputs relative to surface loads**
   - **extent of sediment denitrification**
   - **realistic sediment oxygen demands (dark measurements)**
4. **Comparison of measurements between groups and methodology – validation of *in situ* vs. remote incubations**

Schedule:

1. 1/4/08: KickOff Meeting
2. Field Work
   - 2/(4-7)/08 Systemwide Cores
   - 2/(11-14)/08 Chambers/Cores
3. 3/08: Sample Analyses/Progress Report
4. 4/08: Data Analyses/Draft Final Report
5. 5/08: Final Project Report

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

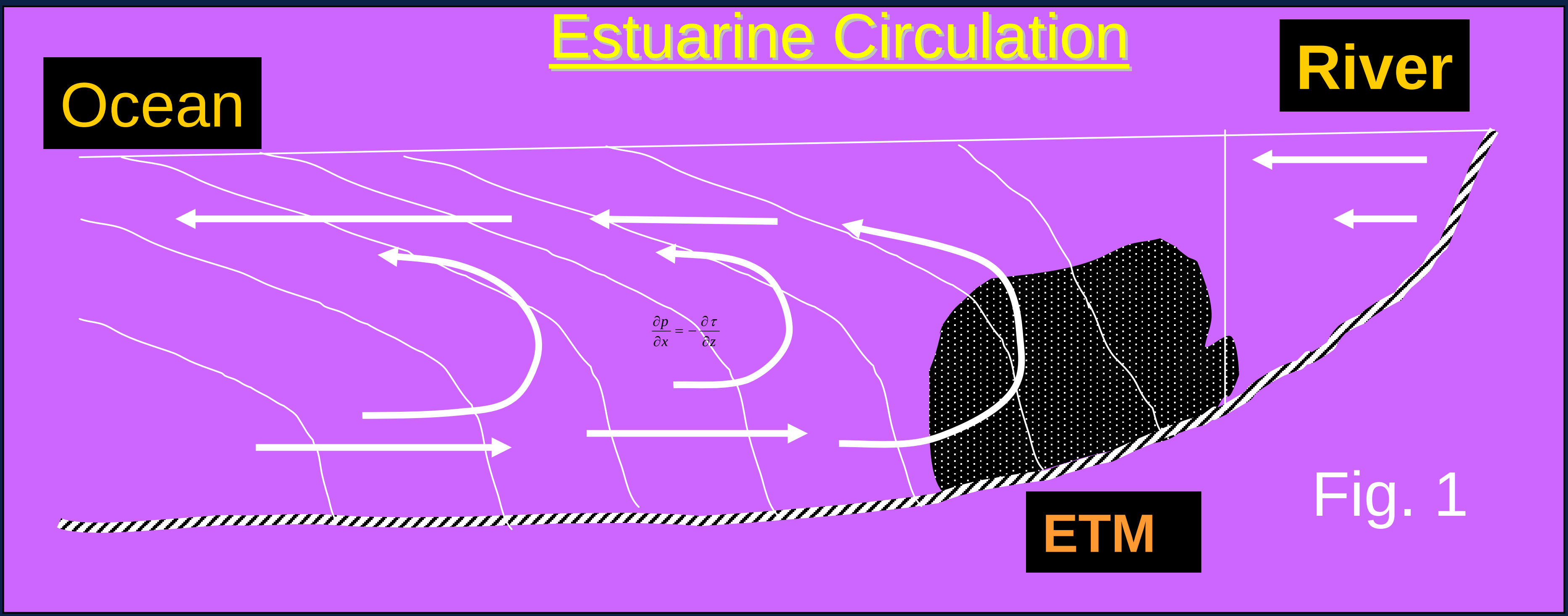
Dynamics of Estuarine Turbidity Maxima (ETM) in Caloosahatchee

Coastal Ecosystem
SFWMD
January 2008

sfwmd.gov

What is (Estuary Turbidity Maximum) ETM ?

Strong tidal forces push salinity upriver beneath the outflowing river water. The turbulence caused by this tidal forcing results in resuspension of sediment and other particulate material present on the river bed. Concurrently, dissolved material in the river water flocculates when it comes into contact with the salt wedge pushing its way upriver.


Estuarine Circulation
Ocean
River
$\frac{\partial p}{\partial x} = -\frac{\partial \tau}{\partial z}$
ETM
Fig. 1

Importance of ETM

- Abundant food and stable stratification in the ETM enhance feeding conditions and production of zooplankton and fish larvae.
- Excess turbidity can also be detrimental to the ecosystem by shading and killing sea grasses or adversely affect oyster beds.
- ETM dynamics are a result of complex interactions between hydrodynamic tidal processes, freshwater discharge, nutrient loading and mobile pools of sediment within an estuary.

Objectives

- The goal is to identify and evaluate the vertical and horizontal density and turbidity structure with respect to DO, salinity, and/or Chl-a stratification.
- The results of this project will be used for the development and calibration of a numerical sediment transport model that can be used to predict the location and strength of ETM and how it relates to the performance of ongoing efforts to improve water quality and quantity.

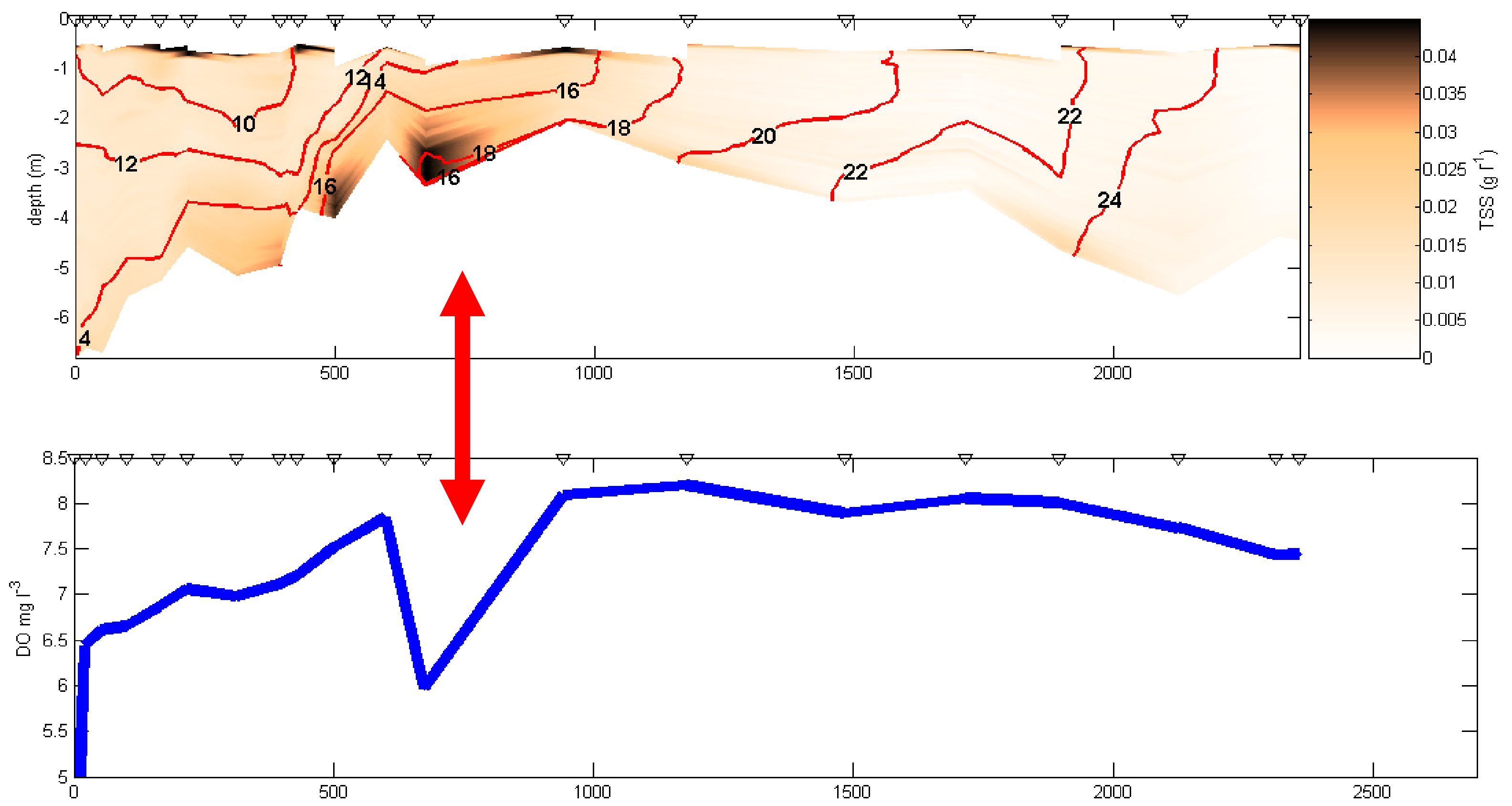
Methods

- Profiles will initially be made every 500 m. Once the extent of the salinity intrusion is encountered (10ppt), profiles will be made about every 100 m to obtain a high resolution of the salinity front and associated ETM.
- Data collected from profiles made during the transects will be used to map out the 2D longitudinal and vertical density structure and turbidity structure for each transect.
- Bulk water samples will be collected to estimate the density, size, and settling velocity of suspended aggregates in the water column.

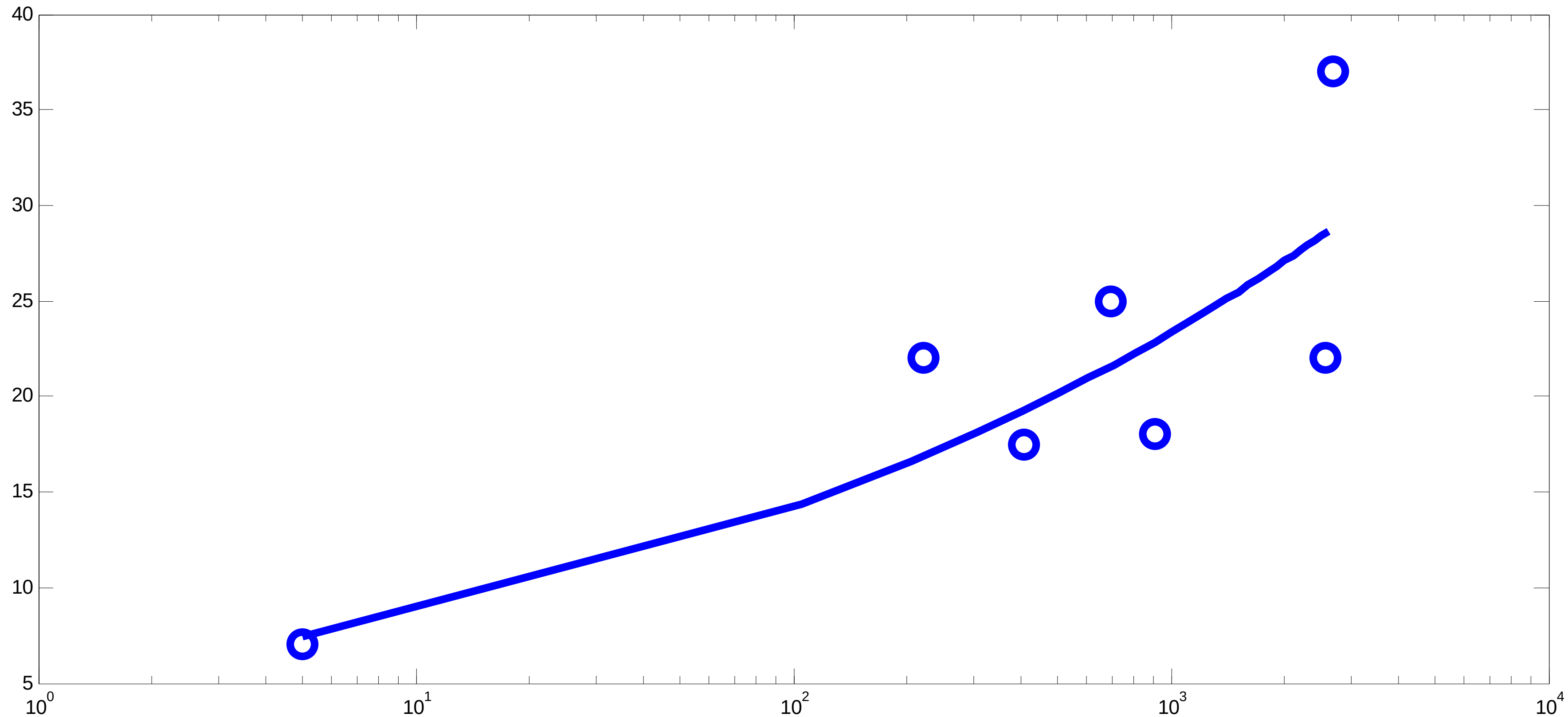
Sampling Schedule

Sampling Date	Spring/Neap	Phase
1/8/08	Spring	Slack after ebb
2/7/08	Spring	Slack after flood
2/28/08	Neap	Slack after flood
3/15/08	Neap	Slack after flood

Sampling Transects from Previous Studies



3 Day Avg of Discharge from Franklin Locks (cfs)



SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Mixing and Degradation of Riverine Dissolved Organic Nitrogen in the Caloosahatchee Estuary

January 23, 2008

sfwmd.gov

Nutrient Limitation in CRE

- **Bioassay experiments conducted during the FDNR study (DeGrove, 1981) indicated:**
  - **nitrogen limitation in the upper estuary**
  - **phosphorus limitation in the lower estuary**
- **Indirect evidence summarized by Doering and Chamberlain (2005) and Doering et al (2006) indicates:**
  - **nitrogen predominately limits micro-algal growth in the Caloosahatchee, although depending on location, phosphorus can also be limiting**

Nutrient Limitation in CRE

- According to measurements from monitoring programs:
  - About 20% of the nitrogen load entering the head of the estuary at S-79 is inorganic & immediately available for uptake by algae, bacteria and other plants
  - Remainder (80%) of the nitrogen load is organic
    - Few data that are available suggest that the large majority of this organic nitrogen is dissolved.
  - Nutrient Management Question: How much of this dissolved organic nitrogen (DON) can become available to support phytoplankton production?

Previous Studies

- District has funded a project to examine:
  - Conduct nutrient limitation bioassays
  - Examine the susceptibility of DON in the downstream estuary to bacterial degradation
- So far:
  - Phytoplankton appear N-limited
  - Total Dissolved Nitrogen is mainly DON (100 – 700 ug/l) with DIN (7-180 ug/l) a smaller fraction.

Objectives

- This study builds on the previous work by
  - Characterizing the DON from the freshwater Caloosahatchee River
  - Examining the estuarine mixing behavior of river borne DON in laboratory experiments and in the field
  - Determining the susceptibility of river borne DON from the freshwater Caloosahatchee River to:
    - a) Remineralization by estuarine bacteria
    - b) Photolysis

Station Locations in the CRE

Materials and Methods

- ***Synoptic Field Surveys***
  - **Three synoptic field surveys- December 2007, January and February 2008**
  - **10 stations in CRE**
  - ***Field Measurements:*** **Dissolved oxygen, salinity and temperature at the surface (0.5m) at each station**
  - ***Laboratory analysis*****: DIN (as nitrite, NO_2^-; nitrate, NO_3^-& ammonium, NH_4^+) and TDN (Loh and Bauer, 2000)**
    - **[DON] = [TDN] - [DIN]**
    - **Particulate nitrogen (PN) will also be analyzed – upstream of S-79**

Materials and Methods

- *Laboratory Mixing Experiments*
  - Water for mixing experiments collected in December 2007 and January 2008 surveys.
  - These experiments will examine the transformation of organic nitrogen from the dissolved to particulate phase as a function of salinity (Sholkovitz 1976; Sholkovitz et al. 1978)

Materials and Methods

- ***Bacterial Degradation Experiments***
  - **Two experiments will be conducted in January and February 2008 at upstream of S-79.**
  - **Examine the susceptibility of river borne DON to degradation by estuarine bacterial communities**
  - **Experiments will be modeled after Seitzinger and Sanders (1997), with some modifications.**

Materials and Methods

- ***Photochemical Degradation Experiments***
  - **One experiment will be done in February 2008 at the upstream of S-79**
  - **Examine the susceptibility of river borne DON to photochemical degradation by natural sunlight**

Schedule

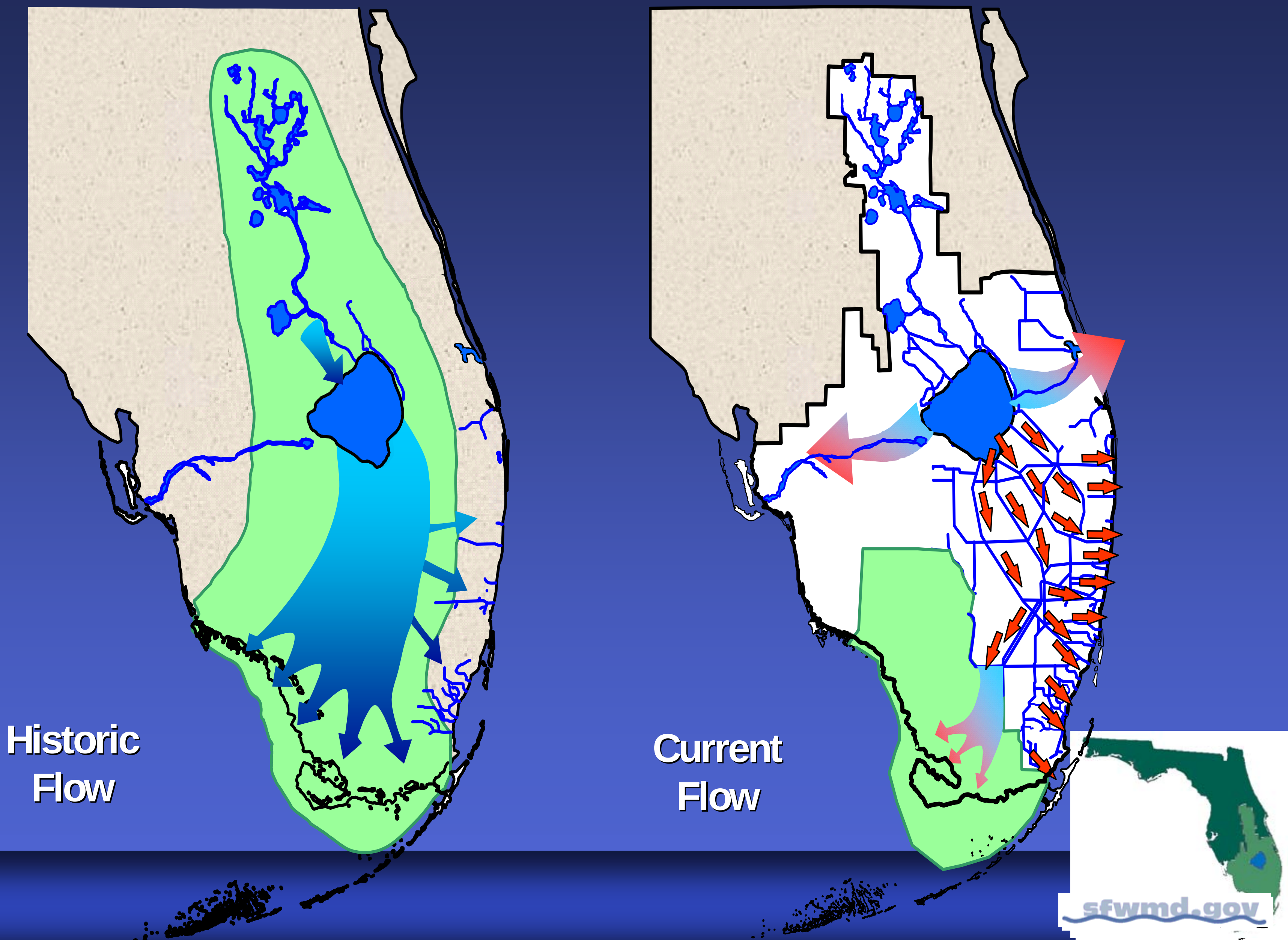
Task	Deliverable	Due Date
*Deliverable 1.1	Draft Project Research Plan	November 14, 2007
*Deliverable 1.2a	Kick-off Meeting	November 29, 2007
*Deliverable 1.2b	Kick-off Meeting Summary	November 30, 2007
*Deliverable 1.3	Final Project Research Plan	November 30, 2007
Deliverable 2.1	Progress Report	January 15, 2008
Deliverable 2.2a	Draft Final Report	April 15, 2008
Deliverable 2.2b	Final Report	April 30, 2008

Summary of Salinity, Inflow, and Supporting Water Quality Targets in the Caloosahatchee Estuary

Presentation to Northern Everglades
Caloosahatchee River Watershed
Research and &WQ Monitoring Plan Working Team
(Meeting # 3)
January 23, 2008

Coastal Ecosystem Division

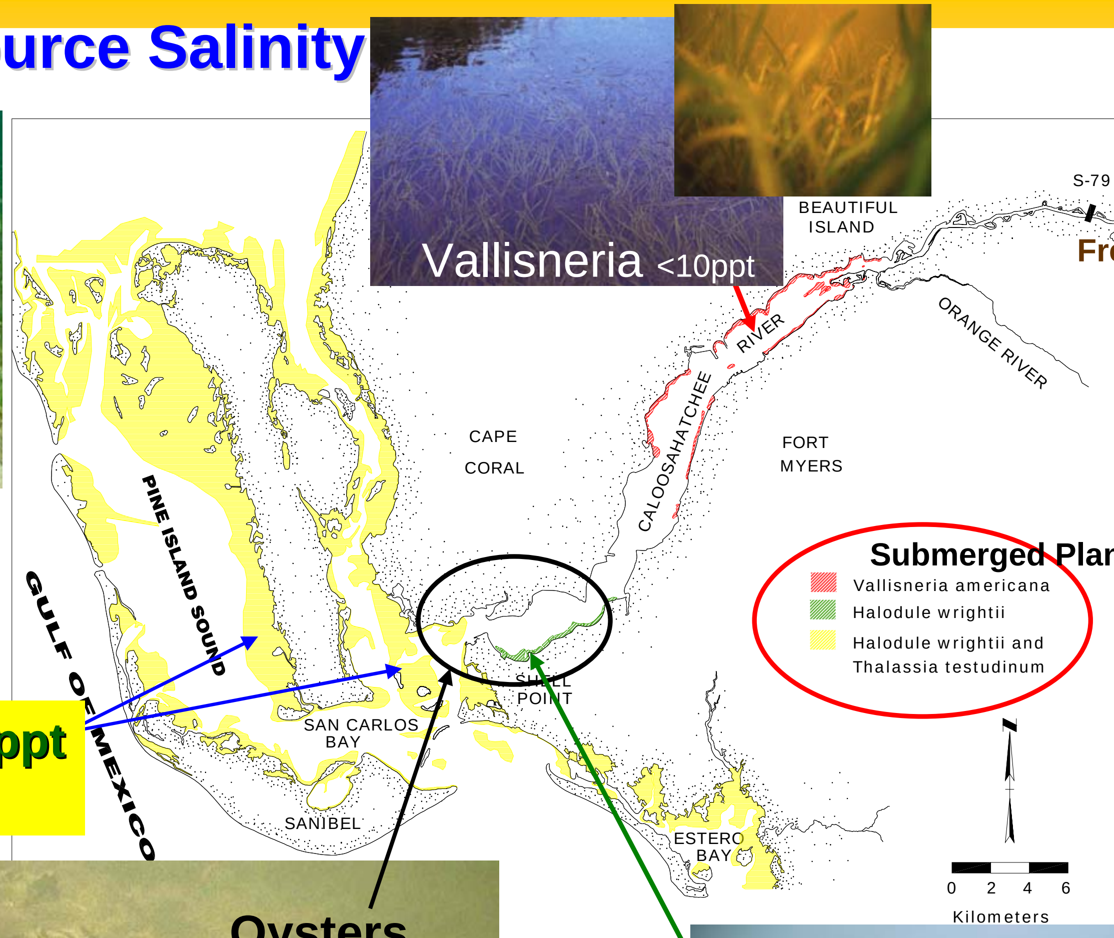
Water Resource Modifications



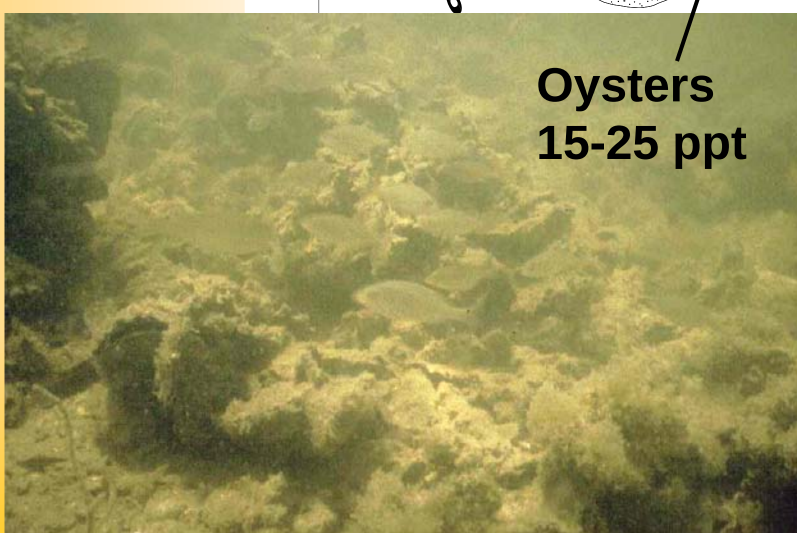
Caloosahatchee Resource Salinity

Blue Crab

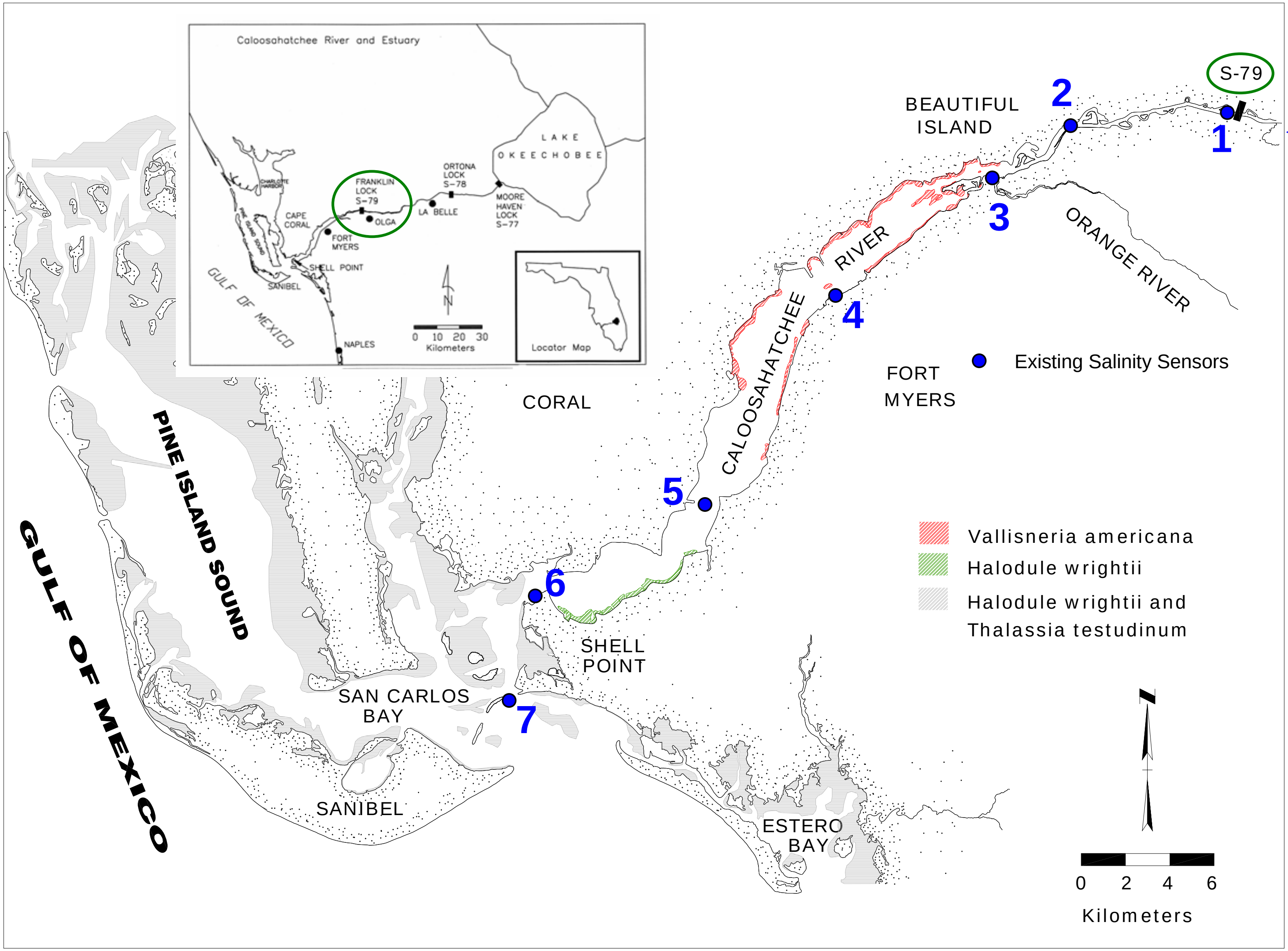
Seagrass >25 ppt Downstream



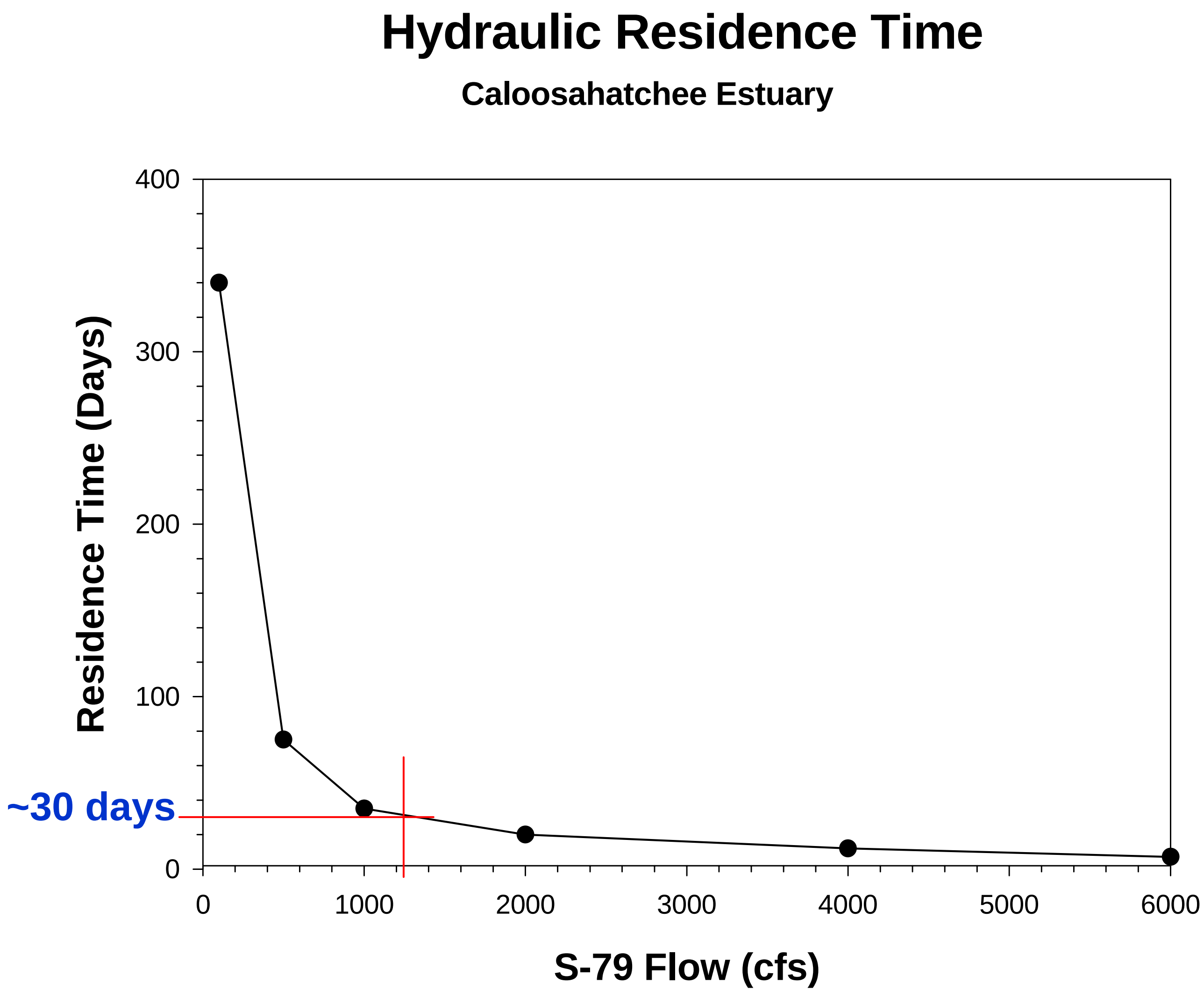
Freshwater

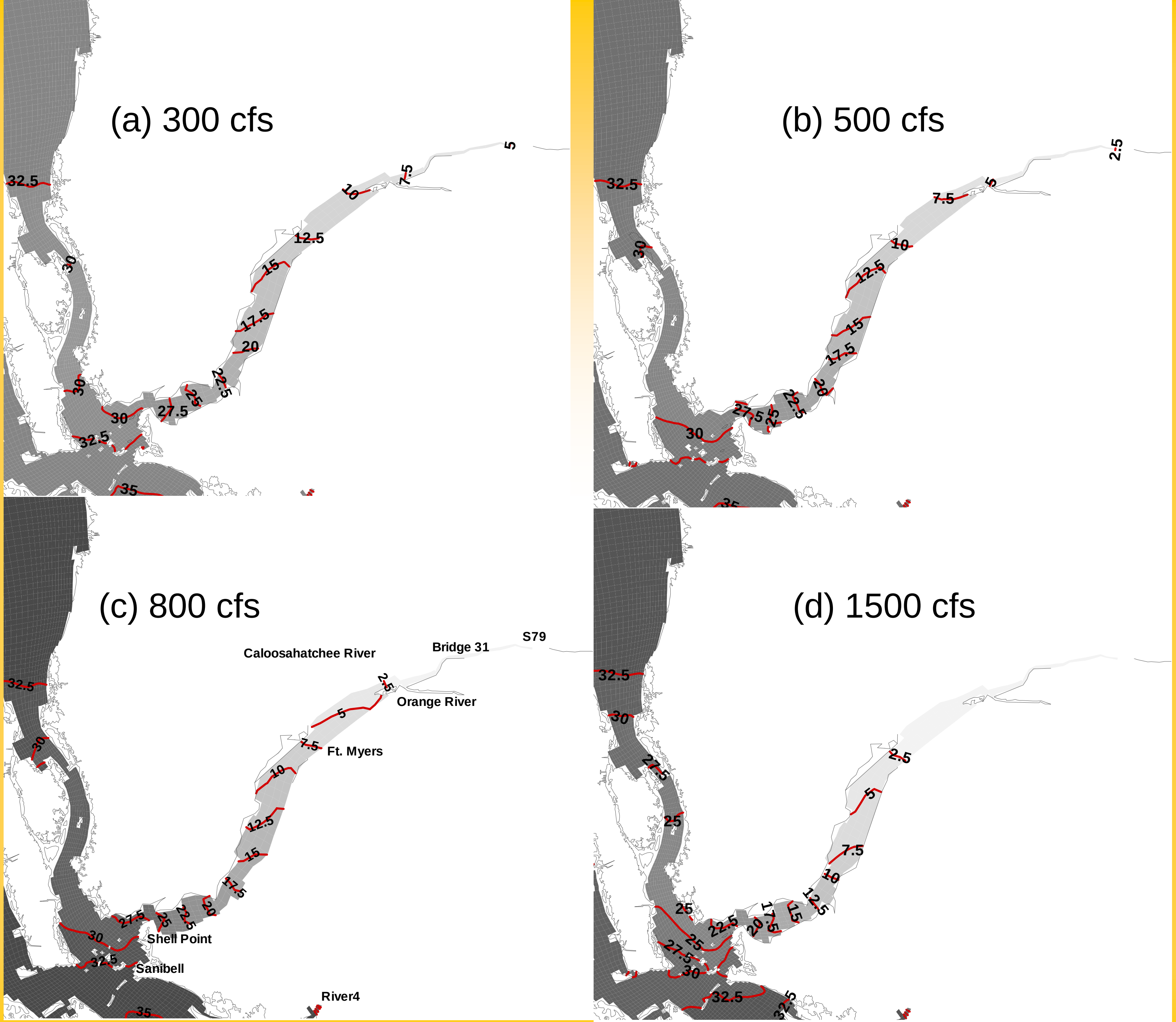


Existing Continuous Salinity Sensor Locations (Sort of)

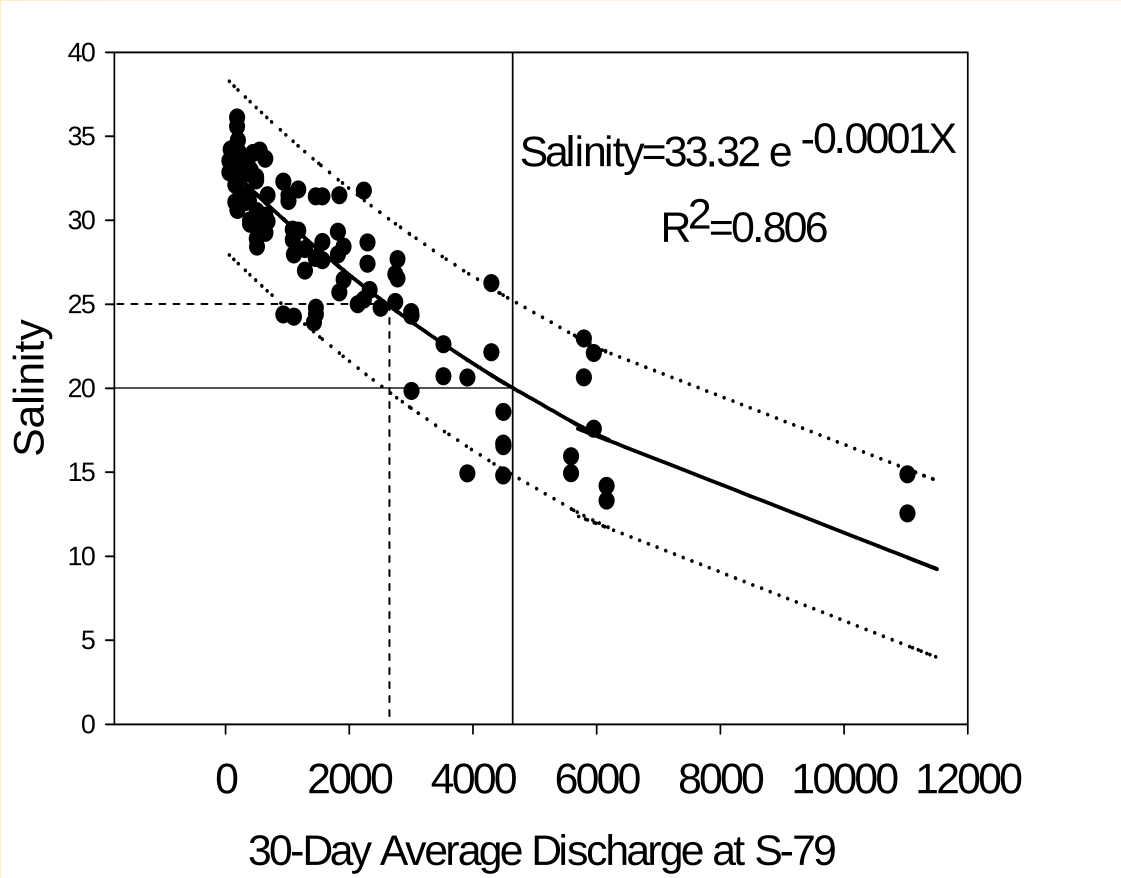


Salinity Model



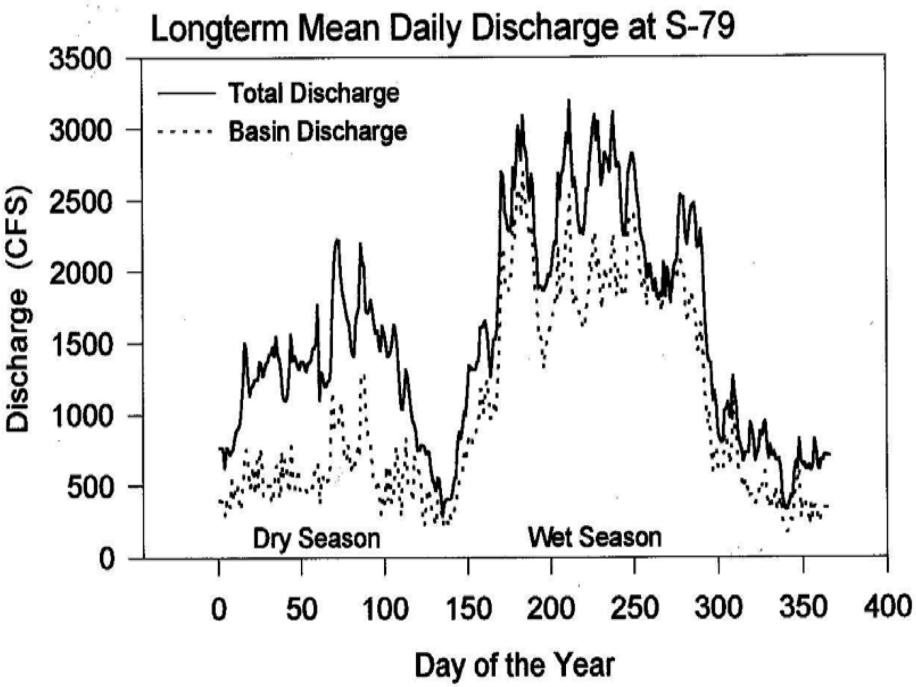

(a) 300 cfs
(b) 500 cfs
(c) 800 cfs
(d) 1500 cfs
Caloosahatchee River
Bridge 31
S79
Orange River
Ft. Myers
Shell Point
Sanibell
River4

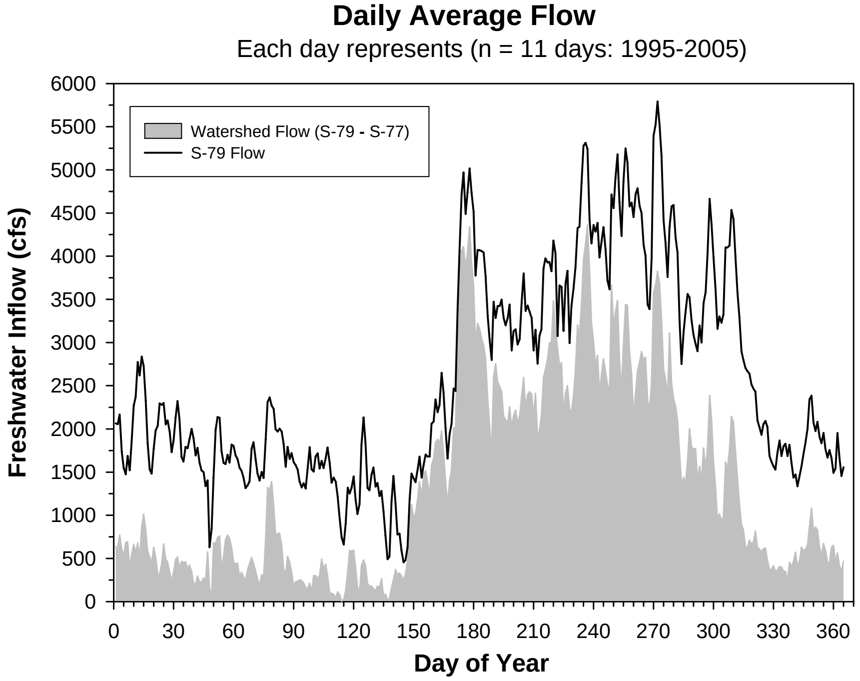
Salinity in San Carlos Bay

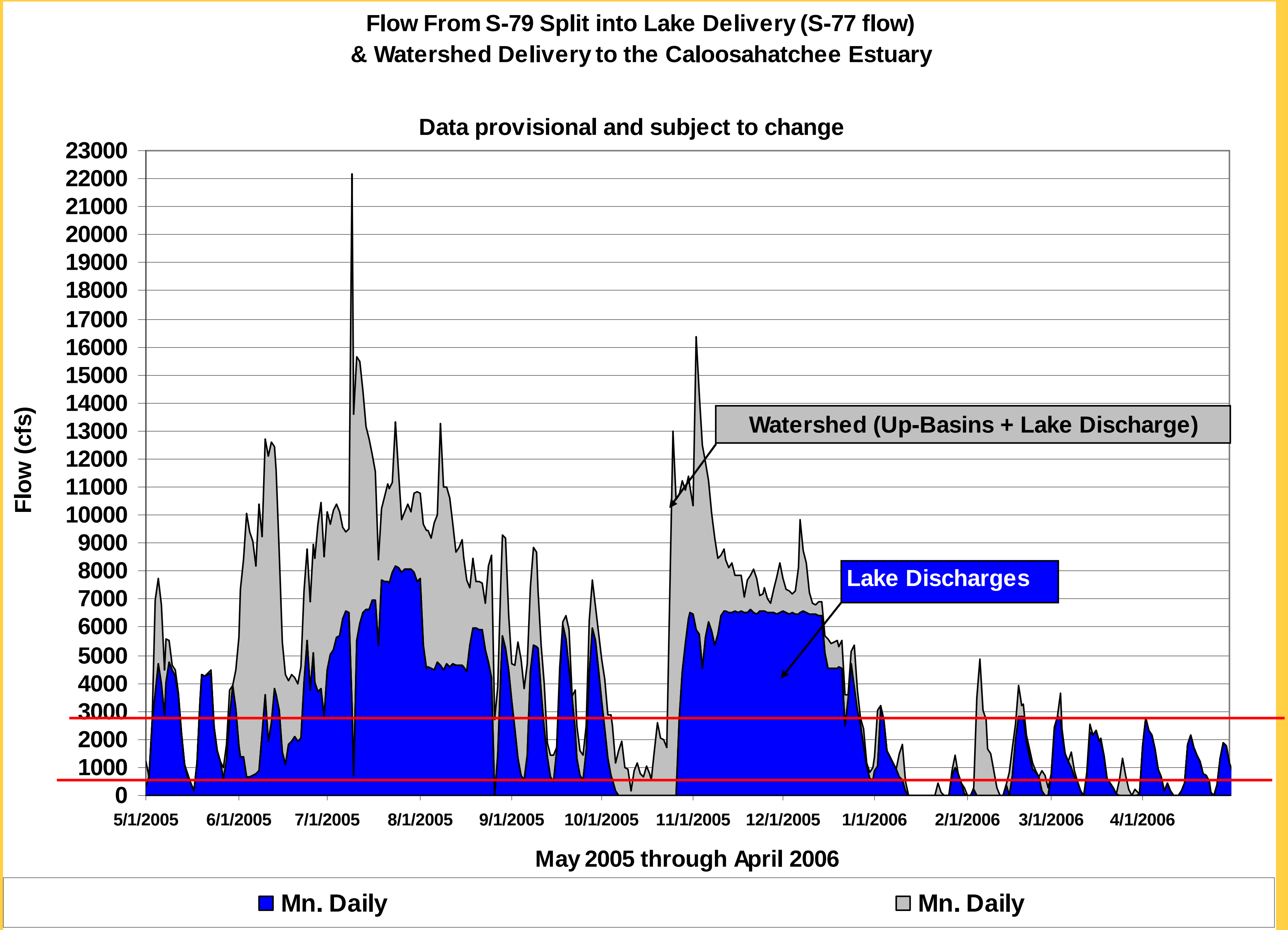


Freshwater Inflow Variability

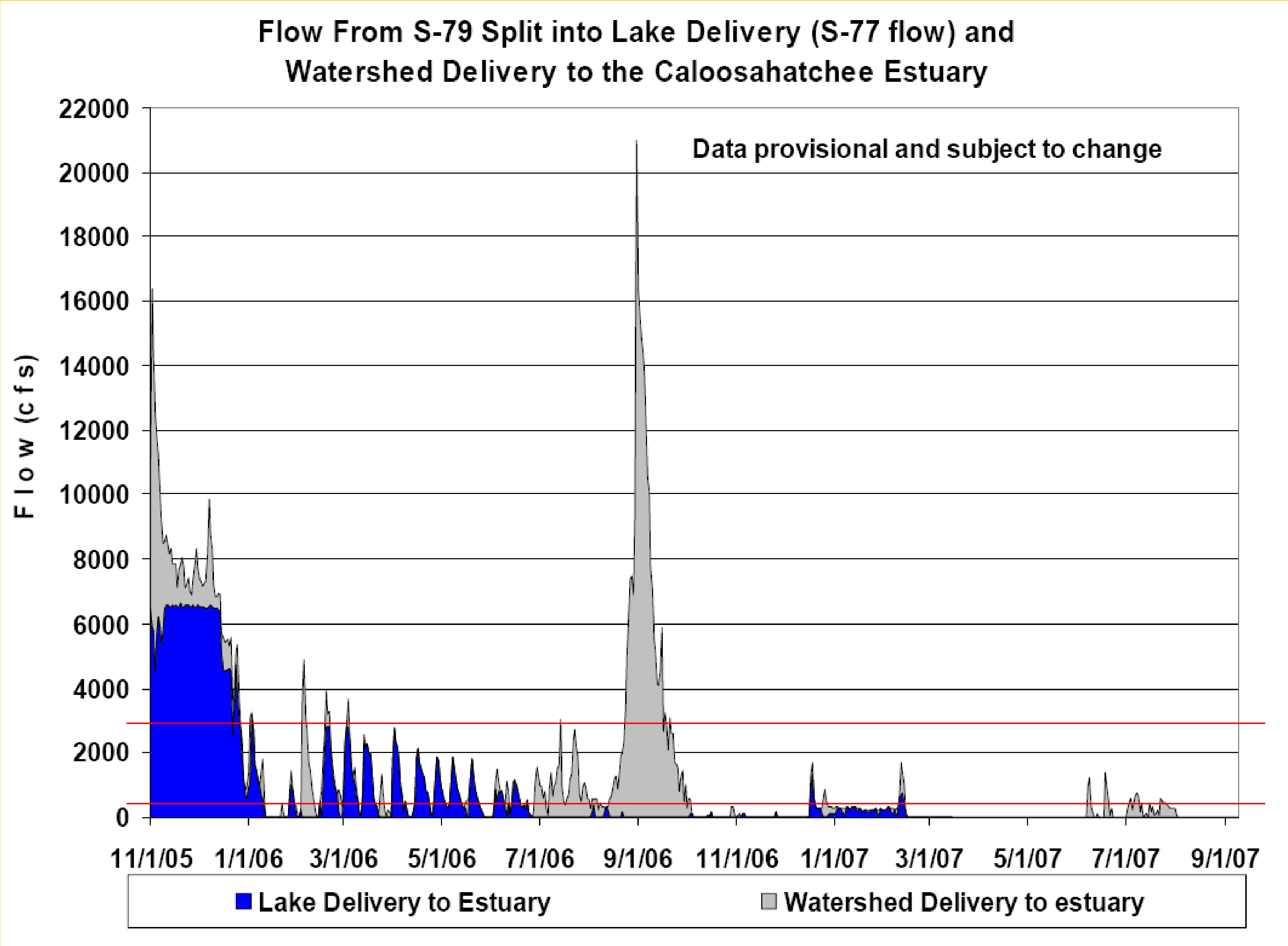
Long-term S-79 Inflow Averaged for Each Day of Period of Record



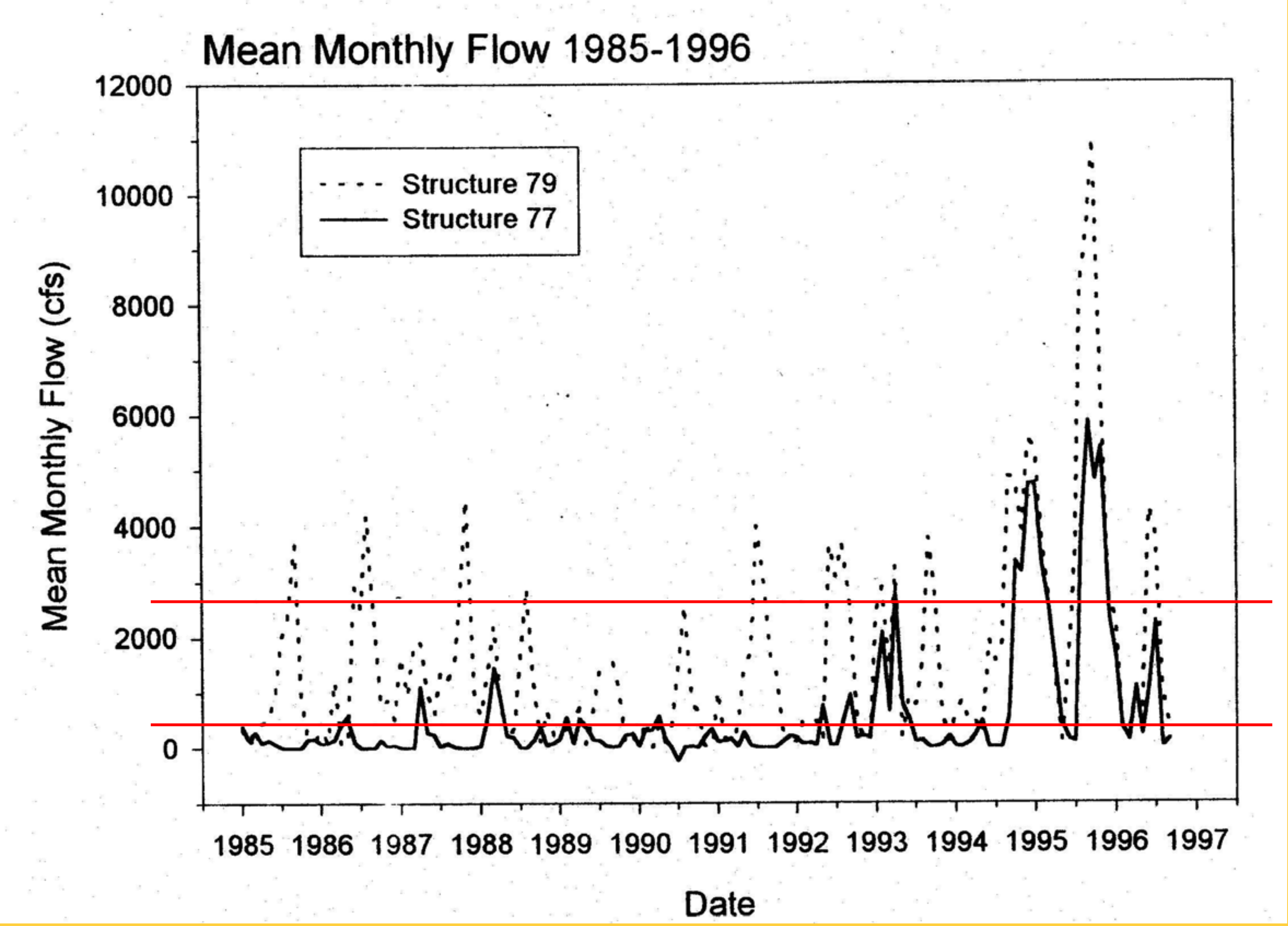


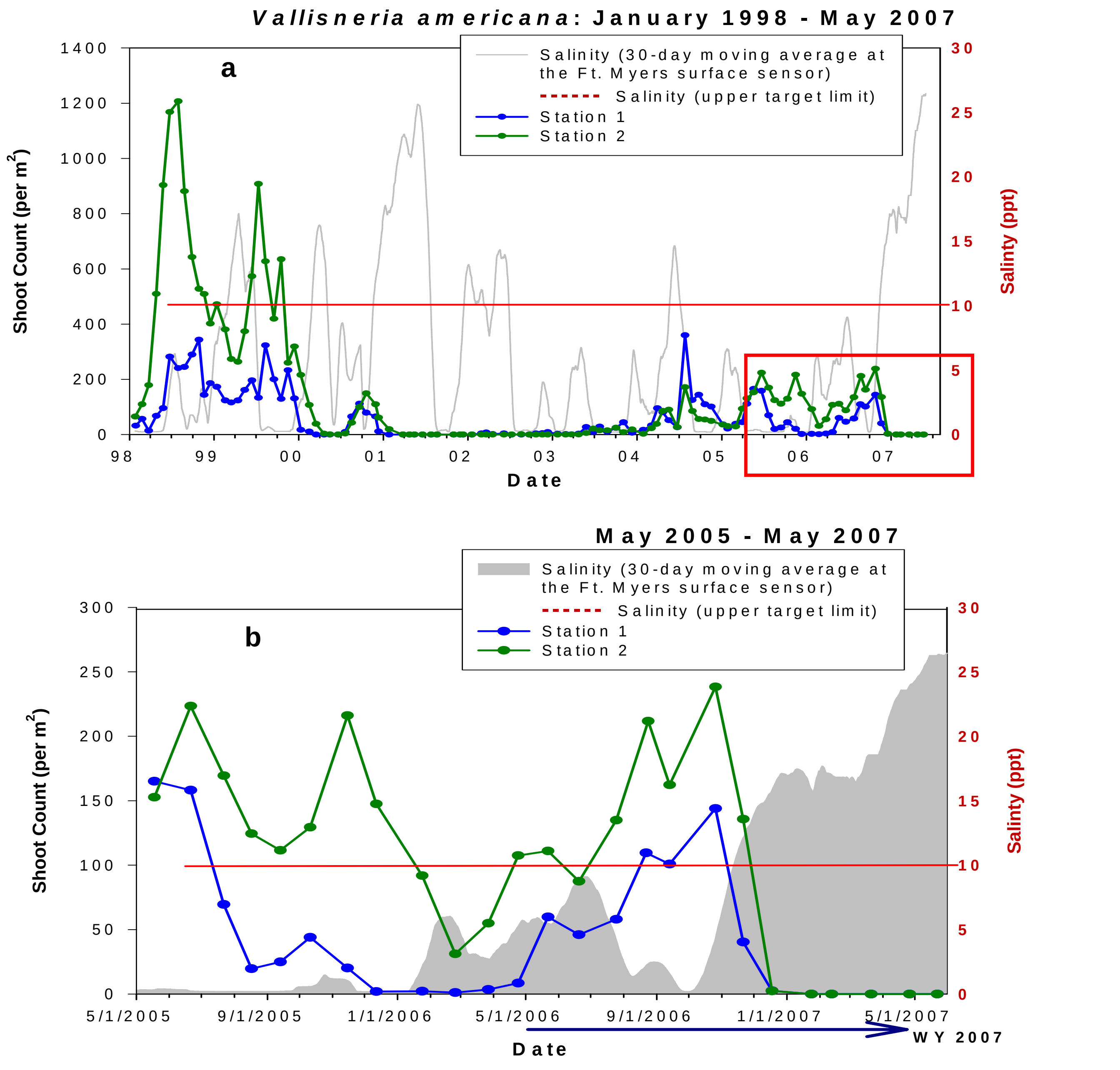


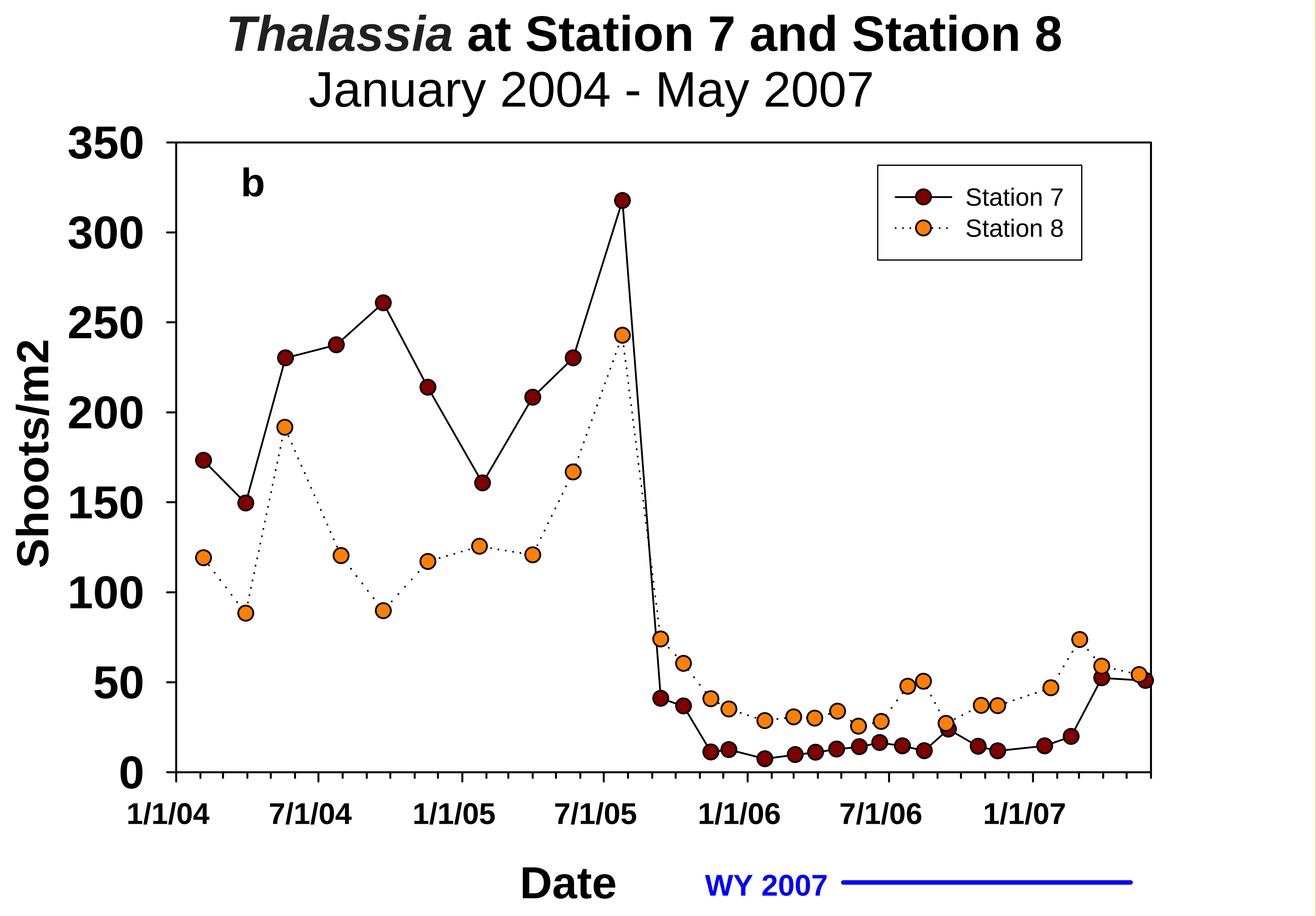
Flow From S-79 Split into Lake Delivery (S-77 flow)
& Watershed Delivery to the Caloosahatchee Estuary
Data provisional and subject to change
Flow (cfs)
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Watershed (Up-Basins + Lake Discharge)
Lake Discharges
5/1/2005
6/1/2005
7/1/2005
8/1/2005
9/1/2005
10/1/2005
11/1/2005
12/1/2005
1/1/2006
2/1/2006
3/1/2006
4/1/2006
May 2005 through April 2006
Mn. Daily
Mn. Daily


Flow From S-79 Split into Lake Delivery (S-77 flow) and
Watershed Delivery to the Caloosahatchee Estuary
Data provisional and subject to change
Flow (cfs)
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
11/1/05
1/1/06
3/1/06
5/1/06
7/1/06
9/1/06
11/1/06
1/1/07
3/1/07
5/1/07
7/1/07
9/1/07
Lake Delivery to Estuary
Watershed Delivery to estuary

Freshwater Inflow Variability

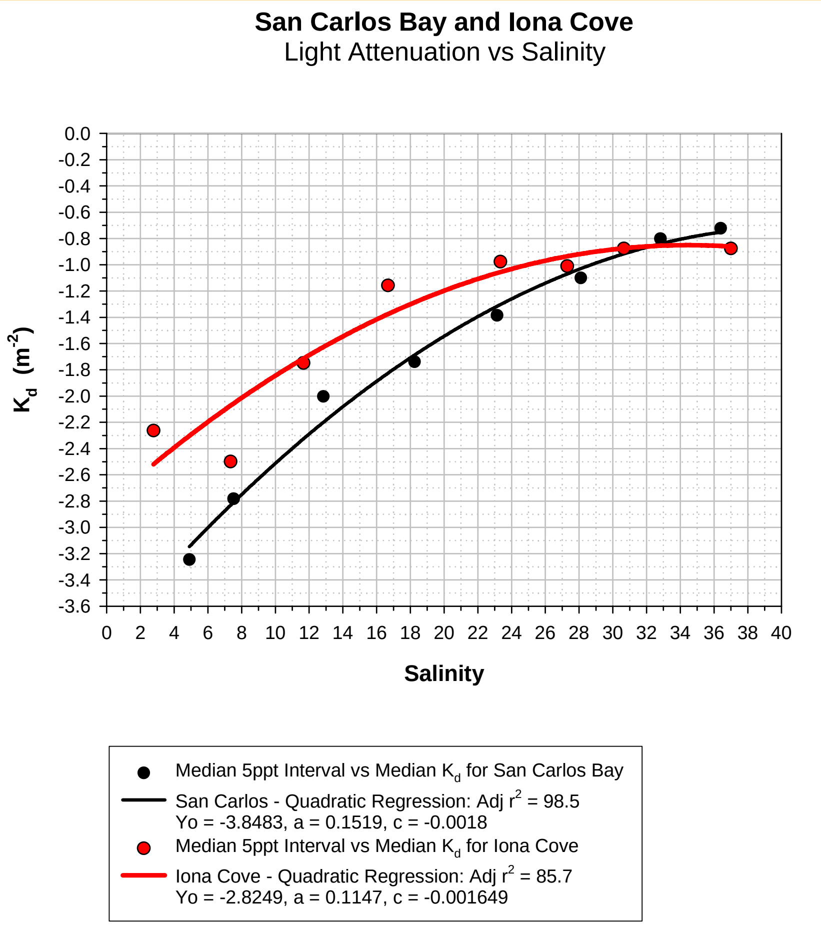



Vallisneria americana: January 1998 - May 2007
a
Salinity (30-day moving average at the Ft. Myers surface sensor)
Salinity (upper target limit)
Station 1
Station 2
Shoot Count (per m2)
Salinty (ppt)
Date
May 2005 - May 2007
b
Salinity (30-day moving average at the Ft. Myers surface sensor)
Salinity (upper target limit)
Station 1
Station 2
Shoot Count (per m2)
Salinty (ppt)
Date
5/1/2005
9/1/2005
1/1/2006
5/1/2006
9/1/2006
1/1/2007
5/1/2007
WY 2007

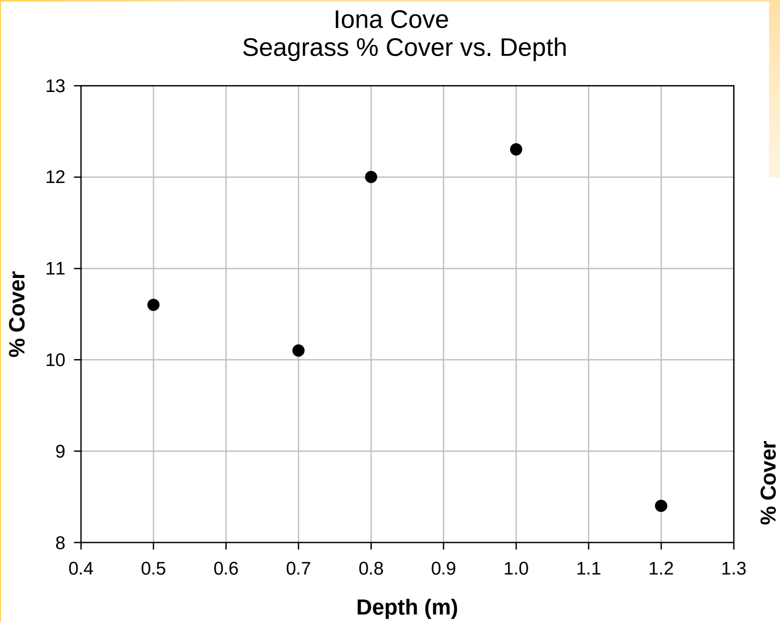


Data collected by Sanibel-Captiva Conservation Foundation
using traditional transect methods deployed in shallow water ~≤1.0m

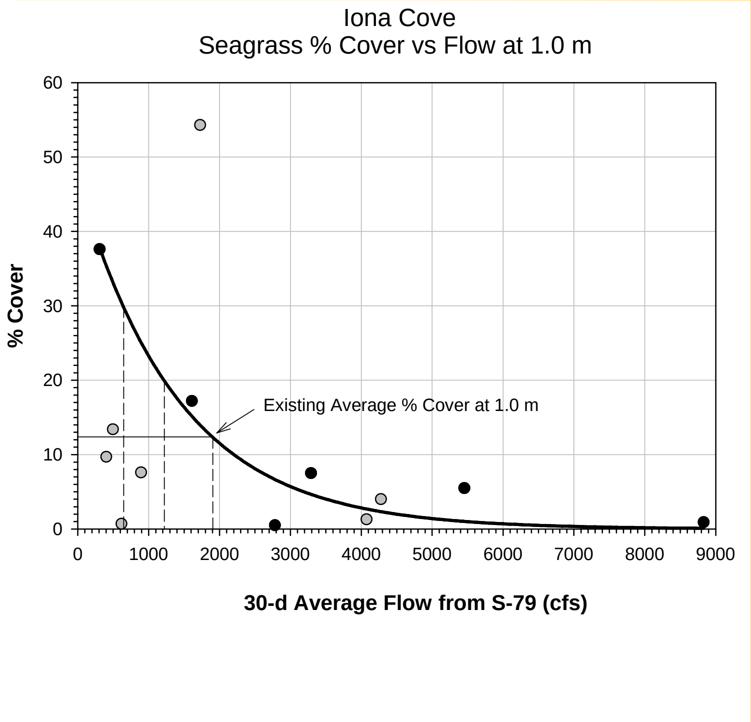
Relationship between light attenuation (K values) vs. salinity in seagrass areas. (Iona Cove and San Carlos Bay).



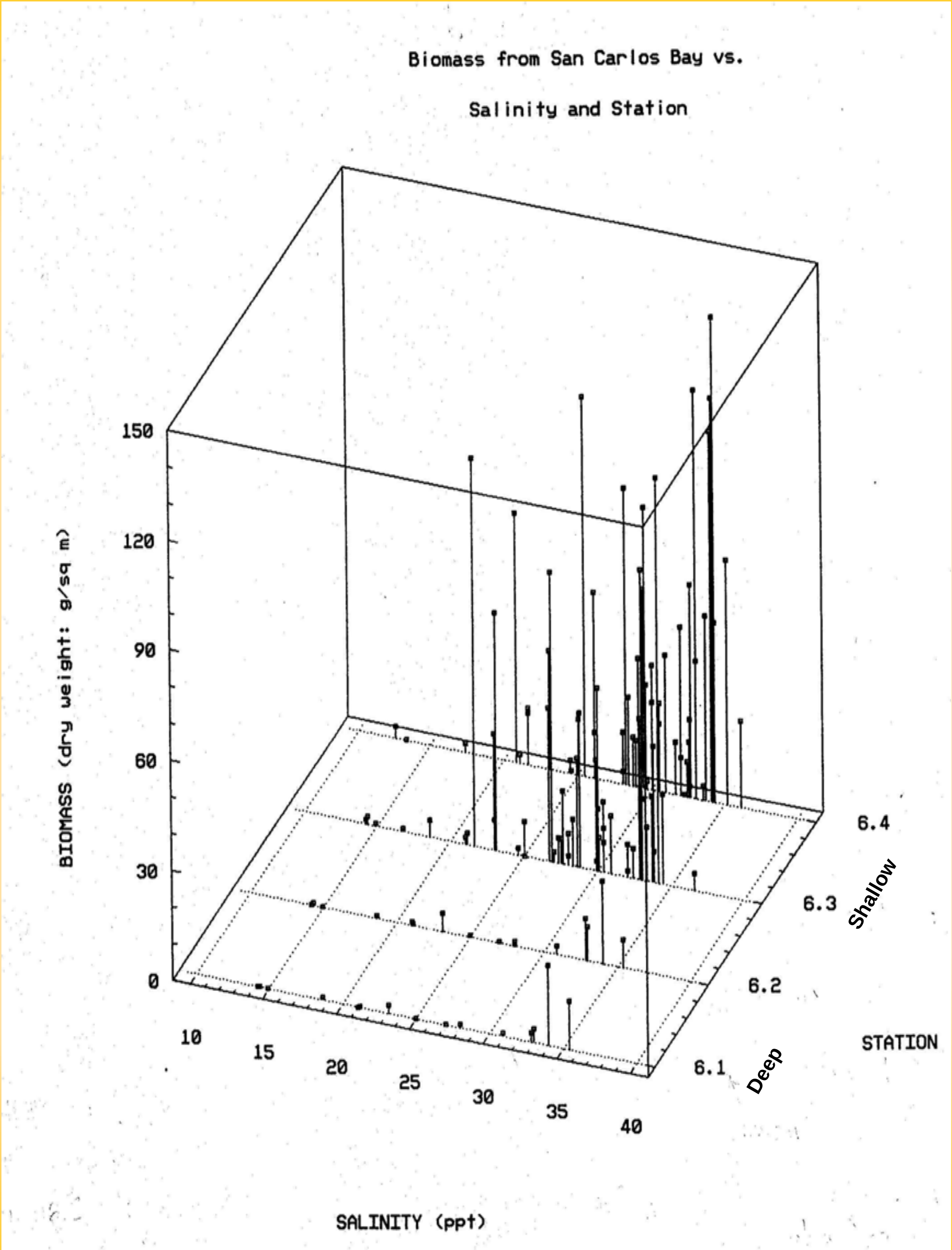
Freshwater Inflow Influence on Iona Cove Shoal Grass Depth



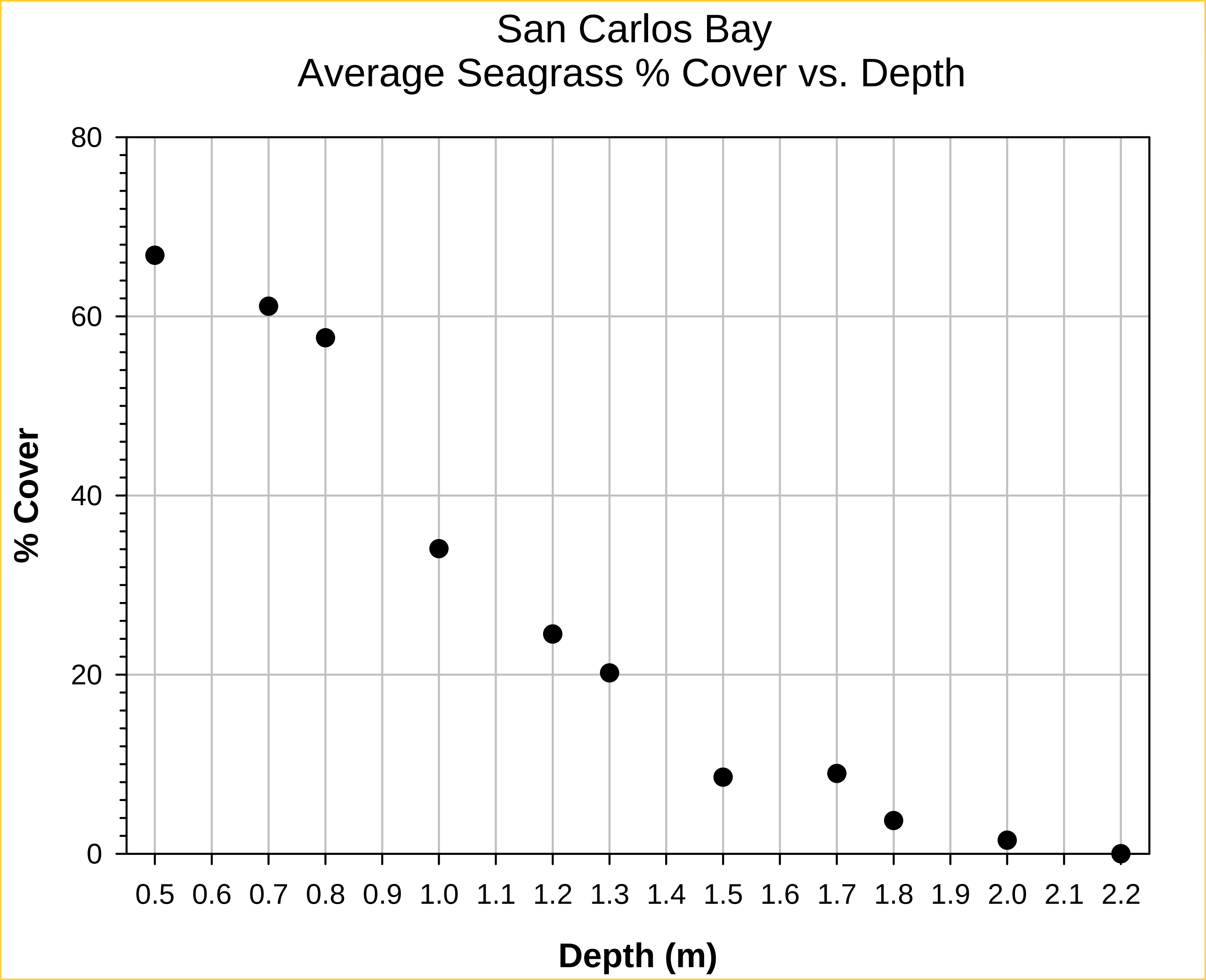
Iona Cove average seagrass coverage (*Halodule wrightii*) per depth for all flows sampled using hydroacoustic methodology for sampling seagrass.



Percent seagrass coverage (*Halodule wrightii*) at 1.0 meter in Iona Cove vs. all the flows sampled using hydroacoustic methodology for sampling seagrass. An exponential decay regression line is fitted to the subset of flows (bold points) that represent the full range of flow sampled and have consistent 30-day to 60-day average flows. Drop lines from the existing % coverage and improved coverages of 20% and 30% indicate correlated flows.

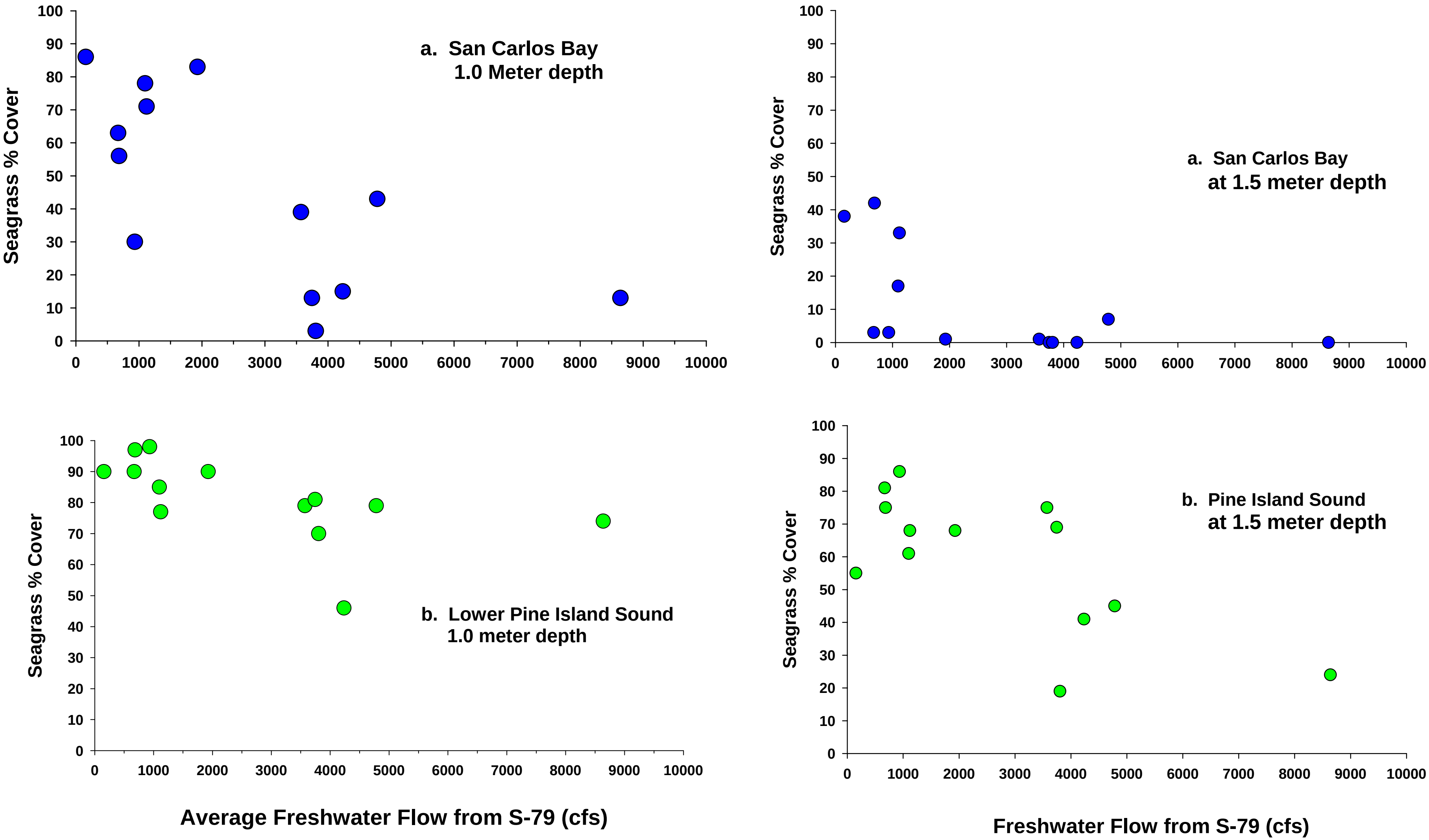


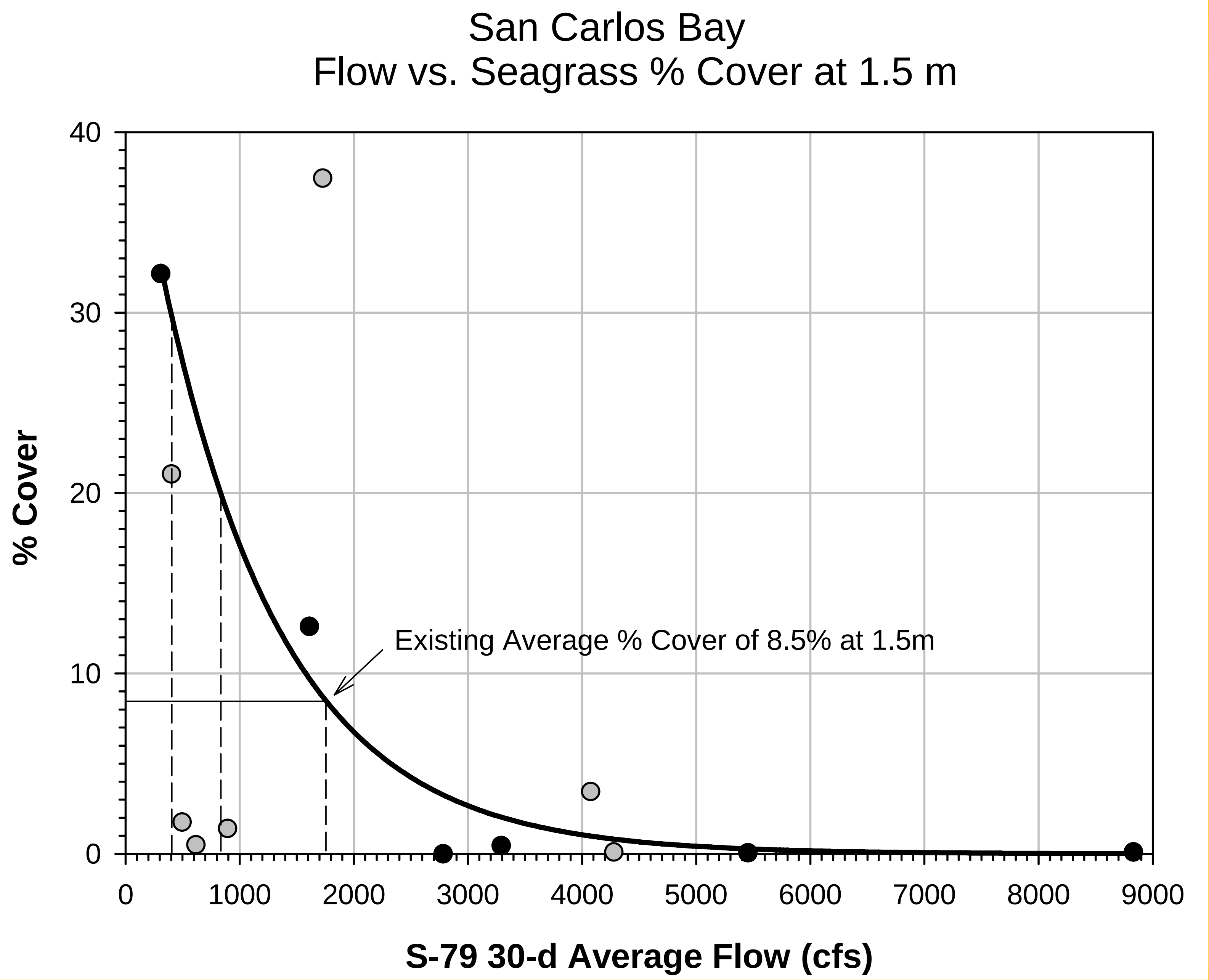
Biomass from San Carlos Bay vs.
Salinity and Station
BIOMASS (dry weight: g/sq m)
150
120
90
60
30
0
10
15
20
25
30
35
40
SALINITY (ppt)
6.4
6.3
6.2
6.1
STATION
Shallow
Deep


San Carlos Bay
Average Seagrass % Cover vs. Depth
80
60
40
20
0
% Cover
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
Depth (m)

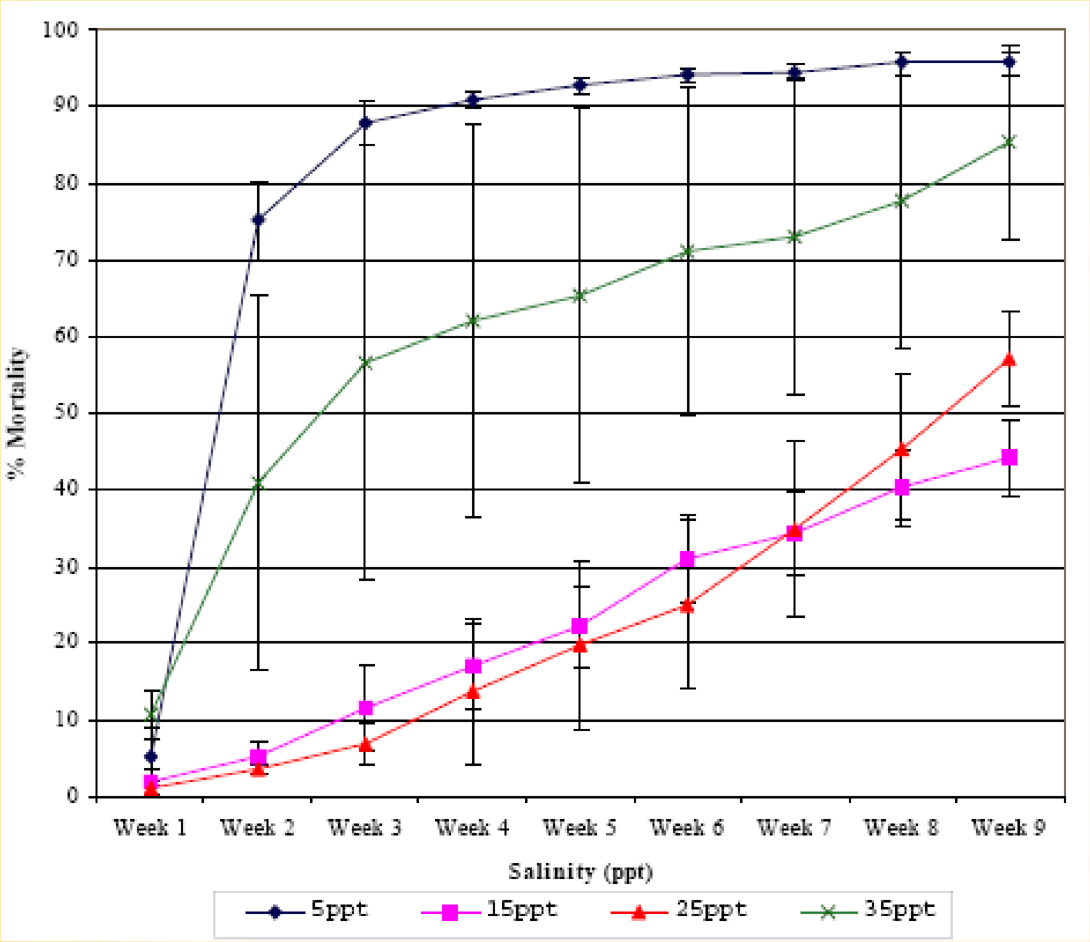
Freshwater Inflow Influence on Iona Cove Shoal Grass Depth

Percent seagrass coverage (all species present) at 1.0 and 1.5 meters at two locations downstream of the Caloosahatchee River compared to average freshwater inflow from S-79 prior to sampling (using hydroacoustic methodology for sampling seagrass).




San Carlos Bay
Flow vs. Seagrass % Cover at 1.5 m
% Cover
S-79 30-d Average Flow (cfs)
Existing Average % Cover of 8.5% at 1.5m
0
10
20
30
40
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

Oyster Mortality



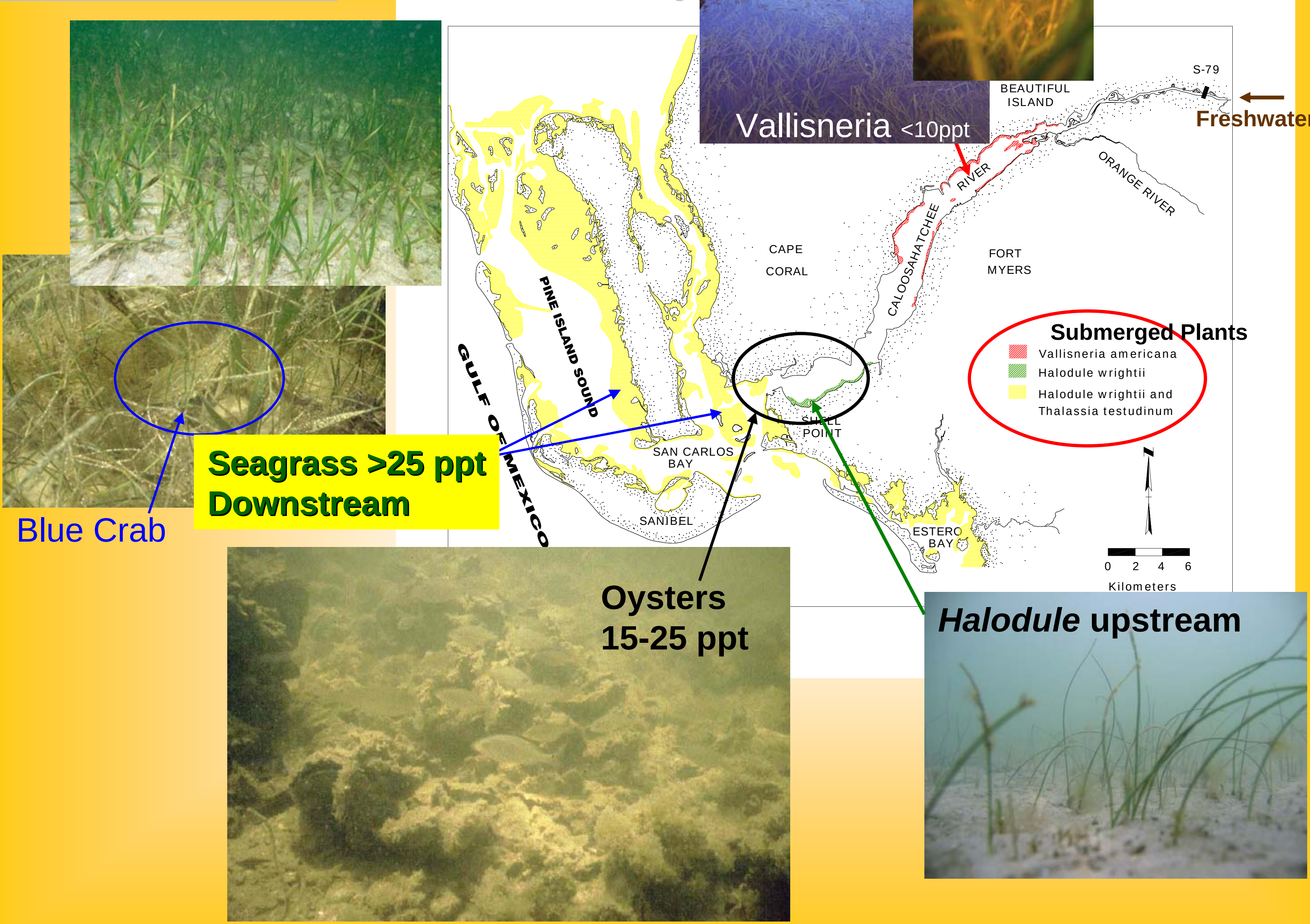
Mortality of juvenile oysters in the Caloosahatchee exposed to 5, 15, 25 and 35 ppt for 9 weeks (Volety 2003).

Results: 1. Oysters exposed to very low (5 ppt) or very salinities (35 ppt) encountered heavy mortalities compared to those at intermediate salinities (15 and 25 ppt).

2. Greatest threat when flows exceed ~3,000 cfs for 2-4 weeks

3. Prefer flows > 300 cfs

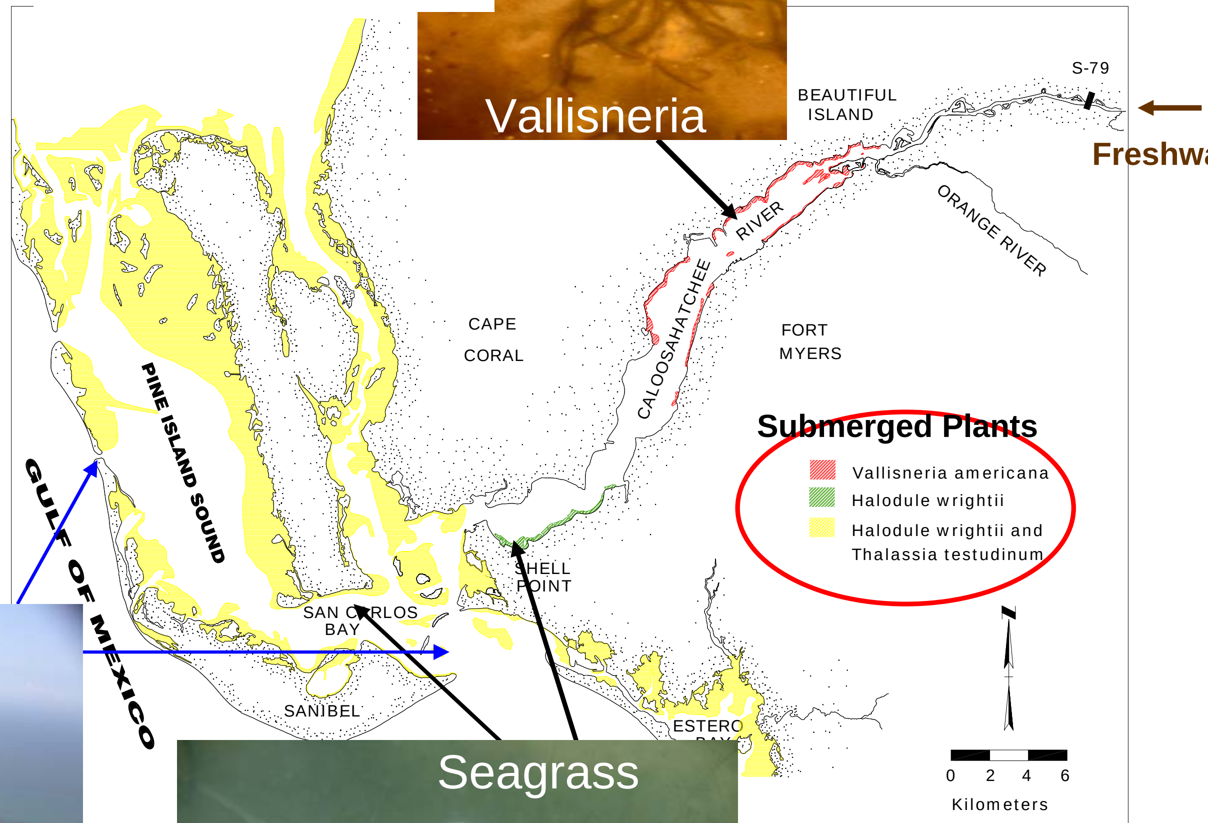
Caloosahatchee Resource Salinity

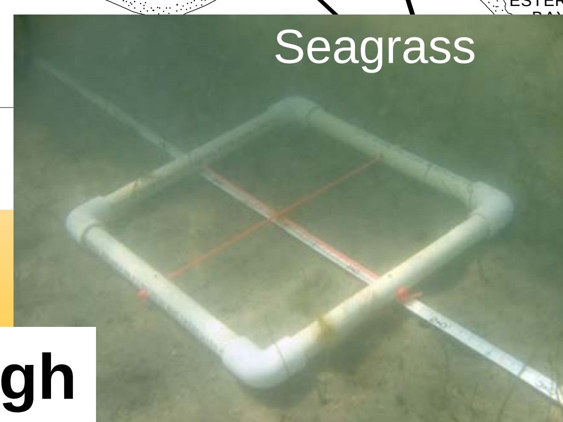


Caloosahatchee

Resource impacts when

Flows too low





Flows Too High

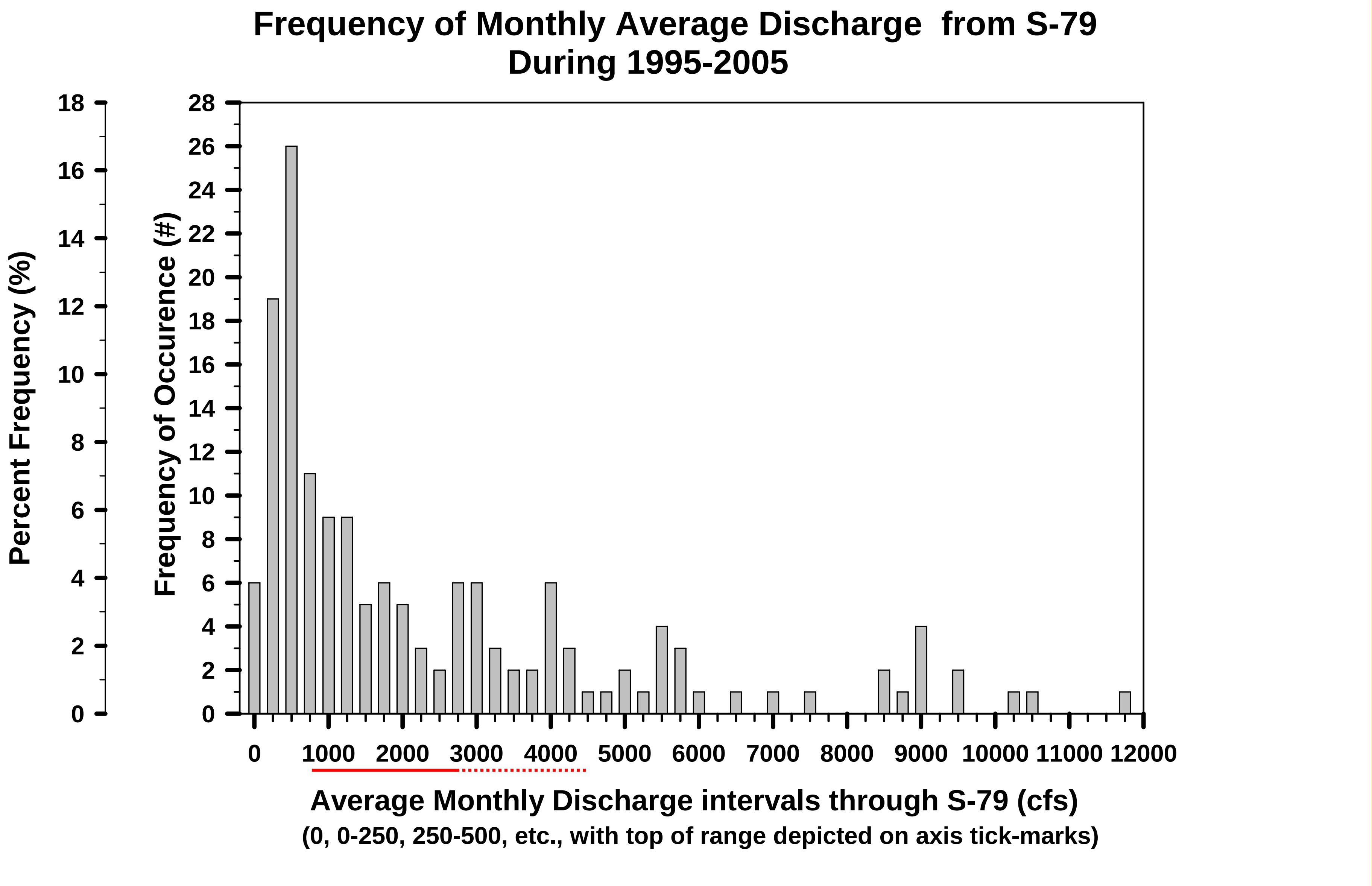
Important Discharge Levels for the Caloosahatchee Estuary at S-79

1. **< 450 cfs:** high salinity in upper estuary causes mortality of tape grass habitat.
2. **>2800 cfs:** low salinity causes mortality of marine organisms in the seaward portion of the estuary.
3. **>4500 cfs:** low salinity in San Carlos Bay causes mortality of seagrasses.
4. **>6500 cfs:** low salinity plume enter Gulf of Mexico adverse impacts on SAV and WQ in Pine Island Sound

Flow Based Hydrologic Performance Measure (Targets)

Preferred Alternative, with:

- **Fewest number** of times mean monthly flows from S-79 exceed the above important discharge levels (1-3).
- **Lowest frequency** of exceedence (Important Discharge Levels 1-3) for just 1 month, as well as the frequency of 2, 3, 4,..consecutive months.


Frequency of Monthly Average Discharge from S-79
During 1995-2005
Percent Frequency (%)
0
2
4
6
8
10
12
14
16
18
Frequency of Occurence (#)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
Average Monthly Discharge intervals through S-79 (cfs)
(0, 0-250, 250-500, etc., with top of range depicted on axis tick-marks)

Target frequency distribution of mean monthly flows from S-79 (SWFFS and C-43 WBSR – Caloosahatchee Estuary Hydrologic Evaluation Performance Measures, 2005).

Discharge Range (cfs) Mean Monthly Flows From S-79	Percent Distribution	
0 to 450	0%	
450 to 500	42.8%	**74.5%**
500 to 800	31.7%	
800 to1500	19.2%	**93.7%**
1500 to 2800	5.6%	
2800 to 4500	0.7%	
>4500	0%	

Targets for VECs with Supporting Salinity and WQ Requirements

Vallisneria

- Vallisneria not < 20% coverage (at sites 1 and 2) of average potential shoot density (~ 200-300 shoots /m^2 of potential >1000 shts /m^2)
- blade length $\leq$ 15 cm upstream of Ft. Myers at historical sampling locations
- Maintain a 30-day moving average salinity $\leq$10ppt at the Ft. Myers' near surface continuous sensor, so salinity upstream to Beautiful Island remains < 10ppt
- Daily average salinity shall not be > 20 ppt more than once every two years, nor shall the 30-day moving average of 10 ppt.
- Target Secchi Disc Depth readings (**Minimum**) $\geq$ 0.9 - 1.1m upstream of Ft. Myers salinity sensor when plans are present;

  during **periods of recovery**, $\geq$ 1.1 - 1.3m, contiguous during the early wet season.
- **Minimum** Average Daily Bottom Light (ADBL) at 1 m, measured as PAR during the entire 24 hrs = ~20 uE.
- Desired average ADBL $\geq$ 100 uE

Halodule (shoal grass) in Iona Cove

- Restore continuous presence of shoal grass downstream of Peppertree Point
- Target density $\geq$ 20% at 1 meter depth, with average blade length $\geq$ 10cm.
- Minimize occurrences of average monthly salinity of $<$ 15 ppt at Cape Coral Bridge sensor, so salinity approaches 20 ppt or greater in Iona Cove
- Minimum ADBL = 50 uE
- Desirable ADBL $\geq$ 140uE

Oysters

- During spawning season, maintain spat recruitment = 5 spat per shell (March upstream of Shell Point, May-October downstream)
- Oyster Density > 200 / m^2 at current sampling locations
- Condition Index of oysters maintained at $\geq$ 2.5
- Salinity at Piney Point never < 5 ppt for a month during December and January, or 1 week during March-October
- Desired salinity = 14 - 28 ppt

Seagrass Downstream of Shell Point

- Attain 38% increase in aerial seagrass coverage in San Carlos Bay
- Maintain ≥30% coverage at 1.5 m in mid-San Carlos Bay and 20% coverage at 1.75 m with blade length ≥ 10cm
- Maintain average seagrass coverage ≥ 65% at 1.5 m in lower Pine Island Sound
- At depths ≤ 1.0m MLLW, maintain seagrass species composition at historical average levels
- Maintain salinity ≥ 25ppt
- Provide minimum ADBL = 75-100uE to target depth
- Desired ADBL >150 uE to target depth (100% saturation = 325 uE)


Questions
Image provided by US Geological Survey - Sirenia Project

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