

Pre-drainage Everglades Hydrology and Florida Bay Salinity Based on Paleoecology and Statistical Models

GEER 2008

Florida Bay and Adjacent Marine Systems Science Conference 2008

**Frank Marshall
CLF**

**Lynn Wingard, USGS
Patrick Pitts, USFWS**

**Evelyn Gaiser, FIU
Ania Wachnicka, FIU**

OBJECTIVES OF PALEOSALINITY PROJECTS

- Use paleoecological information from multiple sediment cores in Florida Bay
- Couple with statistical models
- Develop independent estimates of
 - pre-drainage hydrology in the Everglades
 - stage
 - flow
 - salinity in the Bay
- 3 cores evaluated to-date

MULTIPLE FUNDING PARTNERS

Previous Studies:

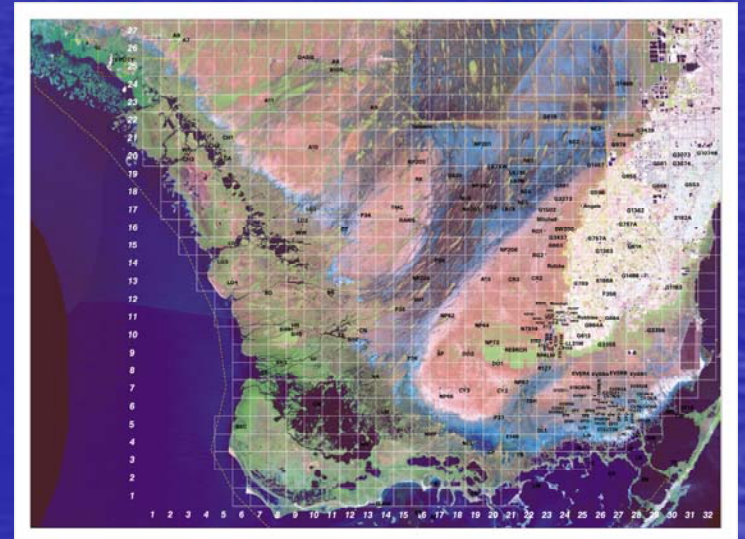
- **CESI / ENP**
 - Whipray Basin
 - Bob Allen Key
- **RECOVER**
 - Whipray Basin
 - Bob Allen Key
 - Shark River (future)

Current Studies:

- **USGS**
 - Rankin Lake
 - Next station
 - Russell Bank?
 - Pass Key?
 - Taylor Creek?

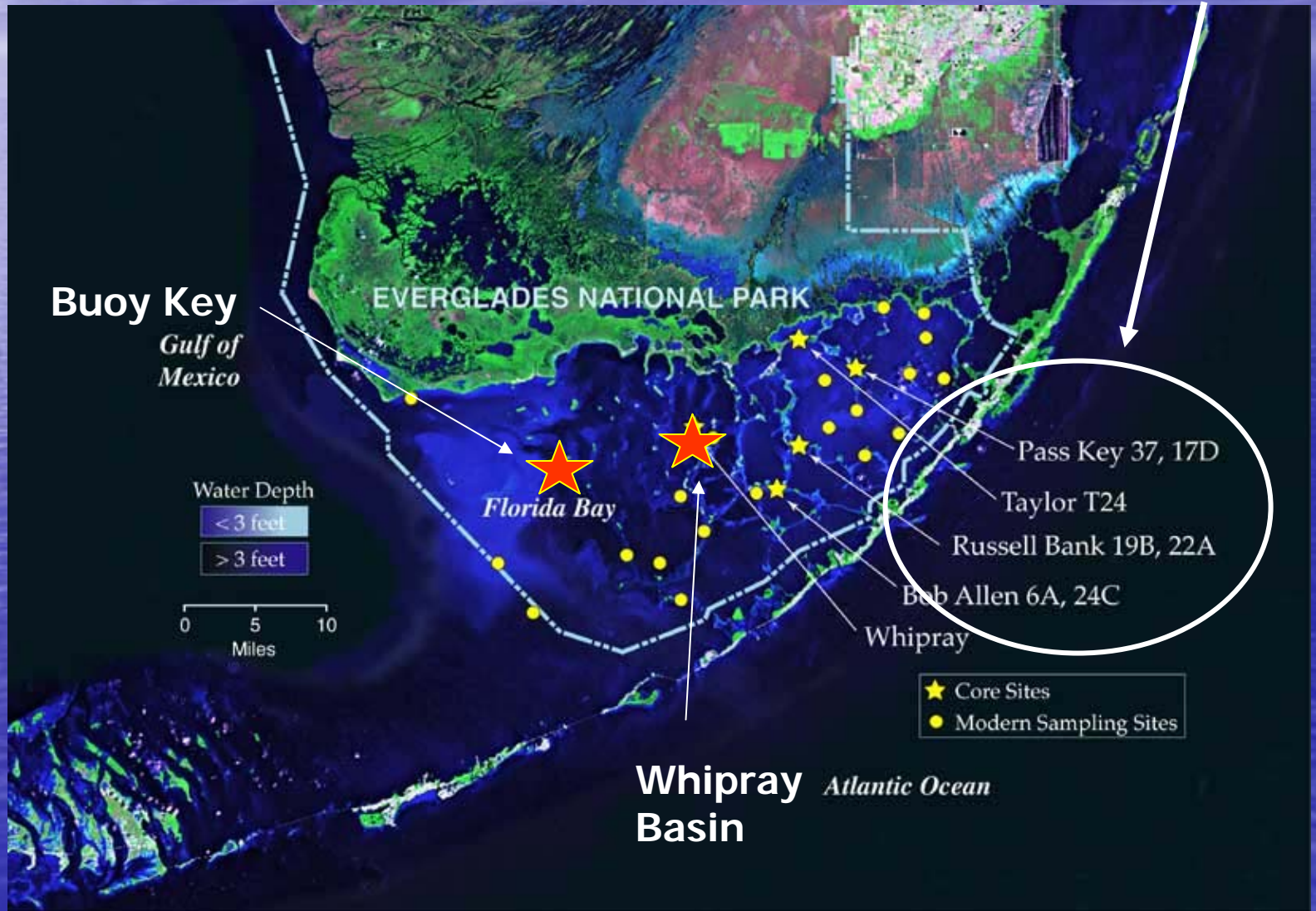
AVAILABLE DATA

- Paleoeecology
- Stage in Everglades
- Flow in Shark River Slough and Taylor Slough
- Salinity in Florida Bay

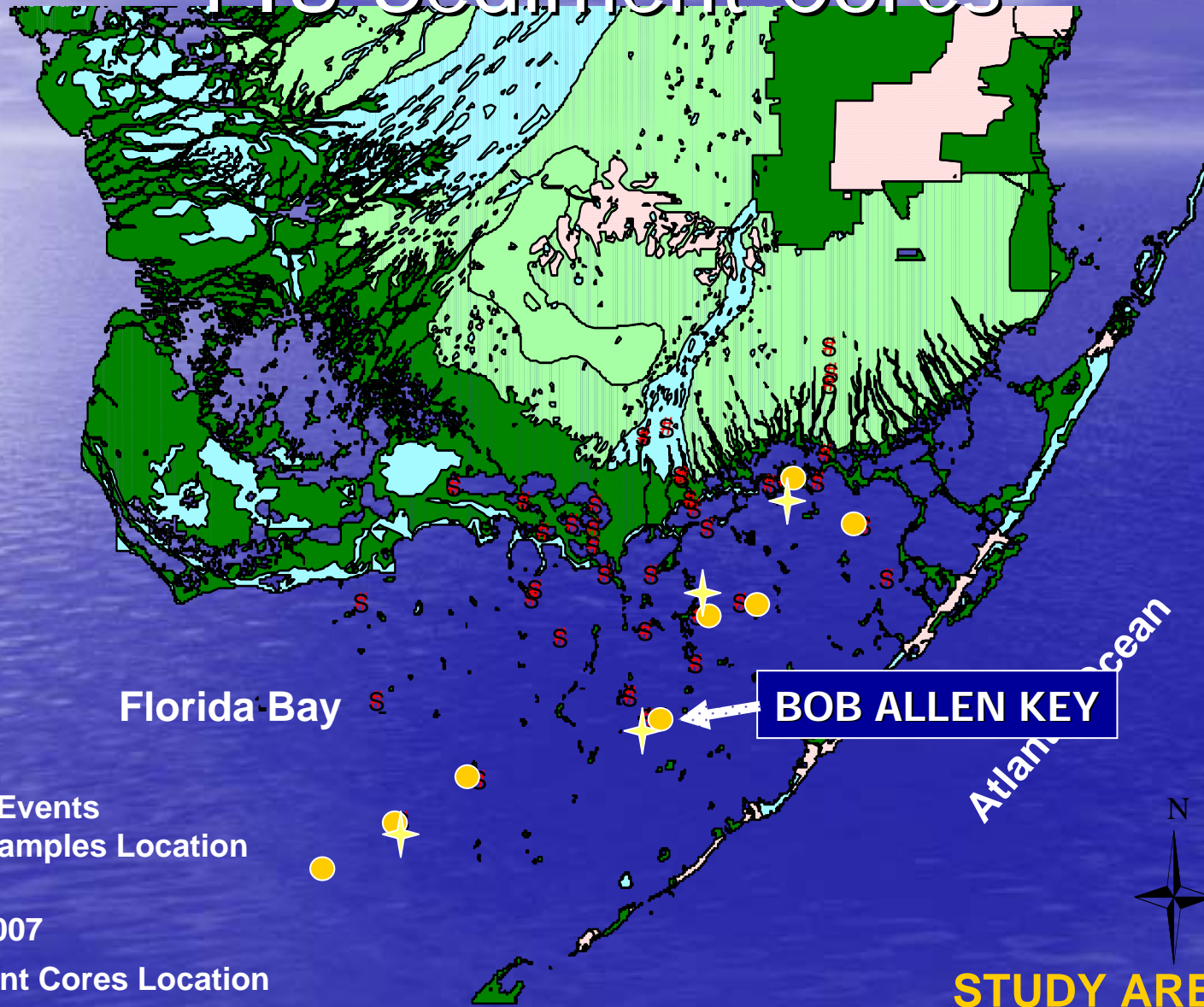
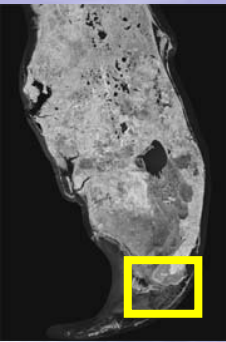


Paleoecological Data: USGS Sediment Cores

Upcoming: one of these

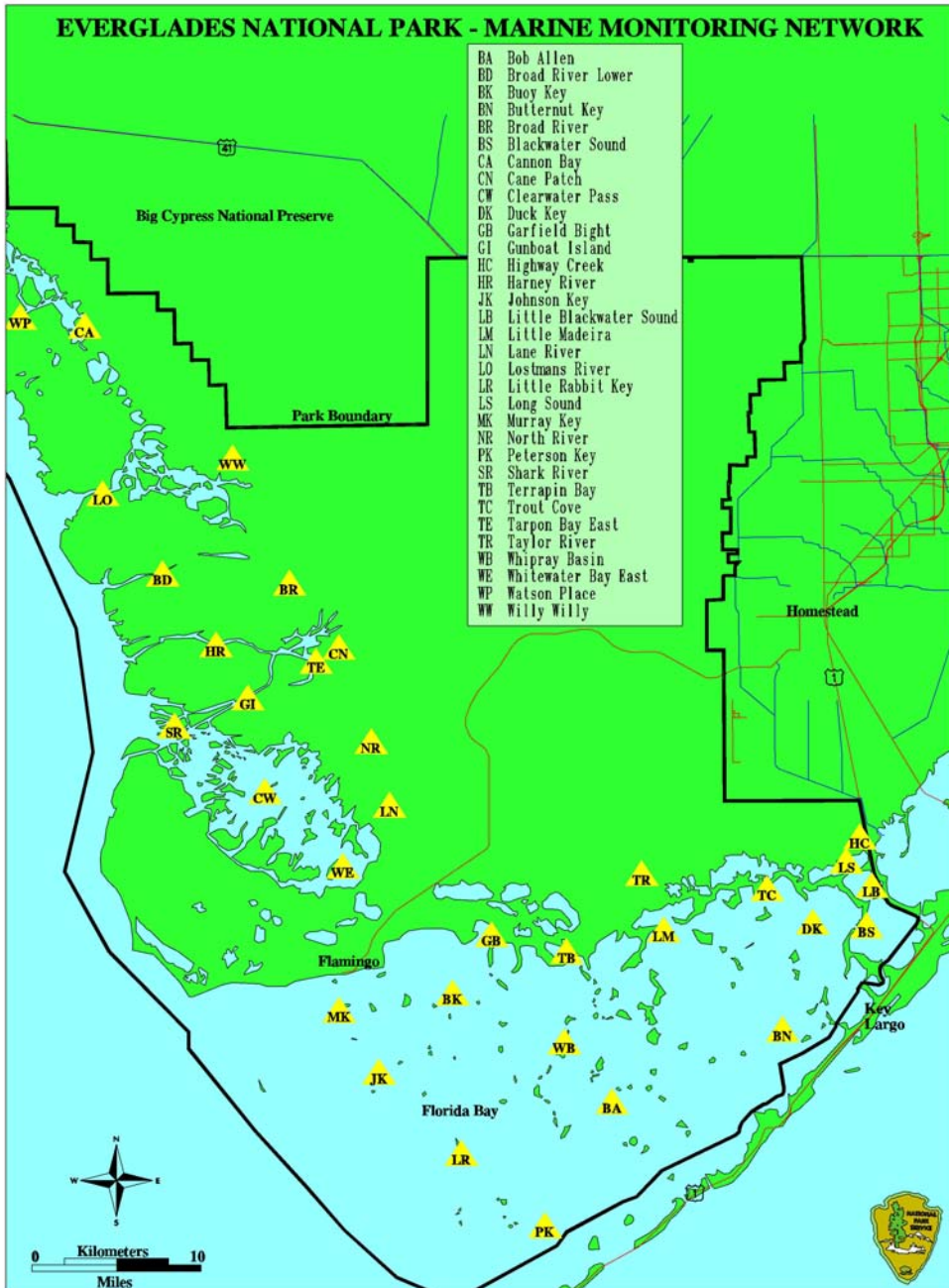


Paleoecological Data: FIU Sediment Cores



- Sampling Events
/Modern Samples Location
- 2002
 - 2006/2007
 - ★ Sediment Cores Location

STUDY AREA



Available Data: Salinity

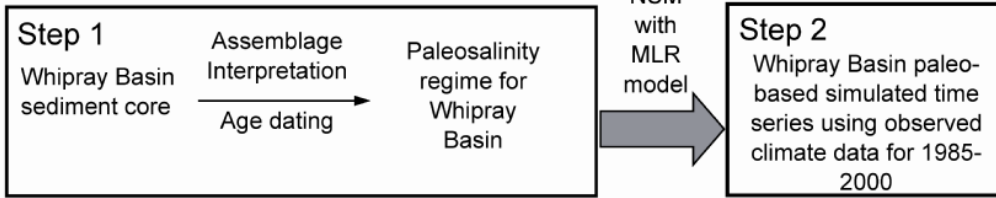
- Everglades National Park Marine Monitoring Network Stations (daily)
- SERC (monthly)

NOTE: MLR Salinity models exist for all 31 MMN stations

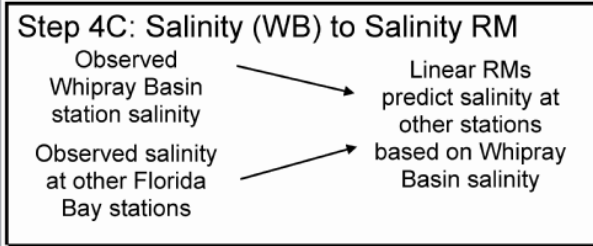
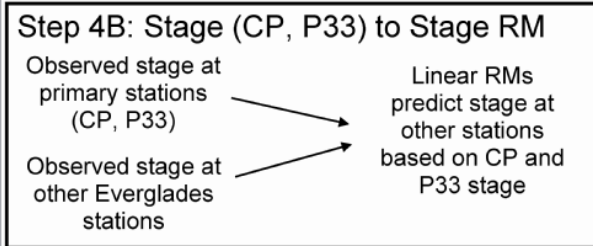
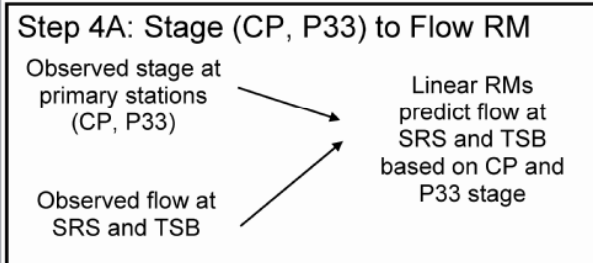
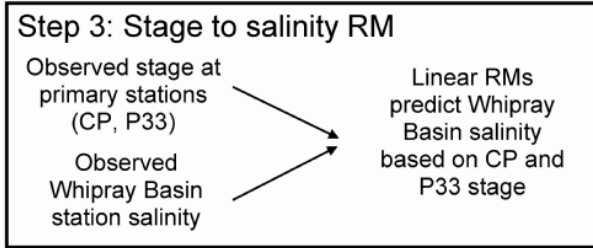
PALEOSALINITY ANALYSIS PROCEDURE

- **3 Phases**
 - Develop paleosalinity regime and time series
 - Develop regression models
 - Link paleosalinity regime and regression models to estimate pre-drainage stage, flow, and salinity
- **8 Steps**

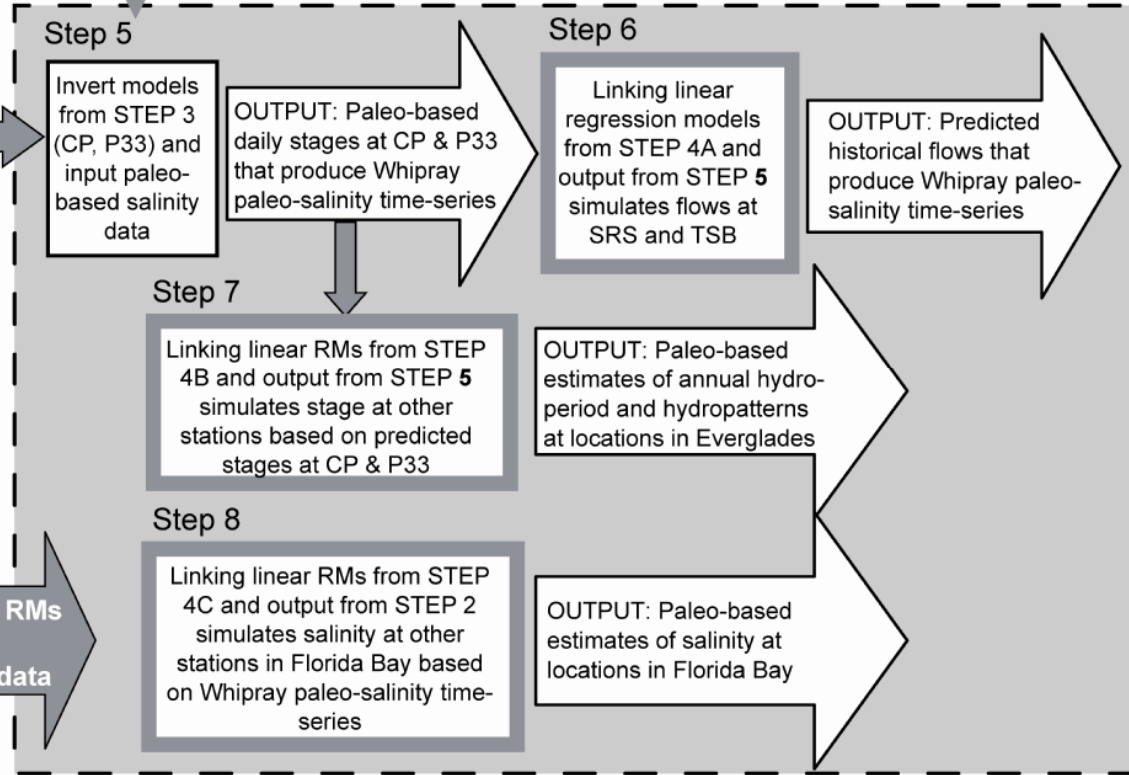
Phase I: Paleoecology



Phase II: Regression Models (RM) based on observed data



Phase III: Linked Regression Models couple Paleoecologic data and RMs based on observed data



Step 4: Linking Regression Models

A Simulation of Historic Hydrology and Salinity in Everglades National Park: Coupling Paleoecologic Assemblage Data with Regression Models

Frank E. Marshall III · G. Lynn Wingard · Patrick Pitts

Received: 29 May 2008 / Revised: 4 November 2008 / Accepted: 6 November 2008
© Coastal and Estuarine Research Federation 2008

Abstract Restoration of Florida's Everglades requires scientifically supportable hydrologic targets. This study establishes a restoration baseline by developing a method to simulate hydrologic and salinity conditions prior to anthropogenic changes. The method couples paleoecologic data on long-term historic ecosystem conditions with statistical models derived from observed meteorologic and hydrologic data that provide seasonal and annual variation. Results indicate that pre-drainage freshwater levels and hydroperiods in major sloughs of the Everglades were about 0.15 m higher and two to four times greater, respectively, on average compared to today's values. Pre-drainage freshwater delivered to the wetlands and estuaries is estimated to be 2.5 to four times greater than the modern-day flow, and the largest

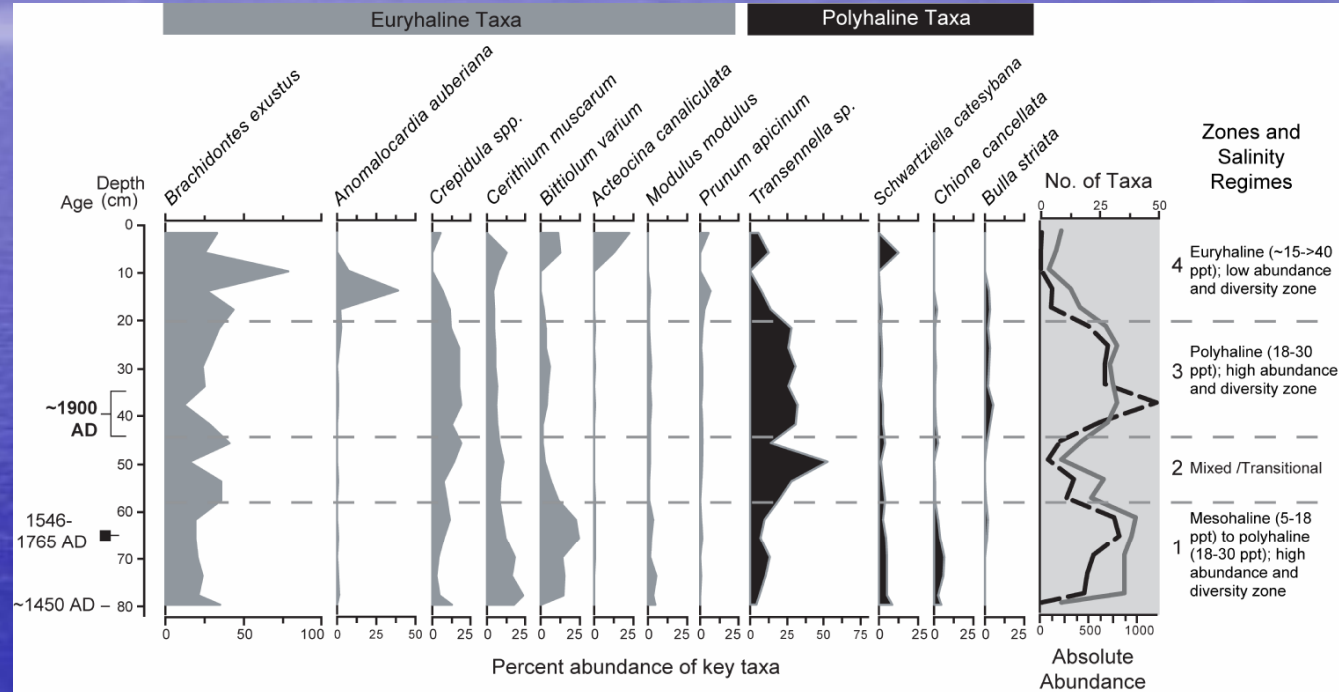
Keywords Everglades · Paleoecology · Statistical models · Restoration targets · Hydrology · Salinity

Introduction

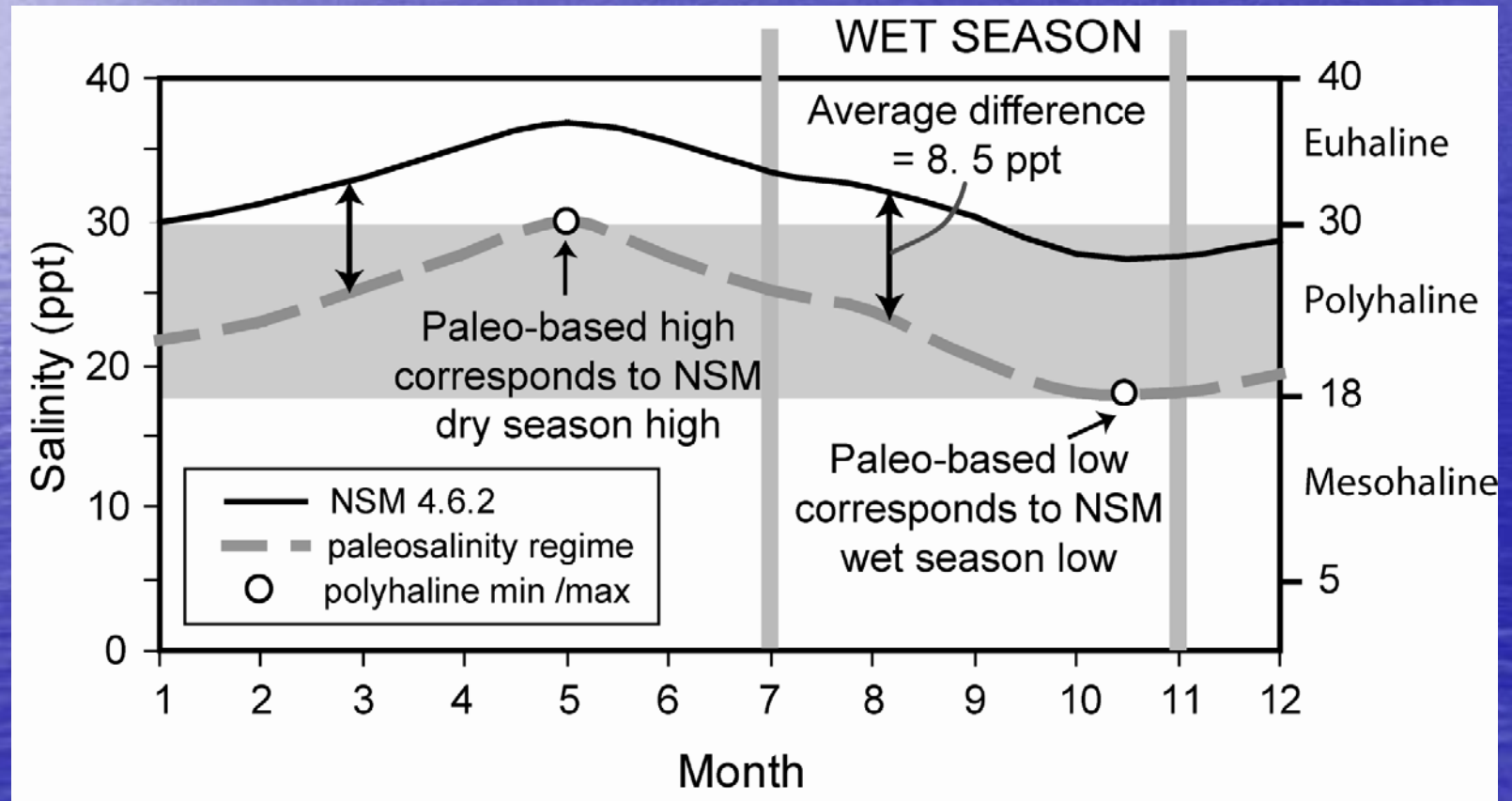
The Greater Everglades Ecosystem of South Florida is a globally unique combination of hydrology and resultant water-based ecology that supports many threatened and endangered species. Encompassed within the Greater Everglades Ecosystem are the wetlands and estuaries of Everglades National Park, including Florida Bay and the southwest mangrove estuaries; Biscayne National Park; Big Cypress National Preserve; and several wildlife

Whipray Basin Paleoeecological Information

**WHIPRAY BASIN
CORE, USGS
ANALYSIS, BASED
ON MOLLUSKS &
FORAMS**



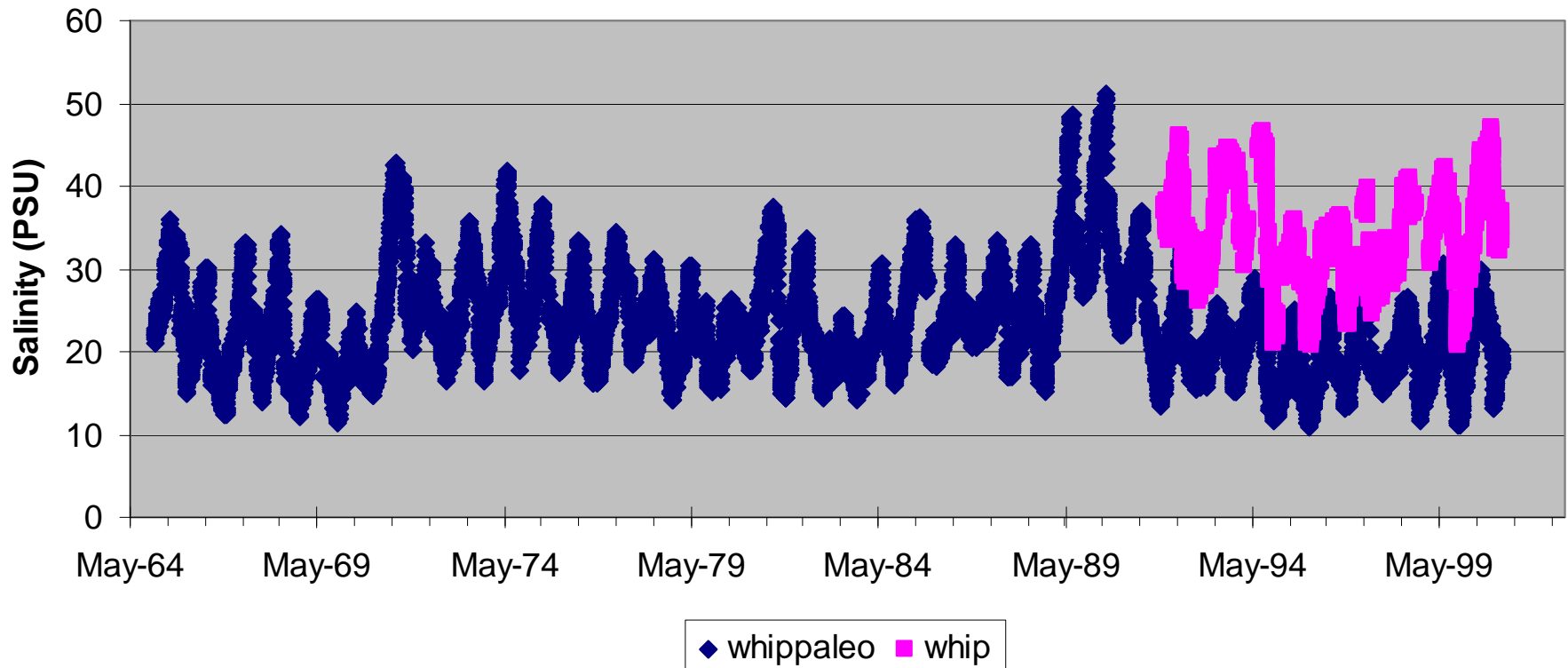
Example: Whipray Basin Paleosalinity Regime



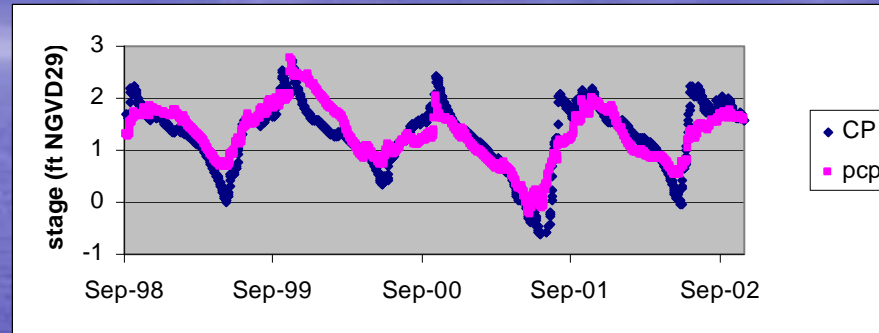
PALEOSALINITY COMPARISON

| Station | Obs Mean | paleo | nsm462 |
|----------------|---------------------|-----------------------------|---------------|
| WB | 35.6 | 23.4 | 31.9 |
| BA | 33.7 | 10.3 (14.9-21.1) | 30.6 |
| BK | 34.2 | 27.7 | 30.4 |

WHIPRAY BASIN PALEOSALINITY (modified NSM/MLR output) Simulated vs. Observed



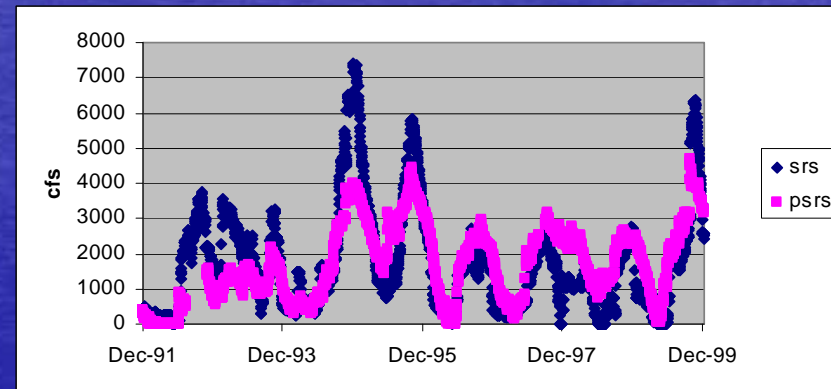
LINKING REGRESSION MODELS – PRIMARY STAGE STATIONS



| Dependent Variable | Independent Variable | Coefficient | Intercept | Adj-R ² |
|--------------------|----------------------|-------------|-----------|--------------------|
| Whipray Basin | P33 | -7.91 | 86.31 | 0.53 |
| | CP | -6.75 | 43.82 | 0.33 |
| Bob Allen Key | P33lag53 | -7.26 | 80.72 | 0.55 |
| | CP lag25 | -7.39 | 43.06 | 0.57 |
| Buoy Key | P33 lag1 | -7.55 | 81.61 | 0.60 |
| | CP lag4** | -6.99 | 41.7 | 0.56 |

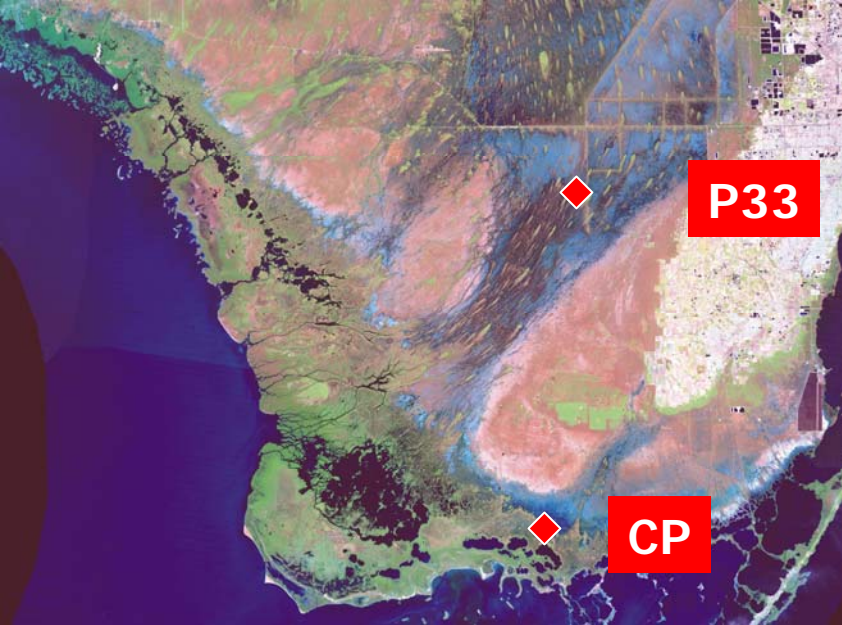
LINKING REGRESSION MODELS – FLOW and STAGE

| Dependent Variable | Independent Variable | Adj-R ² |
|--------------------|----------------------|--------------------|
| TSB | CP | 0.46 |
| SRS | P33 | 0.58 |
| G3273 | P33 | 0.75 |
| NP206 | P33 | 0.61 |
| TSH | CP | 0.71 |



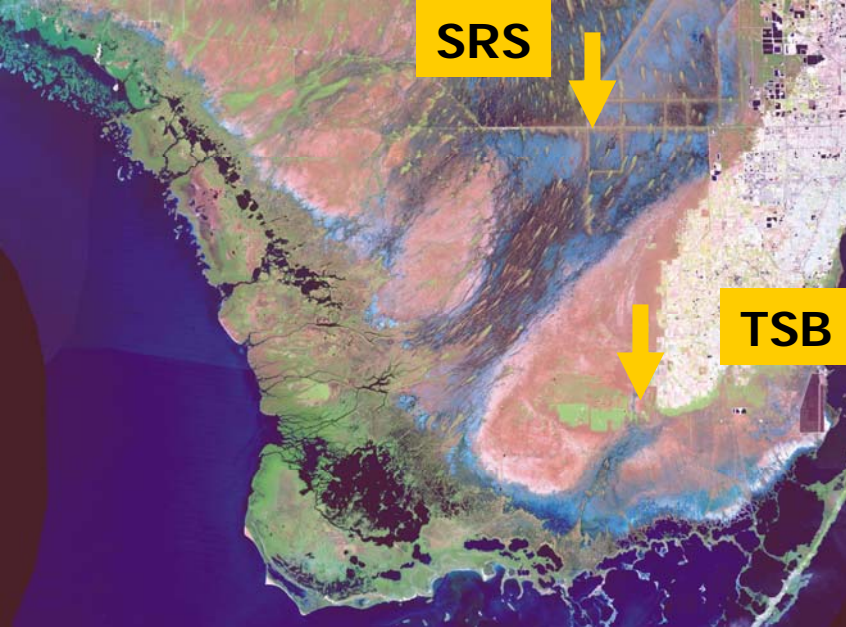
LINKING REGRESSION MODELS – SALINITY

| Dependent Variable | Whipray Basin Adj-R² | Bob Allen Key Adj-R² | Buoy Key Adj-R² |
|---------------------------|--|--|---------------------------------------|
| Bob Allen | 0.83 | | 0.55 |
| Buoy Key | 0.73 | 0.51 | |
| Butternut Key | 0.73 | 0.59 | 0.43 |
| Duck Key | 0.71 | 0.70 | 0.51 |
| Garfield Bight | 0.61 | 0.50 | 0.69 |
| Joe Bay | 0.45 | 0.37 | 0.41 |
| Johnson Key | 0.69 | 0.51 | 0.85 |
| Little Madeira Bay | 0.73 | 0.72 | 0.57 |
| Little Rabbit | 0.68 | 0.54 | 0.77 |
| Murray Key | 0.75 | 0.55 | 0.81 |
| Peterson Key | 0.63 | 0.77 | 0.6 |
| Terrapin Bay | 0.72 | 0.73 | 0.70 |



Output: Primary Stage Stations– Paleo-based vs Observed

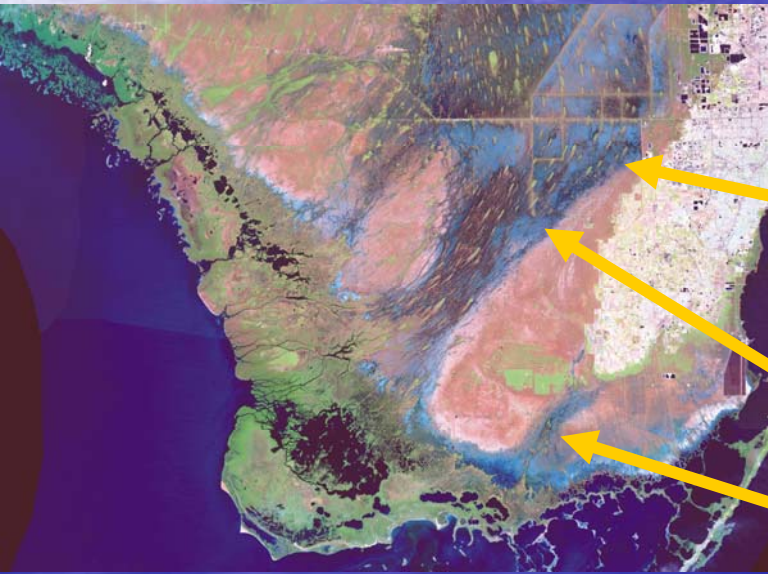
| Stage Station | Salinity Source | Mean (m) | paleo-obs (m) | paleo: observed |
|---------------|-----------------|-------------|---------------|-----------------|
| P33 | observed | 1.93 | | |
| | Whipray paleo | 2.48 | 0.55 | 1.28 |
| | Bob Allen paleo | 2.48 – 2.94 | 0.55 – 1.01 | 1.28 – 1.55 |
| | Buoy Key paleo | 2.18 | 0.25 | 1.12 |
| CP | observed | 0.39 | | |
| | Whipray paleo | 0.99 | 0.60 | 2.54 |
| | Bob Allen paleo | 0.89 – 1.33 | 0.50 – 0.94 | 2.28 – 3.4 |
| | Buoy Key paleo | 0.61 | 0.22 | 1.73 |



Output: Mean Flow – Paleo-based vs Observed

| Station | Salinity Source | Mean Flow (m ³ /sec) | paleo: observed |
|---------|-----------------|---------------------------------|-----------------|
| SRS | observed | 42.4 | |
| | Whipray paleo | 115.8 | 2.73 |
| | Bob Allen paleo | 131 – 220.5 | 3.4 – 5.7 |
| | Buoy Key paleo | 96.9 | 2.28 |
| TSB | observed | 2.23 | |
| | Whipray paleo | 8.9 | 3.99 |
| | Bob Allen paleo | 10.3 – 17.7 | 3.9 – 6.7 |
| | Buoy Key paleo | 5.5 | 2.40 |

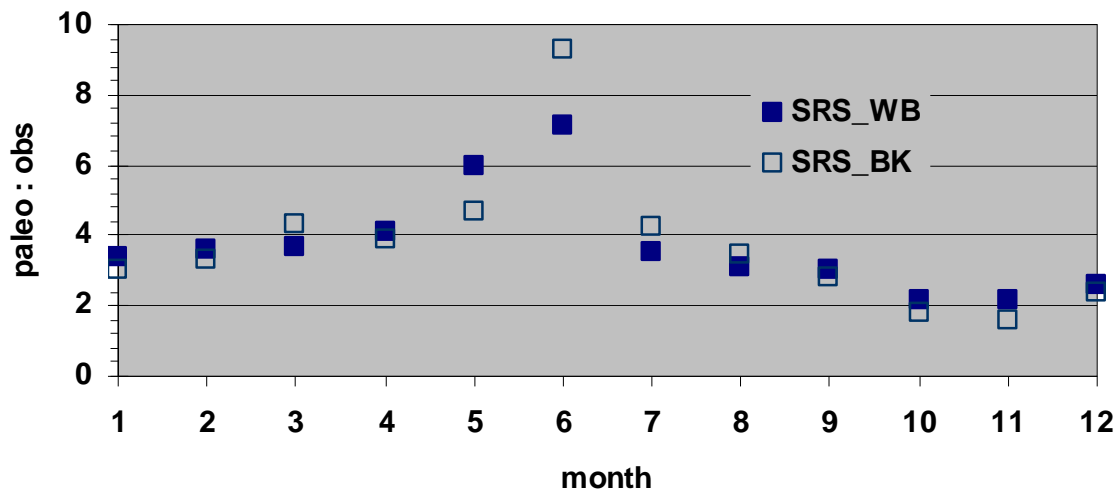
Output: Stage Difference at Other Station – From WB and BK Paleosalinity



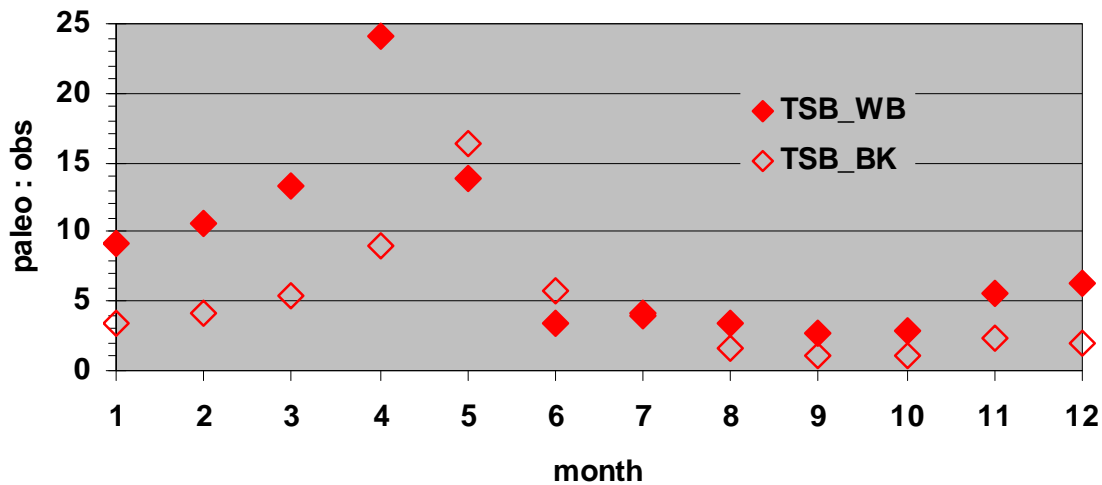
| Station | Location | WB-based Difference paleo-obs (m) | BK-based Difference paleo-obs (m) |
|---------|--------------------|-----------------------------------|-----------------------------------|
| G3273 | Shark River Slough | 0.37 | 0.38 |
| NP206 | Shark River Slough | 0.51 | 0.43 |
| TSH | Taylor Slough | 0.44 | 0.30 |

Output: Paleo-based Salinity Regime in Florida Bay

| Station | Observed Average | WB-based Paleo | BK-based Paleo | BA-based Paleo |
|--------------------|------------------|----------------|----------------|----------------|
| Bob Allen | 33.20 | 21.10 | 28.9 | |
| Buoy Key | 32.80 | 22.20 | | 17.95-25.66 |
| Butternut Key | 31.30 | 17.70 | 24.10 | 8.82-18.22 |
| Duck Key | 29.00 | 16.80 | 26.16 | 8.42-17.36 |
| Garfield Bight | 28.90 | 10.30 | 20.63 | 2.56-14.20 |
| Joe Bay | 15.36 | 2.73 | 8.69 | 0.34-2.57 |
| Johnson Key | 35.30 | 27.00 | 29.99 | 21.5-27.75 |
| Little Madeira Bay | 23.83 | 8.20 | 15.46 | 1.29-8.84 |
| Little Rabbit | 34.40 | 27.30 | 30.97 | 23.7-28.01 |
| Murray Key | 33.00 | 24.80 | 29.28 | 21.40-27.23 |
| Peterson Key | 35.80 | 30.50 | 32.36 | 23.86-29.19 |
| Terrapin Bay | 23.60 | 3.50 | 14.15 | 0.51-3.69 |



Output: Monthly Average Flow Comparison



DRY

WET

Paleo-based Salinity Regime

WBPALEO

BKPALEO

EXIST



Venice System



Biologically-based Estuarine Salinity Zones

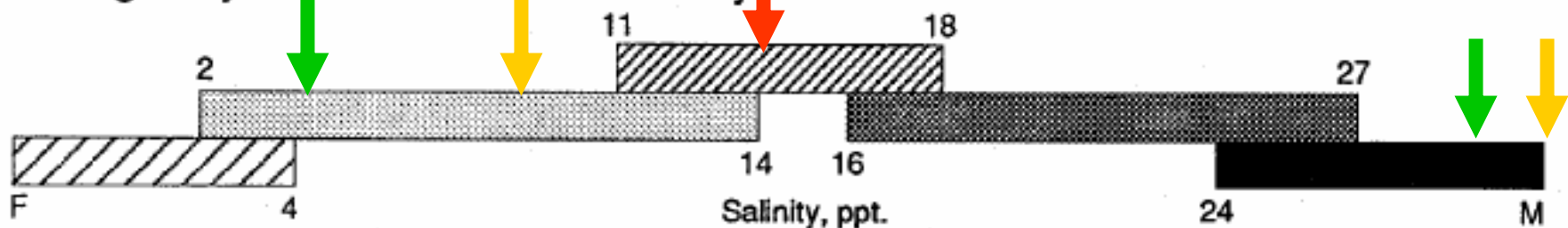


Fig. 1. Comparison of Venice System and estuarine salinity zones derived from multivariate analysis.

SOURCE: Bulger, Hayden, Monaco, Nelson, McCormack-Ray;
Estuaries Vol. 16, No. 2, p. 311-322 June 1993

SALINITY COMPARISON – Observed, Paleo, NSM 462, NSM 512 (New Topography)

| Station | Obs N | Obs Mean | paleo | nsm462 | nsm512 | paleo/NSM N |
|---------|-------|----------|-----------|--------|--------|-------------|
| BA | 1498 | 33.7 | 10.3-21.1 | 30.6 | 25.1 | 13145 |
| BK | 1547 | 34.2 | 27.7 | 30.4 | 25.3 | 13145 |
| WB | 3983 | 35.6 | 23.4 | 31.9 | 26.2 | 13145 |

Obs>NSM 462>NSM 512>Paleo

SUMMARY – FINDINGS OF PALEOSALINITY ANALYSIS TO- DATE

- A methodology has been developed to link paleosalinity data to upstream hydrology in the Everglades using hydrologically defensible regression models
- Based on paleoecology, Florida Bay pre-drainage salinity was oligohaline to polyhaline
- Pre-drainage salinity regime requires about 2-2.5 times more freshwater than the current flow regime.

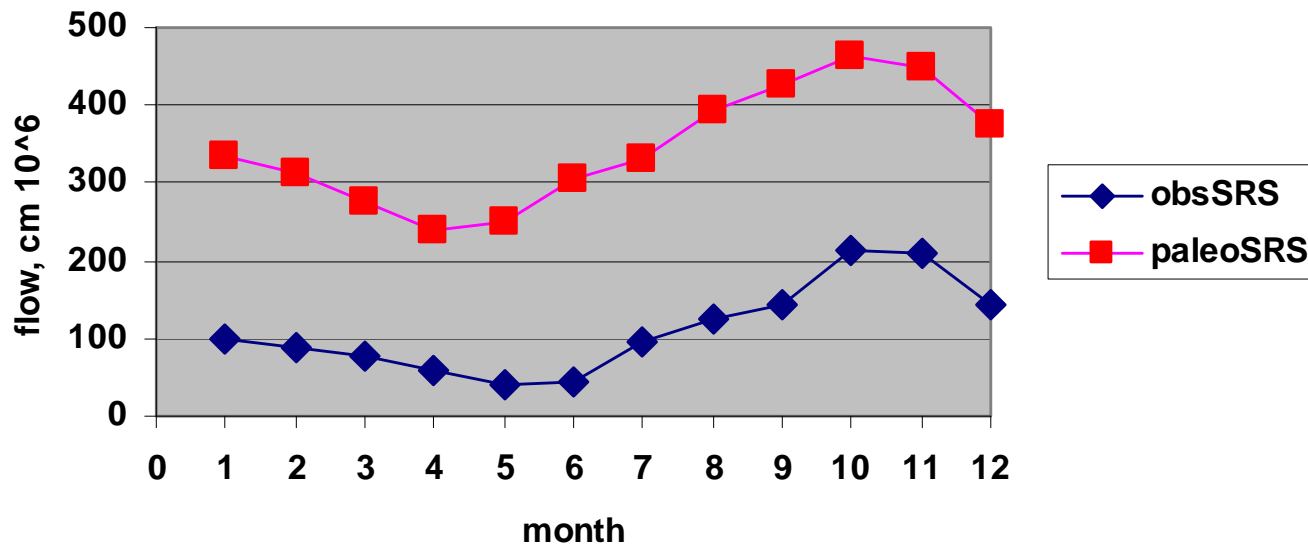
SUMMARY – CURRENT CONDITIONS COMPARED TO PALEO CONDITIONS

- Currently:
 - Taylor Slough flow deficit is >>> than the deficit in Shark River Slough during the dry season.
 - Average Everglades stage is about 0.5 m lower.
 - Florida Bay salinity is about 5 – 15 psu higher.

Comparison of Hydrology and Salinity –Obs vs Regression Models

- **Whipray Basin/ Buoy Key Salinity:**
 - $\text{Obs} > \text{NSM 462} > \text{NSM 512} > \text{Paleo}$
- **CP/P33 Stage:**
 - $\text{Obs} < \text{NSM 462} < \text{NSM 512} < \text{Paleo}$
- **SRS/TSB Flow:**
 - $\text{Obs} < \text{NSM 462} < \text{NSM 512} < \text{Paleo}$

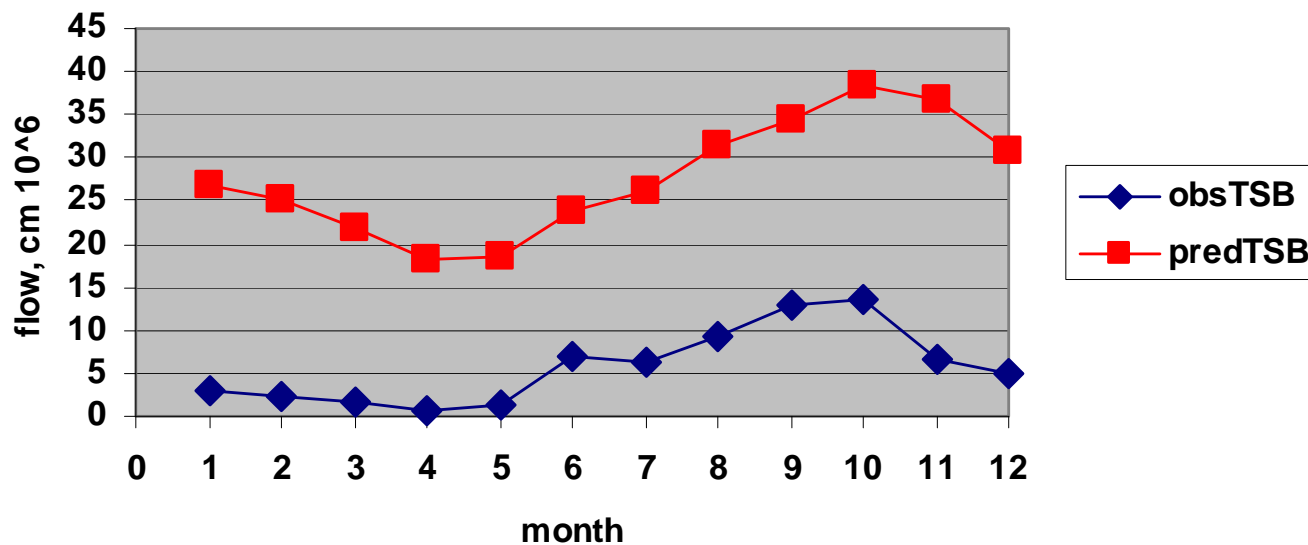
Example Target: Shark River Slough Flow



DRY SEASON

WET SEASON

Based on Whipray
Basin Analysis

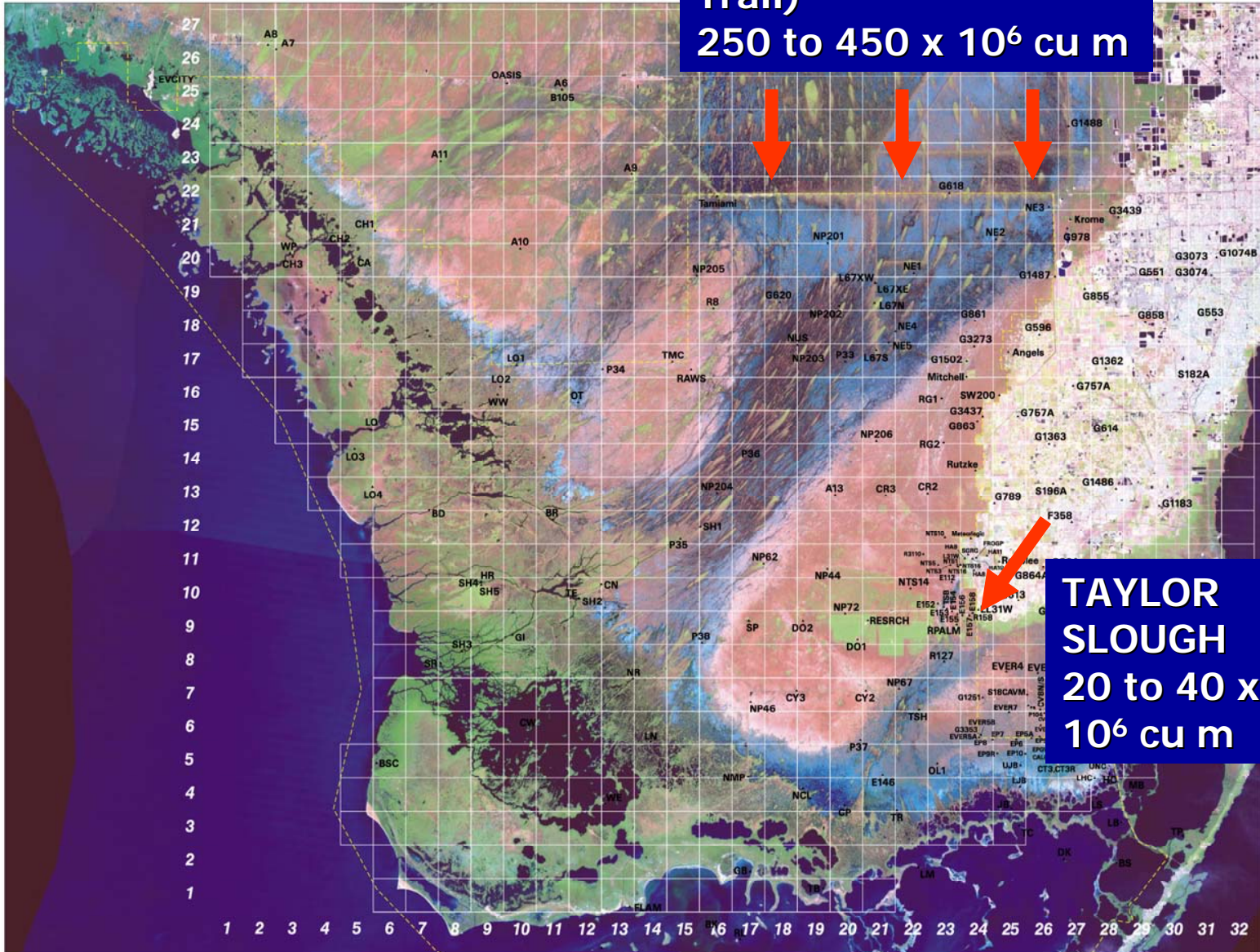


Example Target:
Taylor
Slough
Flow

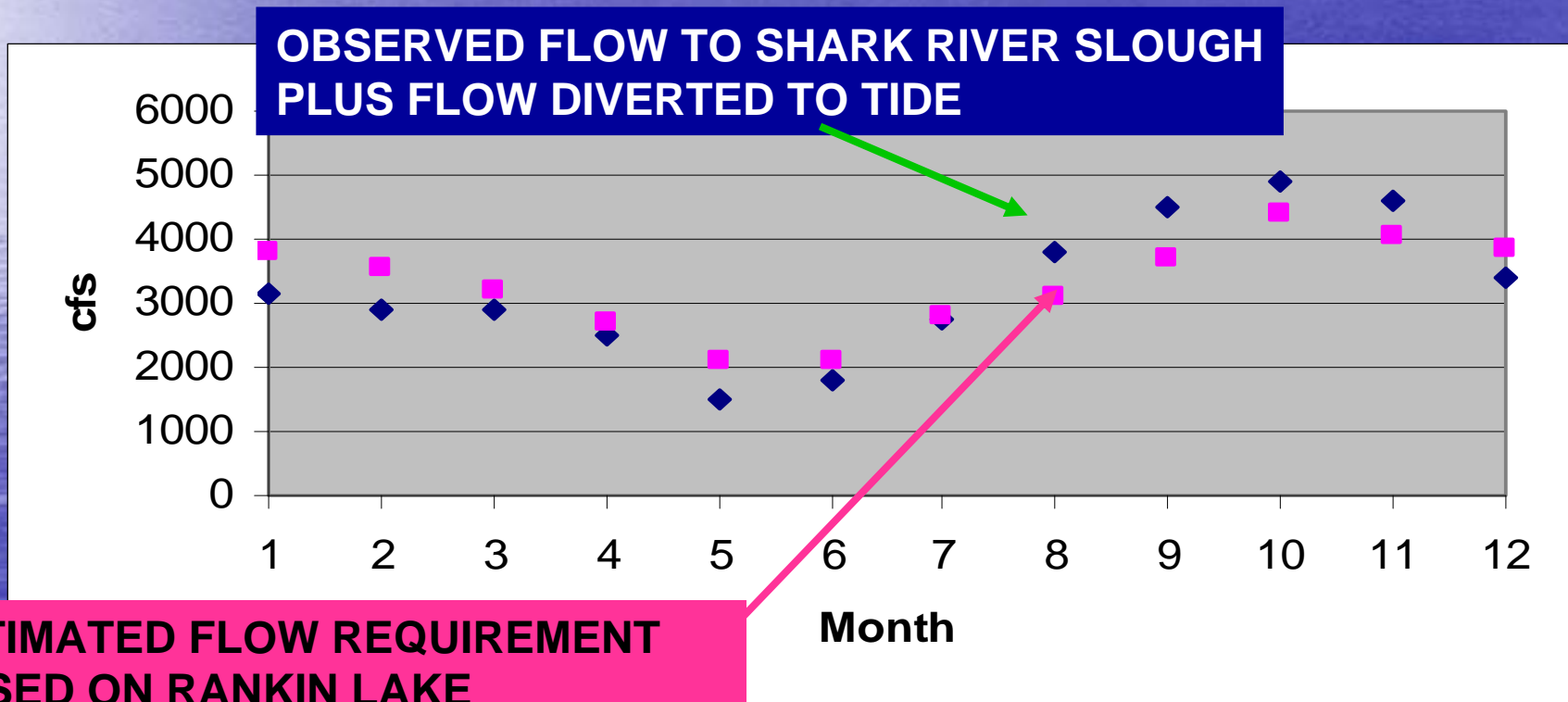
Targets

**SHARK RIVER
SLOUGH (Tamiami
Trail)
250 to 450 x 10⁶ cu m**

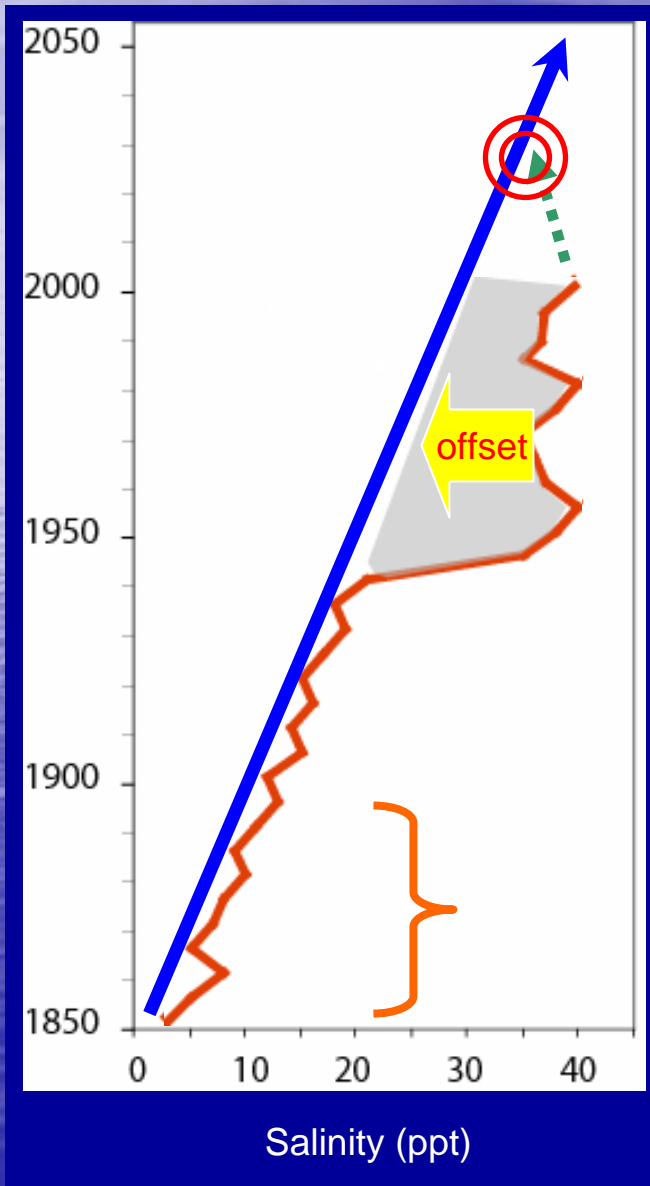
**TAYLOR
SLOUGH
20 to 40 x
10⁶ cu m**



Comparison: Freshwater Diverted to Tide vs Paleo-based Flow Estimates



Where Are We Going With Paleo And Regression Model Analyses?



GOAL: Determine the offset needed for salinity restoration targets taking into account irreversible anthropogenic changes and SLR

**THANK
YOU!**

www.cetaceanlogic.org

