CORROBORATION OF EARLIER ESTIMATES OF LATE 19TH CENTURY FRESHWATER FLOW IN THE EVERGLADES

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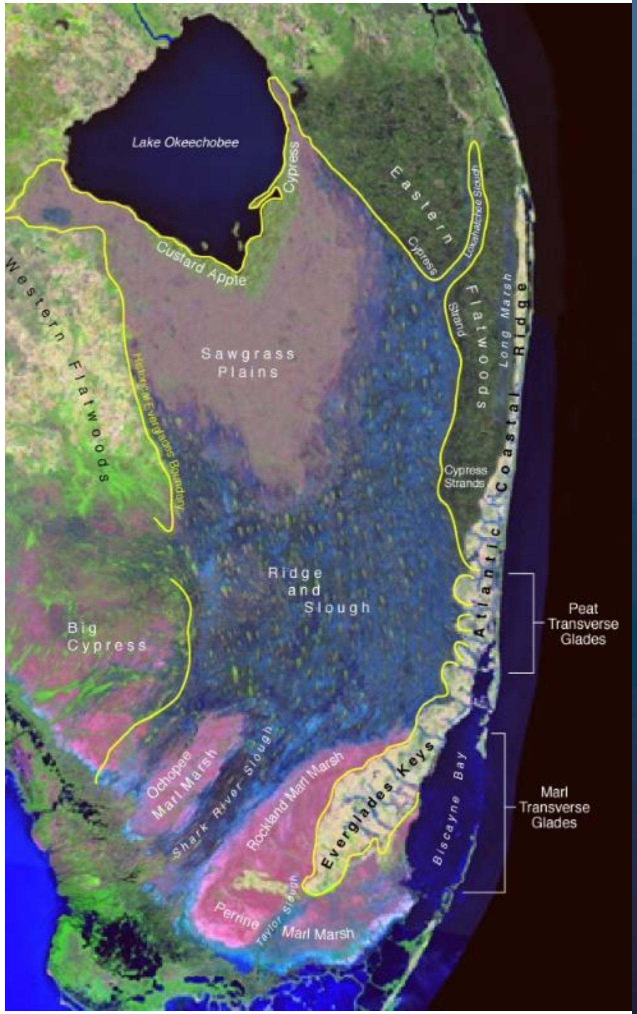
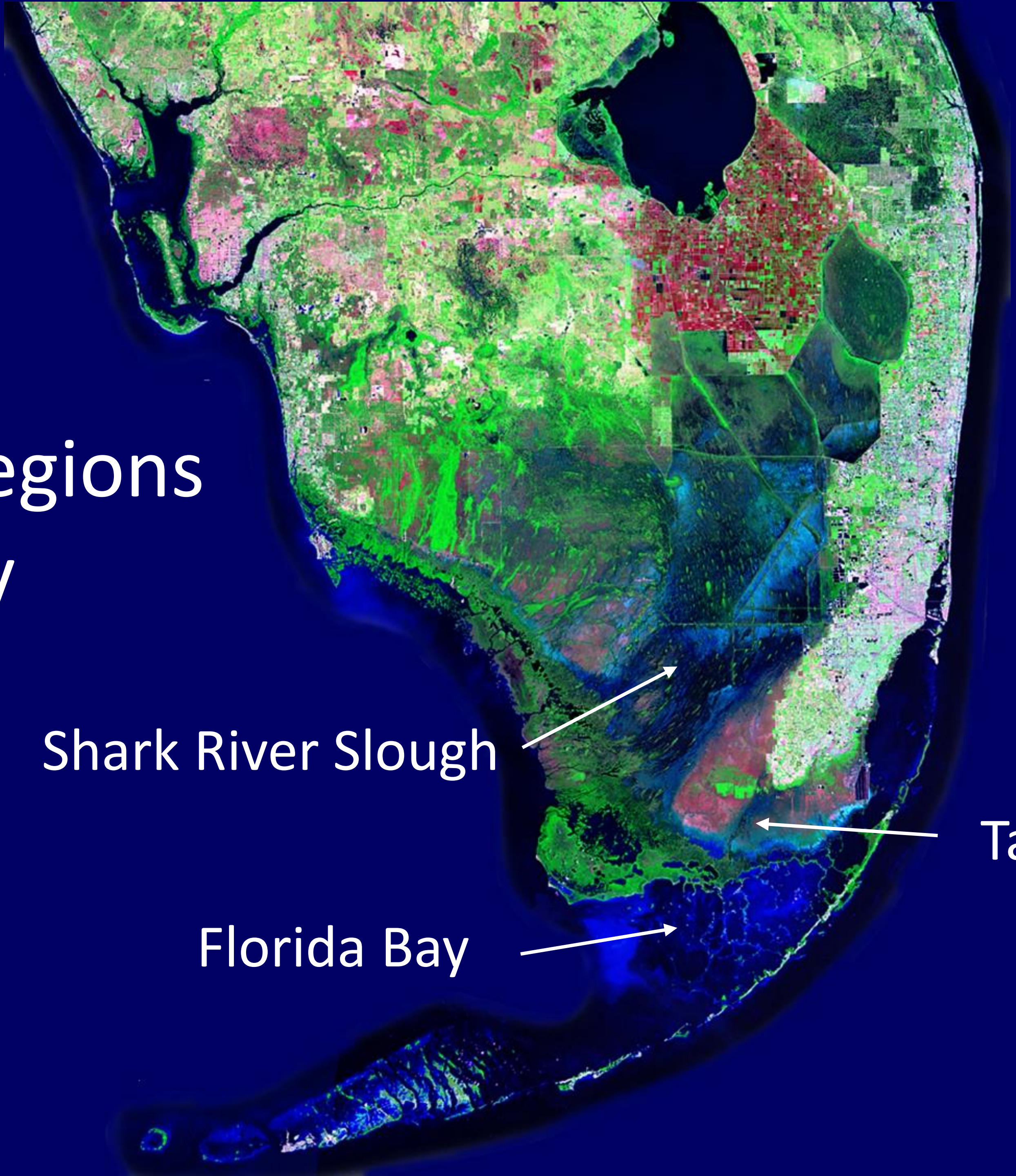
Greater Everglades Ecosystem ~1900 CE



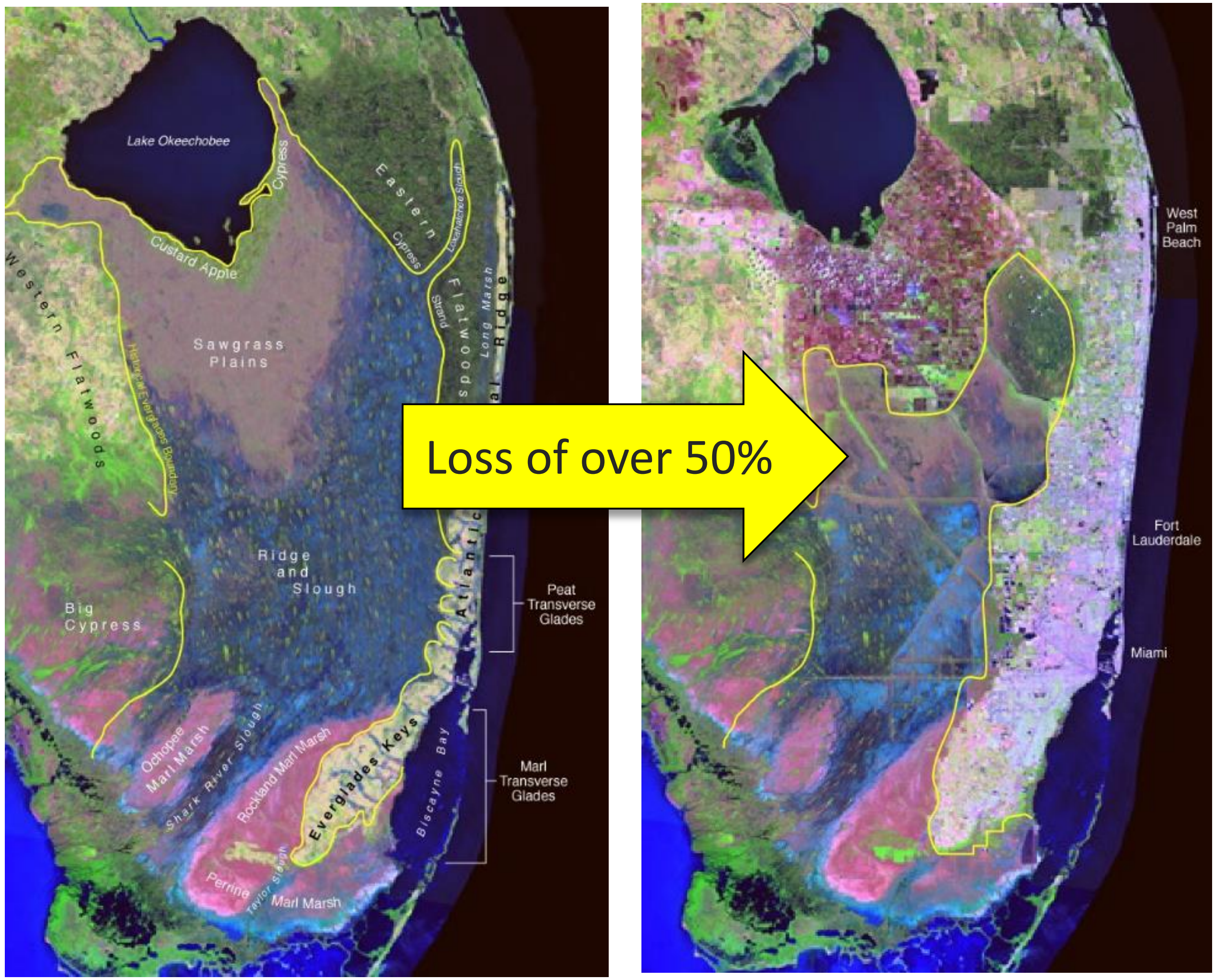
In the case of Everglades Restoration the over-arching goal is "to get the water right" by re-establishing pre-drainage conditions in freshwater wetlands including freshwater flows through the wetlands and natural salinity variability in the receiving estuaries

Hydrologic Regions For this Study



In the Everglades The primary issue is the loss of the pre-drainage wetlands

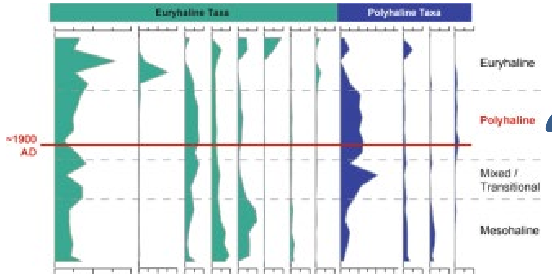
- The compositions of the diverse environments present in the Everglades are determined by the volume and timing of the freshwater supply
- The present-day impairment in the Everglades is a deficiency of adequate flow with a natural variability



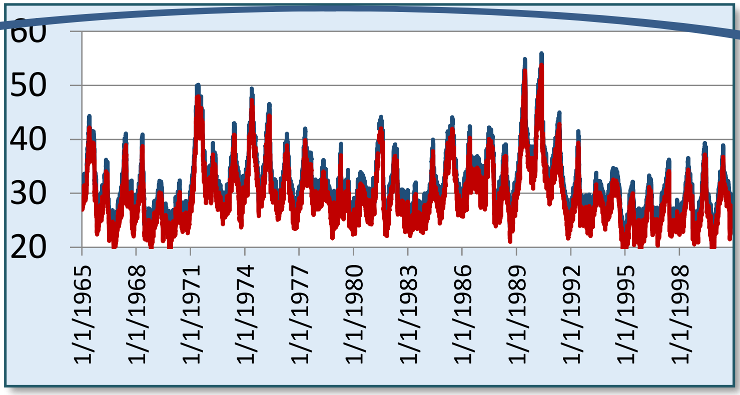
The Problem for Management

- Can defensible values for historic flow be legally established?
- To date, the lead agencies for Everglades restoration have used existing numeric hydrologic model simulations (NSM and NSRSM) as the primary tools for setting goals
- BUT - NSM and NSRSM do not always produce documented historic freshwater conditions at all water level monitoring stations
- Adding to the problem – the existing salinity models rely on these hydrologic model outputs as inputs to salinity models to estimate the historic salinity
- Can existing information from paleoecologic studies be used to solve this problem?

Solution: Link Paleo Data and Statistical Models



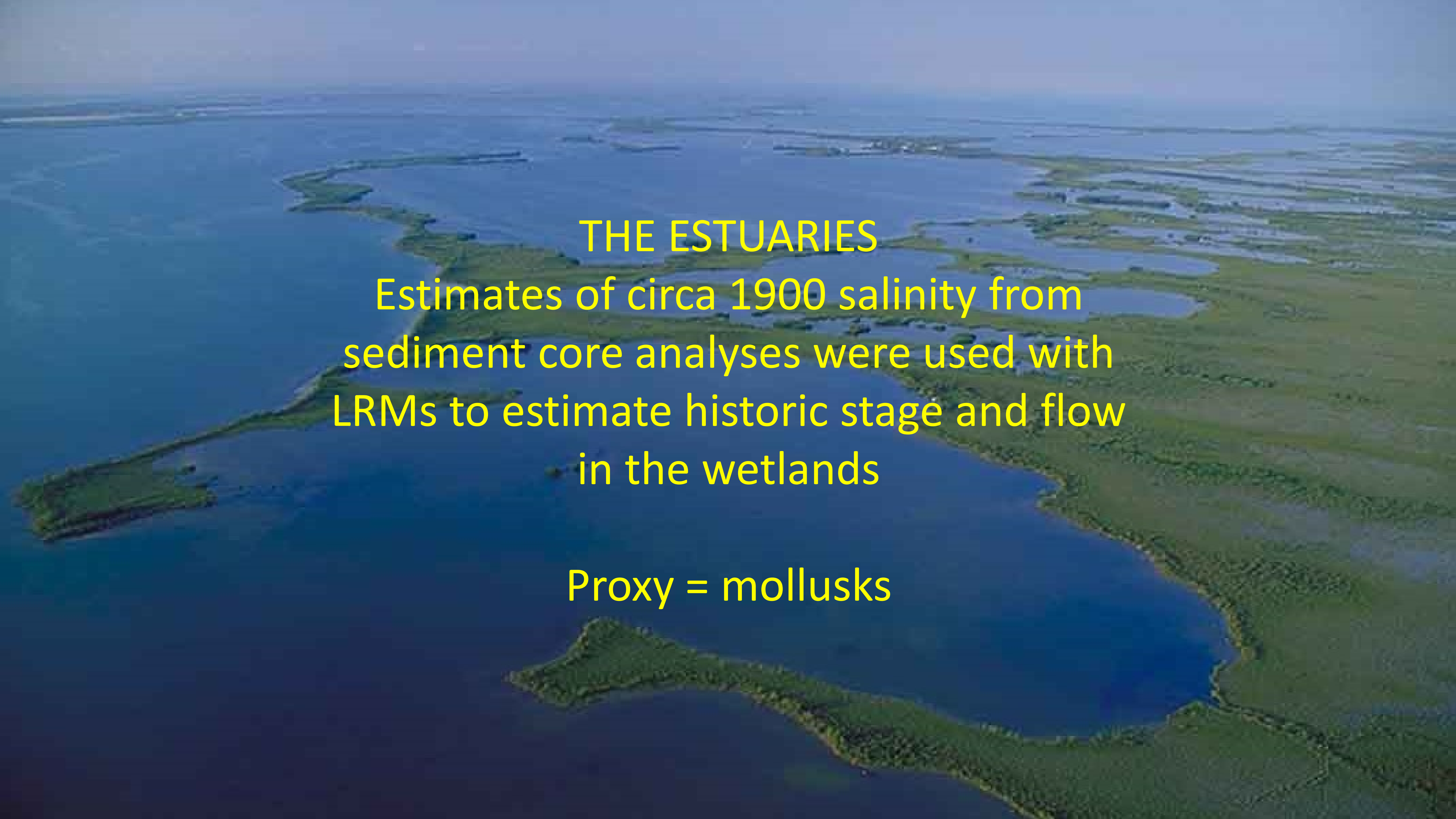
Phase I: Estimate paleo-based hydrologic conditions for ~1900 CE from plant and animal proxies and use the ecologic conditions preferred by the proxies to adjust hydrologic models of the pre-disturbance conditions, in this case NSM



Phase II: Develop Linear Regression Models (LRMs) from observed water levels collected from the existing freshwater wetland and salinity from the estuaries

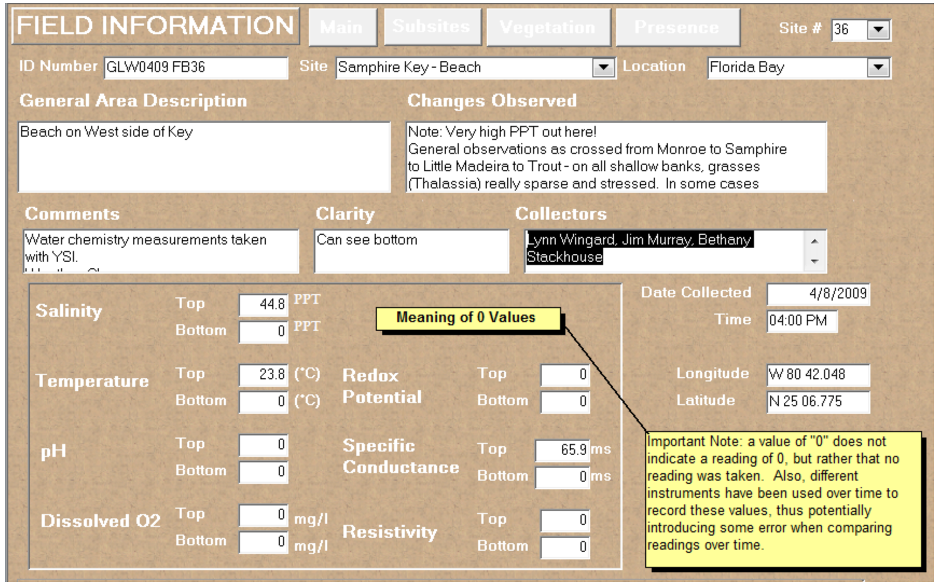
Phase III: Input the paleo- based NSM regime to the LRMs to produces estimates of past hydrologic and salinity conditions

Marshall et al. Estuaries and Coasts (2014) v.37

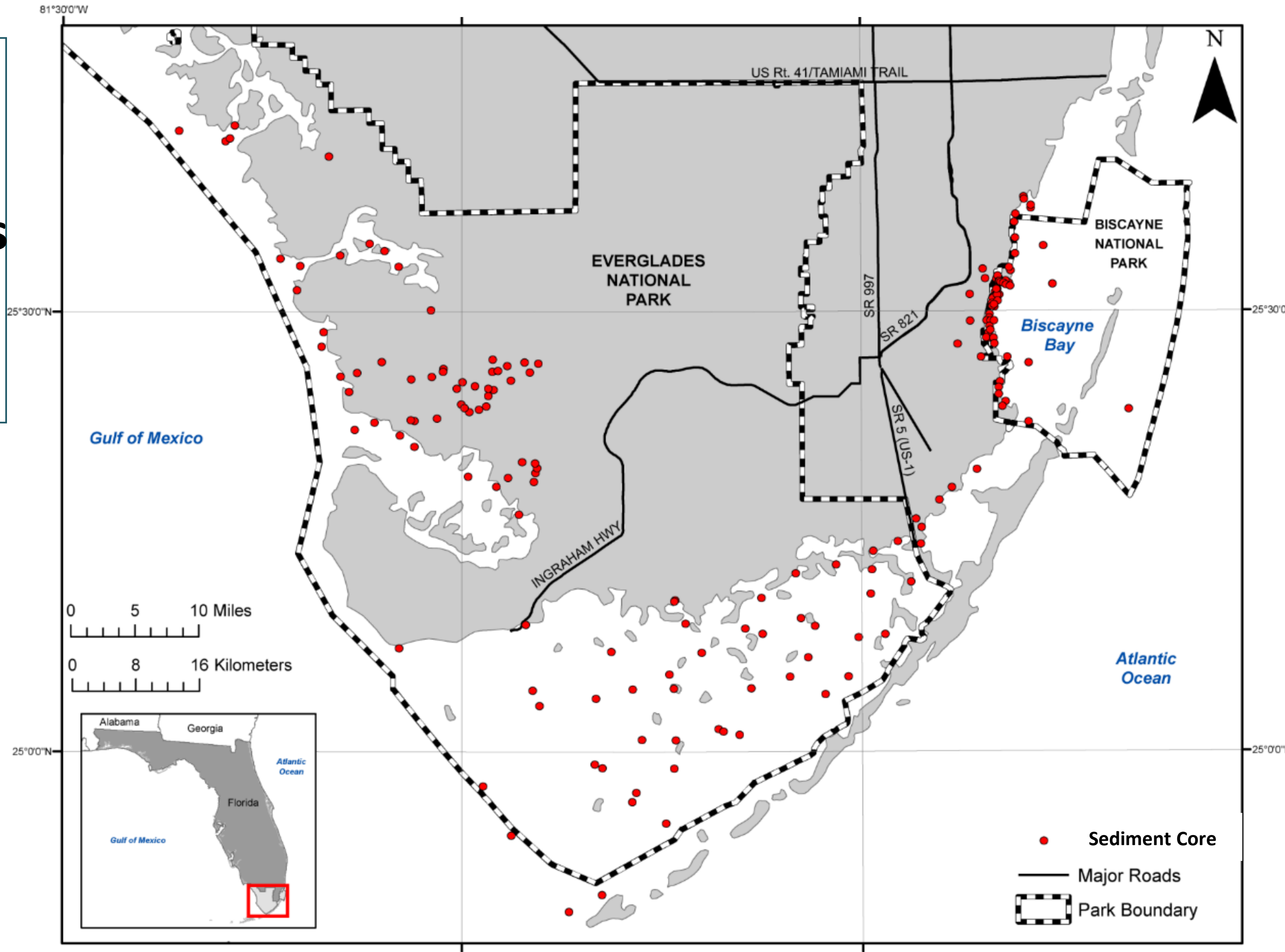

THE ESTUARIES
Estimates of circa 1900 salinity from sediment core analyses were used with LRMs to estimate historic stage and flow in the wetlands
Proxy = mollusks

Step 1: Collect sediment cores and modern analog data

- 217 modern sites for modern analogs
- > 900 site visits since 1994
- ~ 205 mollusks species found alive



Location of Estuarine Sediment Cores

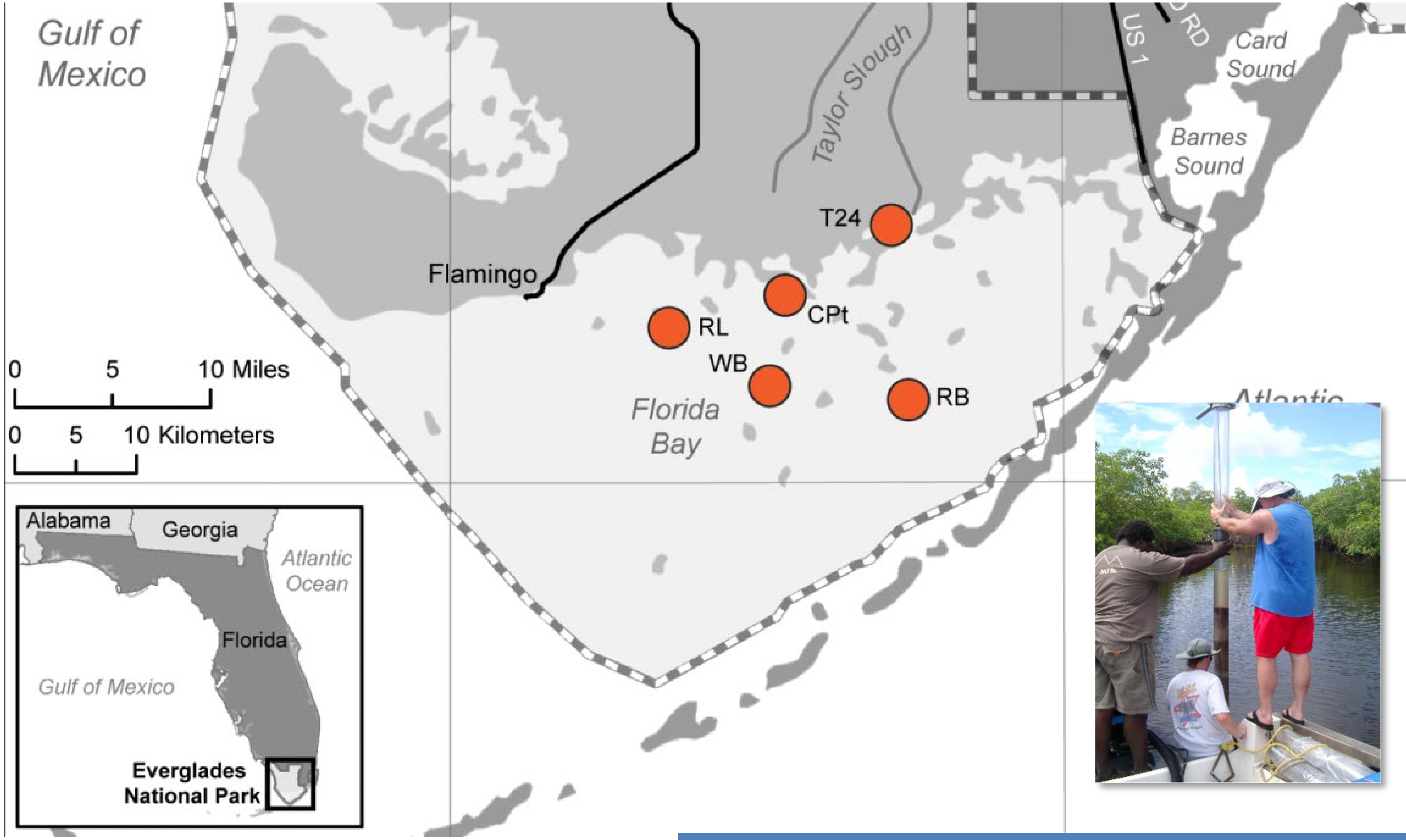


Wingard & Hudley 2012 Est.& Coasts v.35
https://sofia.usgs.gov/exchange/flaecohist/

Developing Pre-drainage Salinity Estimates

Step 2: Analyze sediment cores

- Five cores collected in Florida Bay were analyzed
- Cores were dated radiometrically
- Occurrence of exotic pollen marks the beginning of drainage alterations



Marshall & Wingard 2012 USGS OFR 2012–1054
Marshall et al. 2014 Est. & Coasts, v. 37

Developing Pre-drainage Salinity Estimates

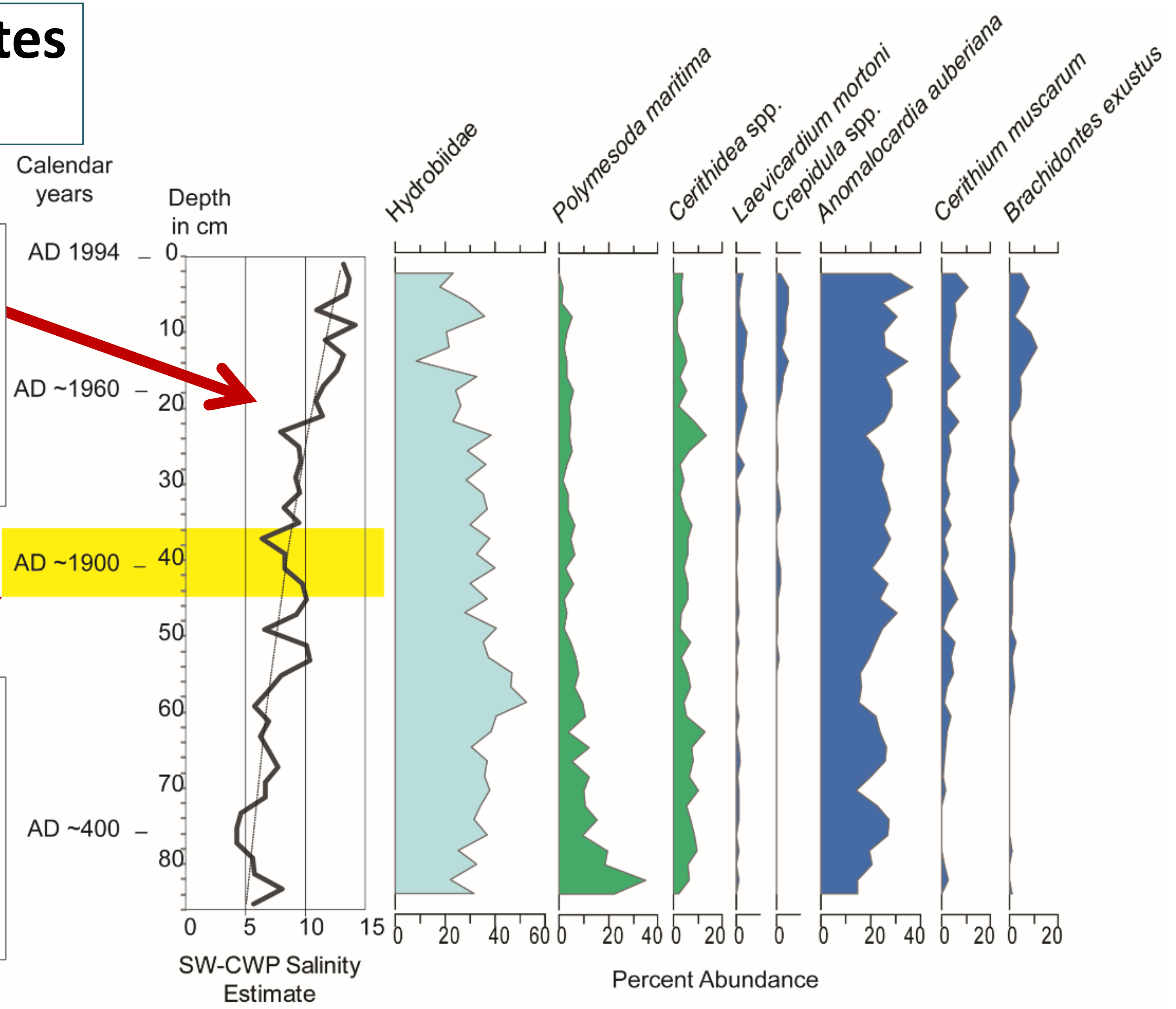
Step 3: Derive Paleosalinity Estimates
Example shown: Taylor Creek Core

Molluscan assemblages are interpreted using average salinity values from the modern analog dataset

Average salinity values from modern analog dataset are weighted by the abundance of species in each sample

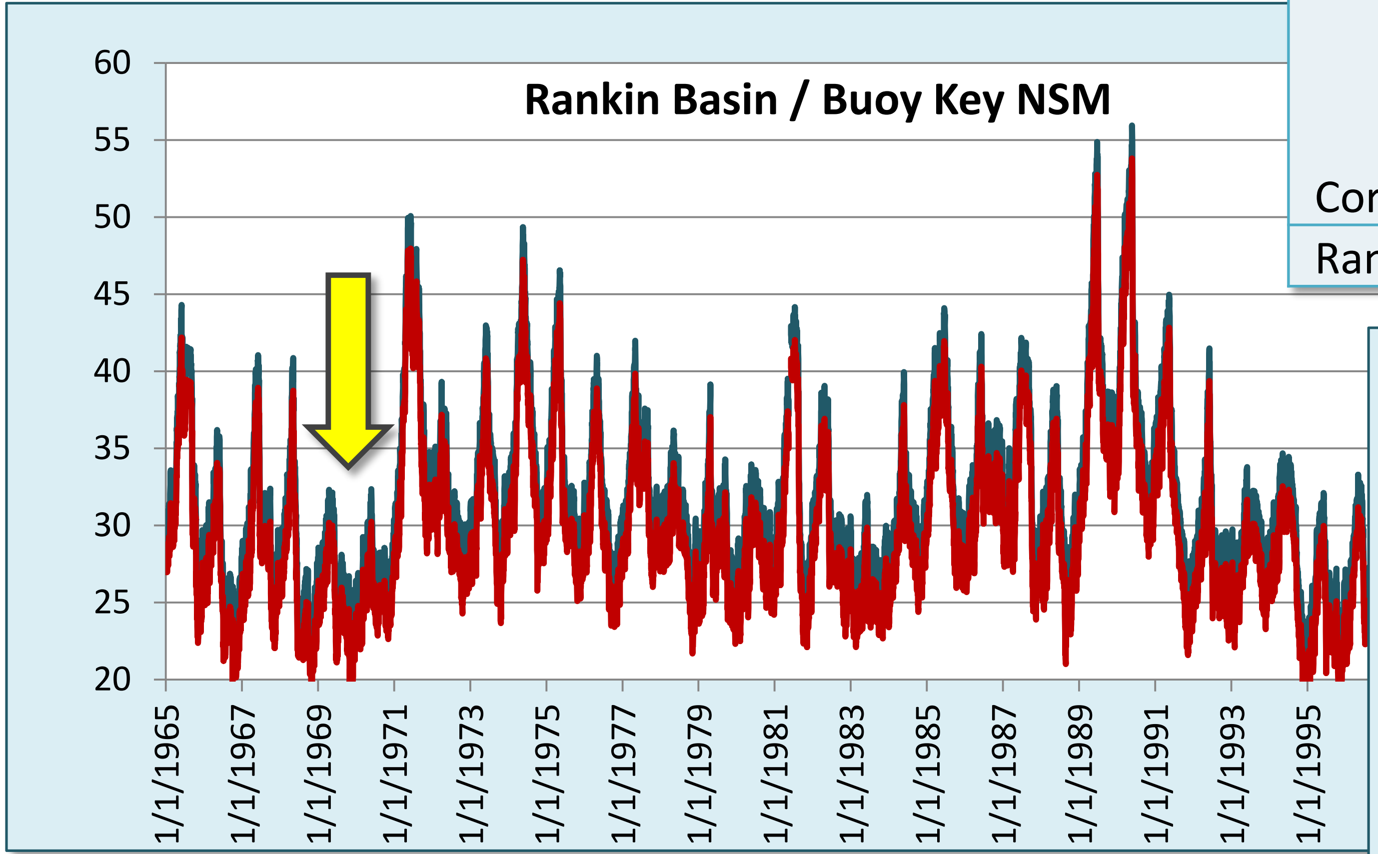
Cumulative weighted average salinity is produced for each 2 cm core segment

Paleosalinity estimates from ~1900 CE are used to adjust the NSM Model

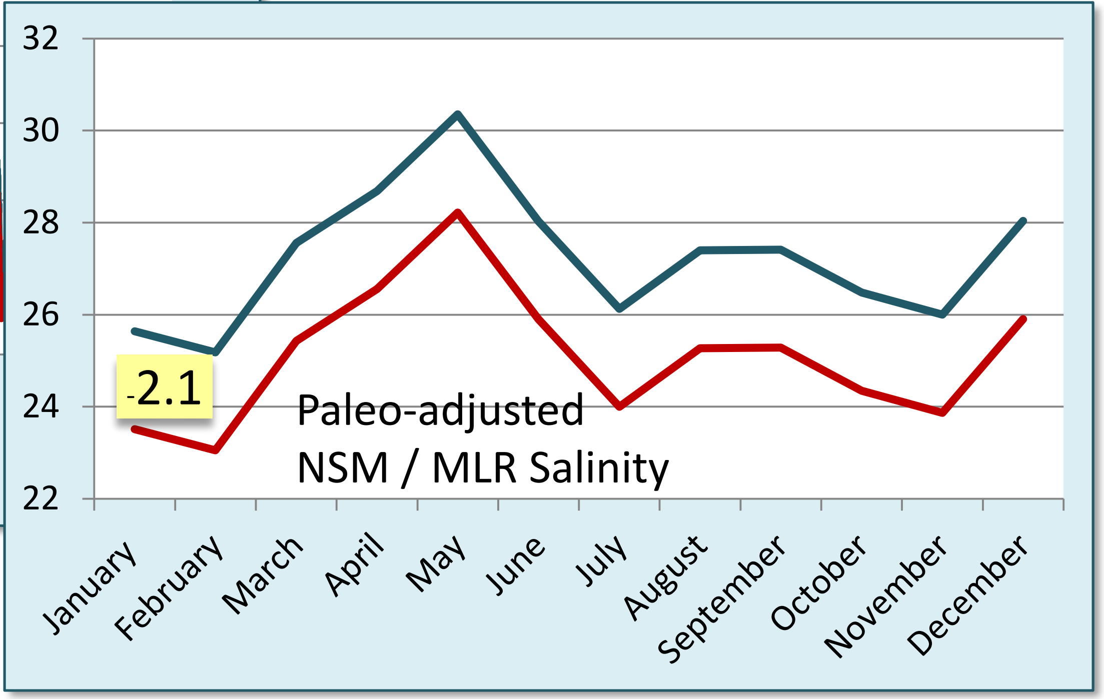


Paleo-adjustment for Natural Systems Model (NSM) Salinity

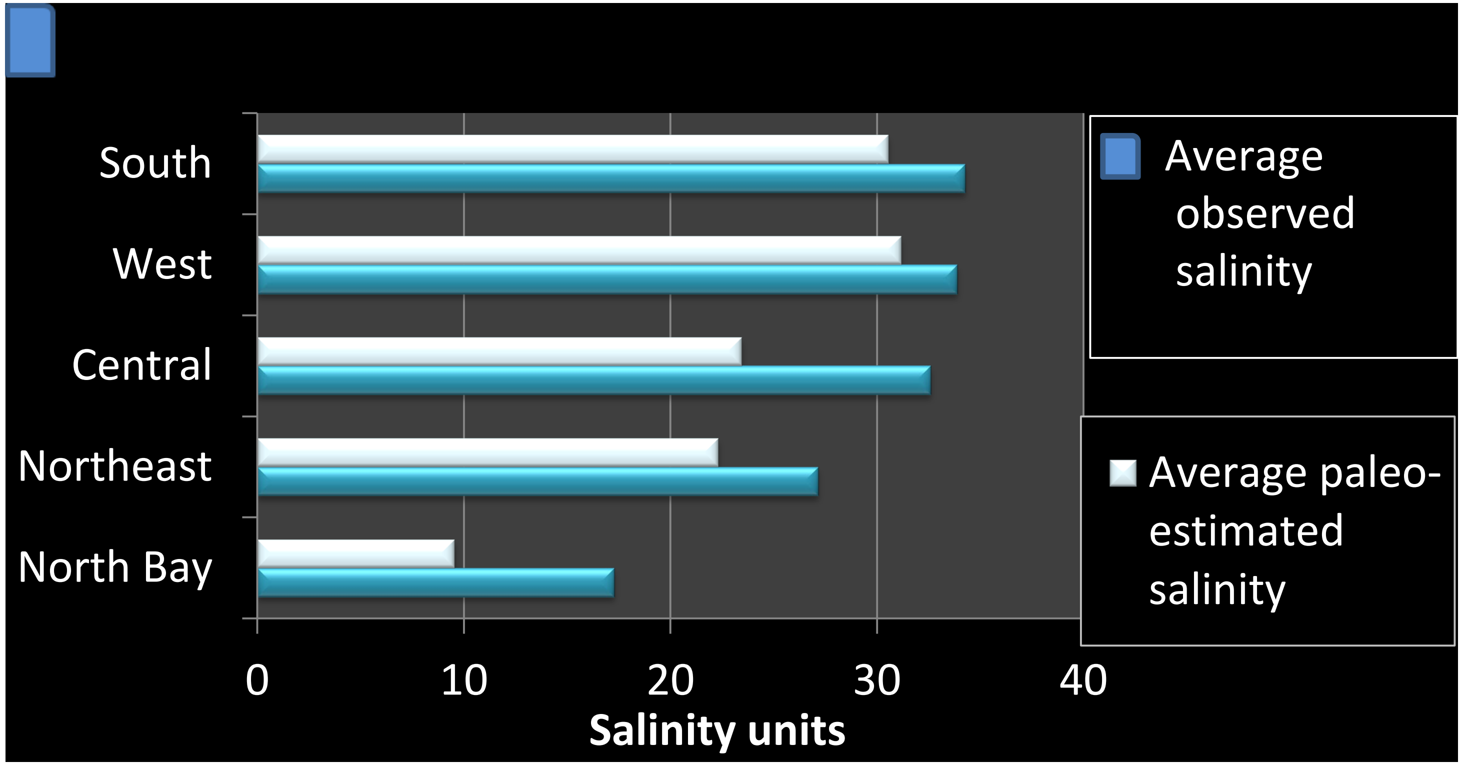
Step 4: Develop paleosalinity time series at each core location

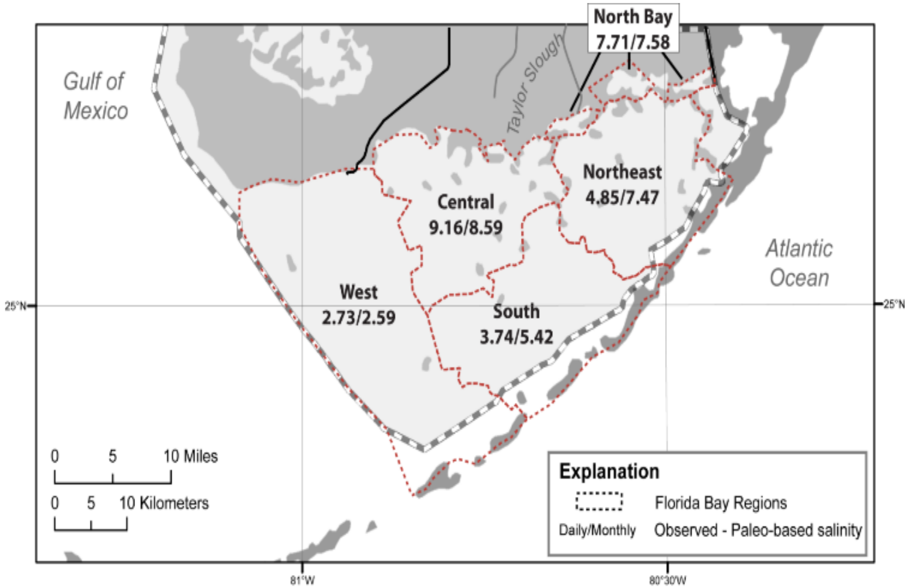


Core Name	NSM/MLR Mean Salinity (1965-2000)	Paleosalinity Estimate (CWP CONFID)	NSM Salinity Adjustment for Paleosalinity Time Series
Rankin Lake	30.4	28.3	-2.1



Salinity Results by Region: Observed vs. Paleo-based Estimates

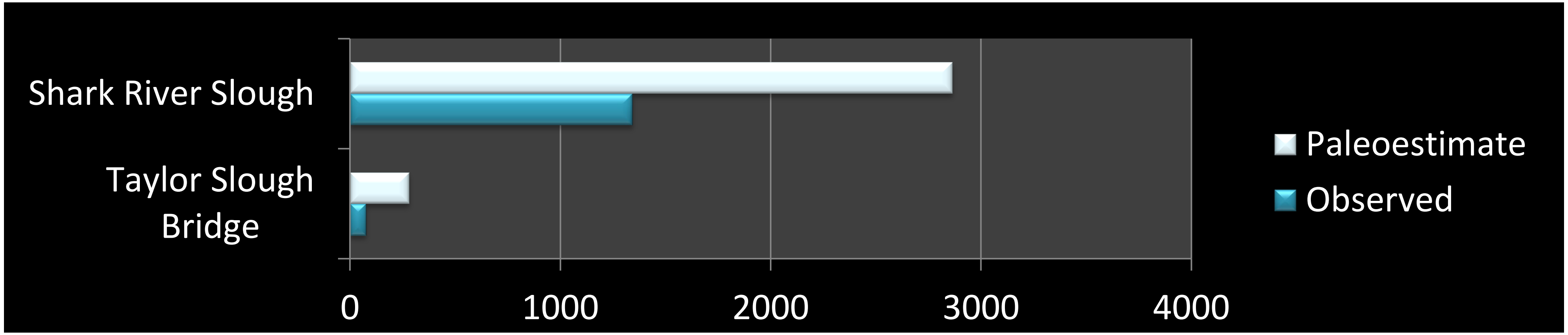




Daily/monthly average salinity differences

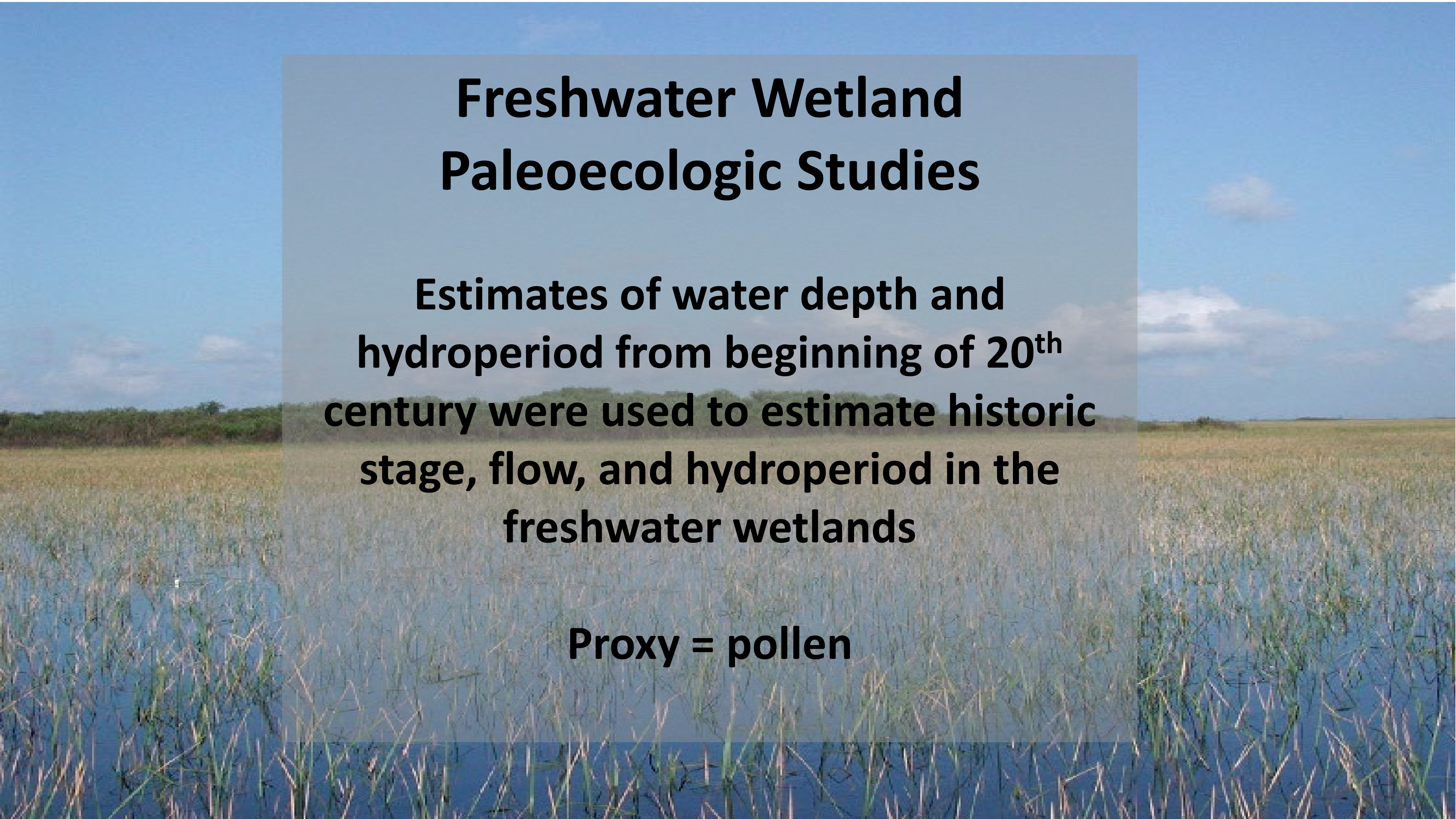
Marshall, Wingard, Pitts
2014 Estuaries & Coasts v 37

Results: Observed vs. Paleo-based Flow Estimates from Estuarine Sediment Core Analyses



Flow through the Everglades needs to be 2.1 to 3.7 times greater than present condition

Marshall, Wingard, Pitts Estuaries & Coasts v 37 4 Estuaries & Coasts v 37



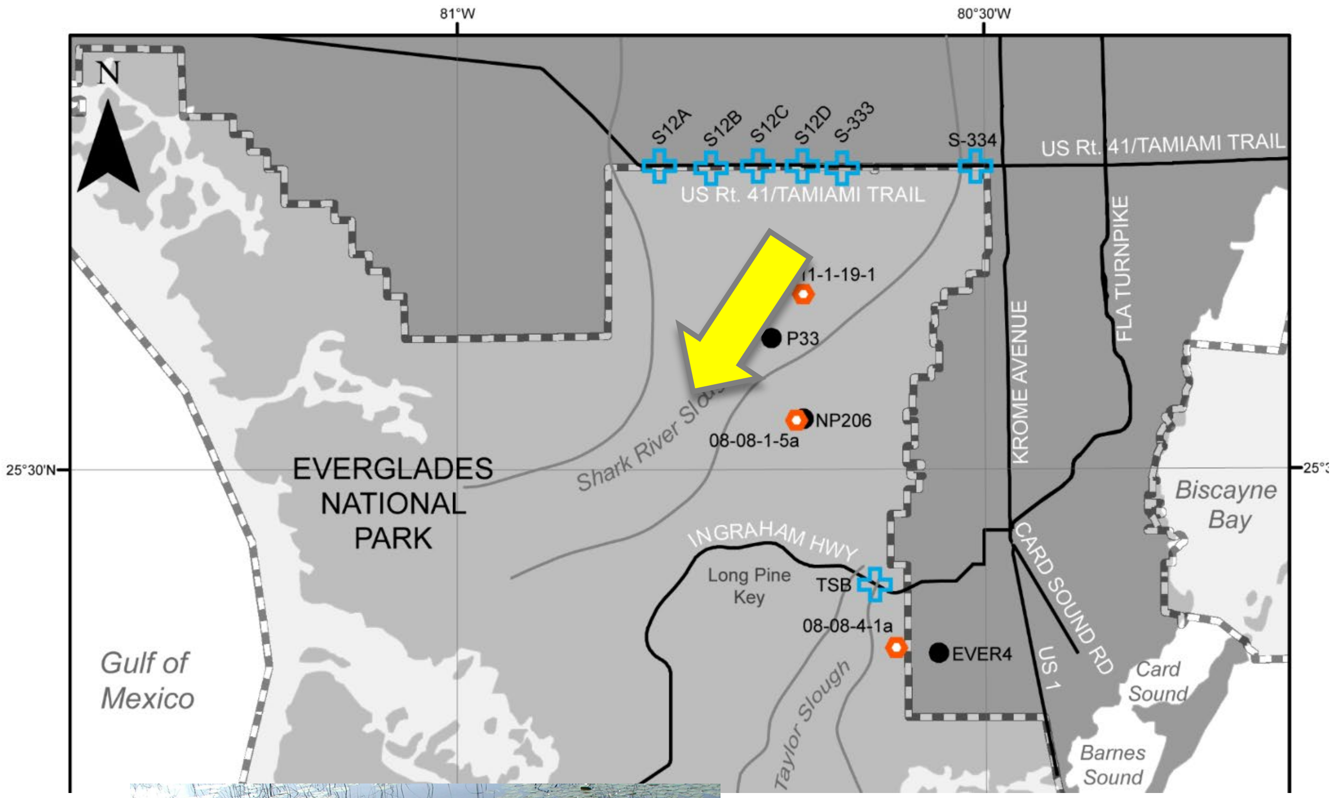
Freshwater Wetland Paleoecologic Studies

Estimates of water depth and hydroperiod from beginning of 20th century were used to estimate historic stage, flow, and hydroperiod in the freshwater wetlands

Proxy = pollen

Predrainage Freshwater Wetland Hydrology Estimates

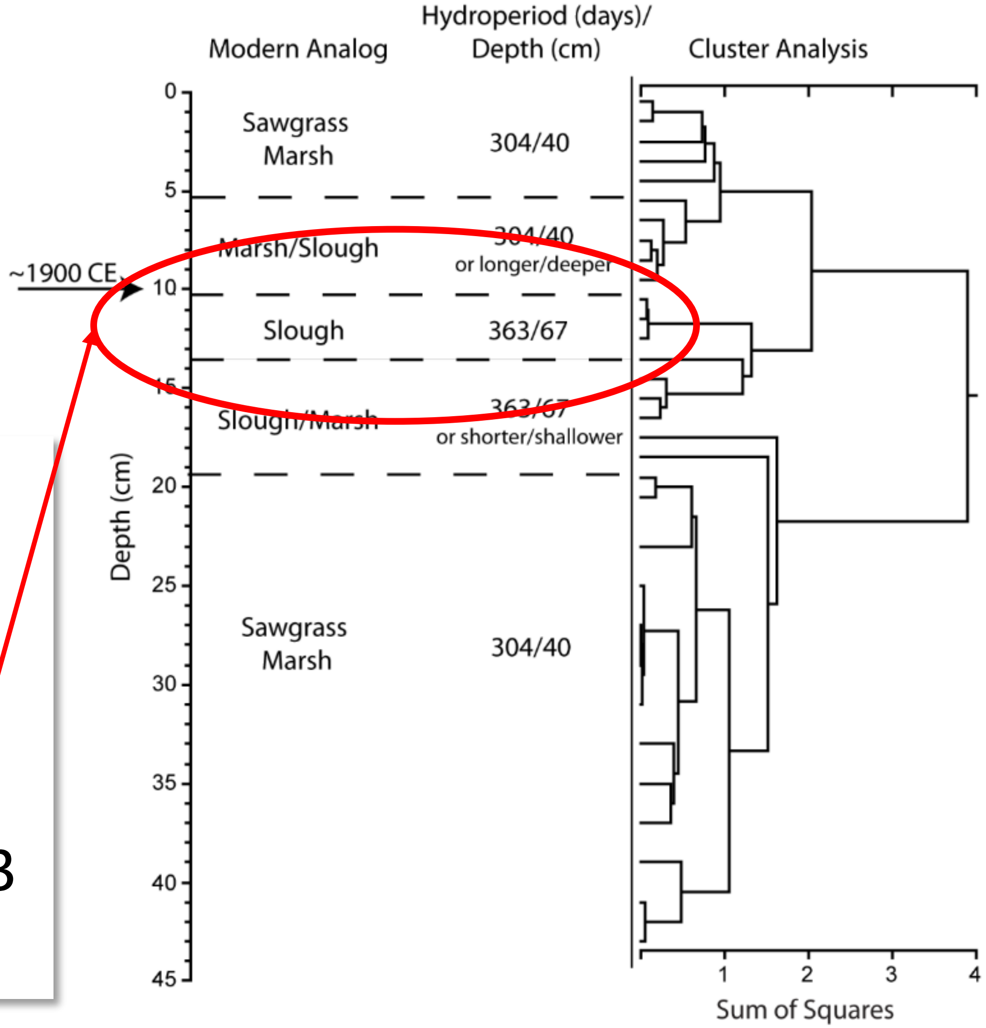
To develop pre-drainage hydrology estimates for the Everglades freshwater wetlands cores were collected from 3 locations that were near water level monitoring stations.



Example of Predrainage Hydrology Estimate Development

Pollen assemblages from core are compared to modern analog dataset

Average depth = 67 cm
Average hydroperiod = 363 days

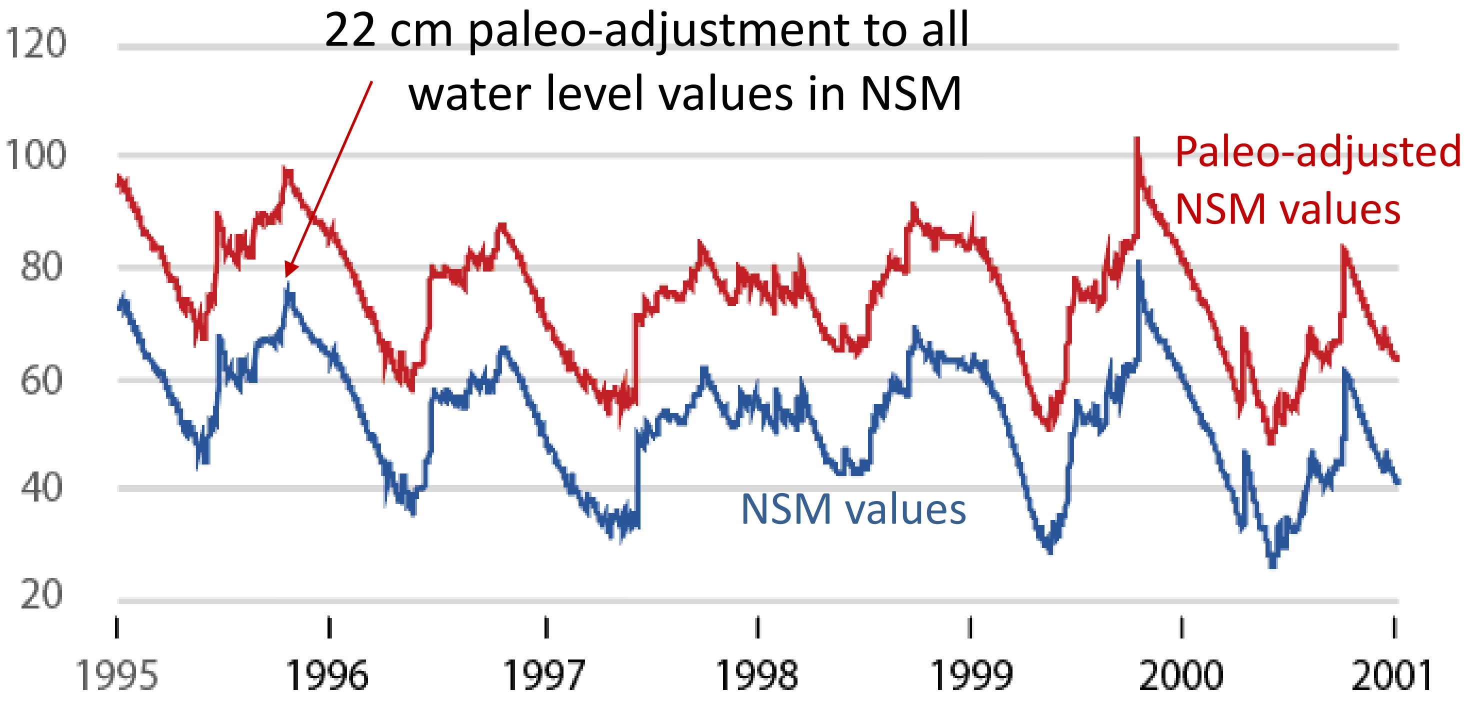


Willard, Bernhardt, et al. 2006 Eco Monographs v. 76
Bernhardt & Willard 2009 Eco Applications v. 19

Developing Predrainage Water Level Estimates

How paleo data are used to adjust each NSM daily water level value to reflect ~1900 CE water level conditions

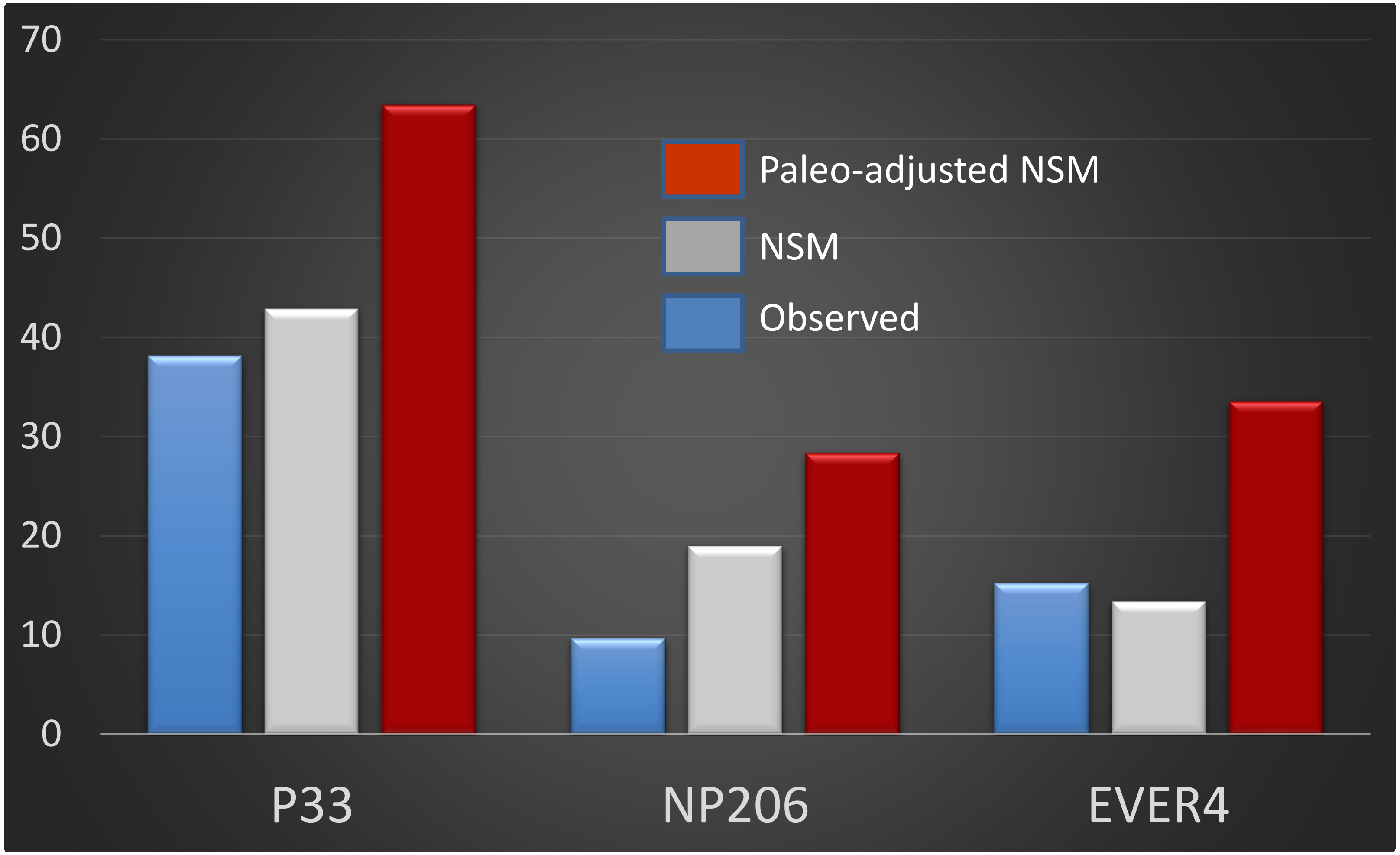
Paleo-ecologic avg water level = 67 cm
Median bias-adj NSM = 45 cm
Difference = paleo adjustment = 22 cm



Example: P33 core / water level monitoring station

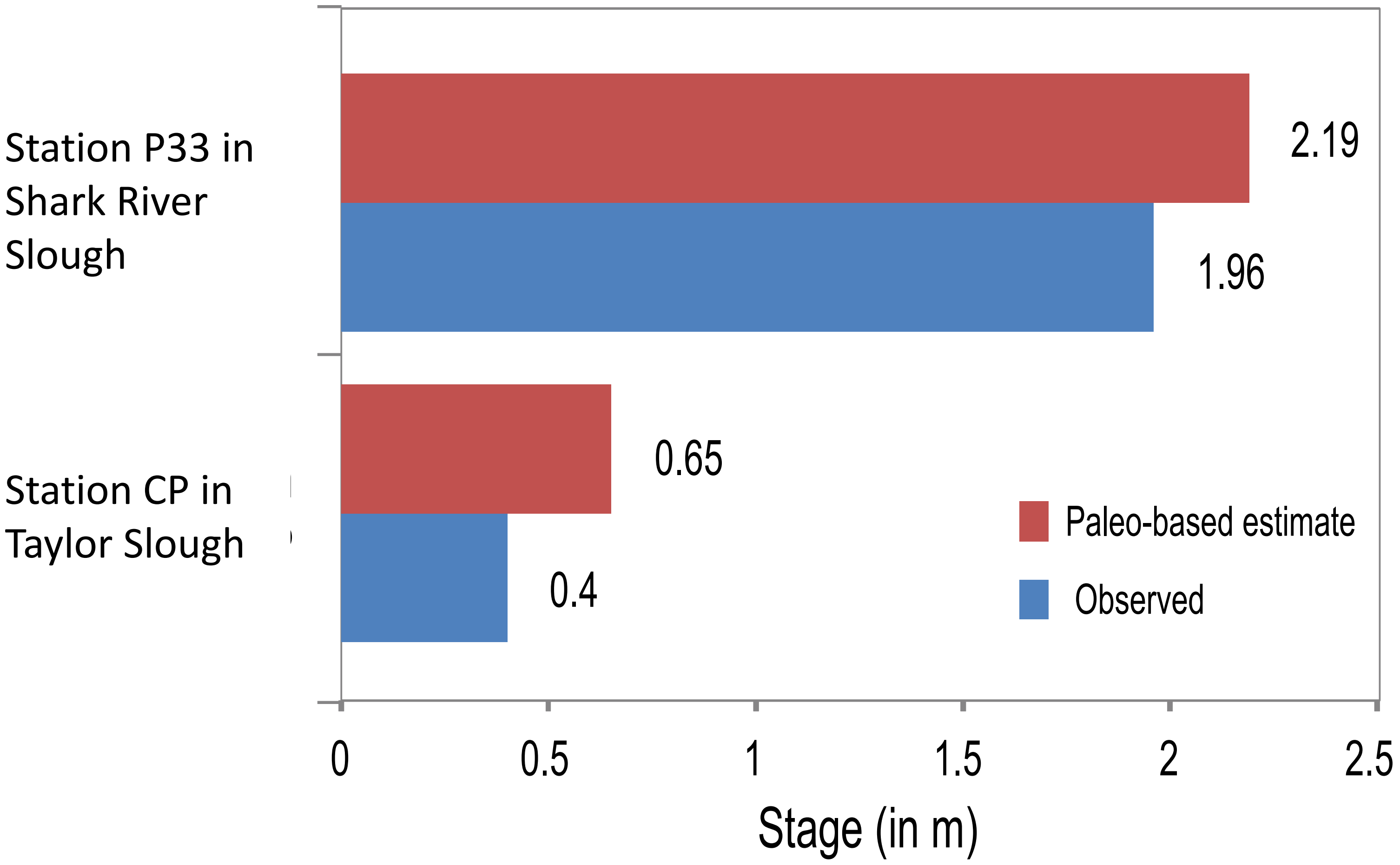
Freshwater Wetland Results: Observed vs NSM vs Paleo-adjusted Water Level Estimates

- Water level needs to be 18-25 cm higher on average than observed to restore pre-drainage levels
- NSM does not come close to approximating pre-drainage estimates

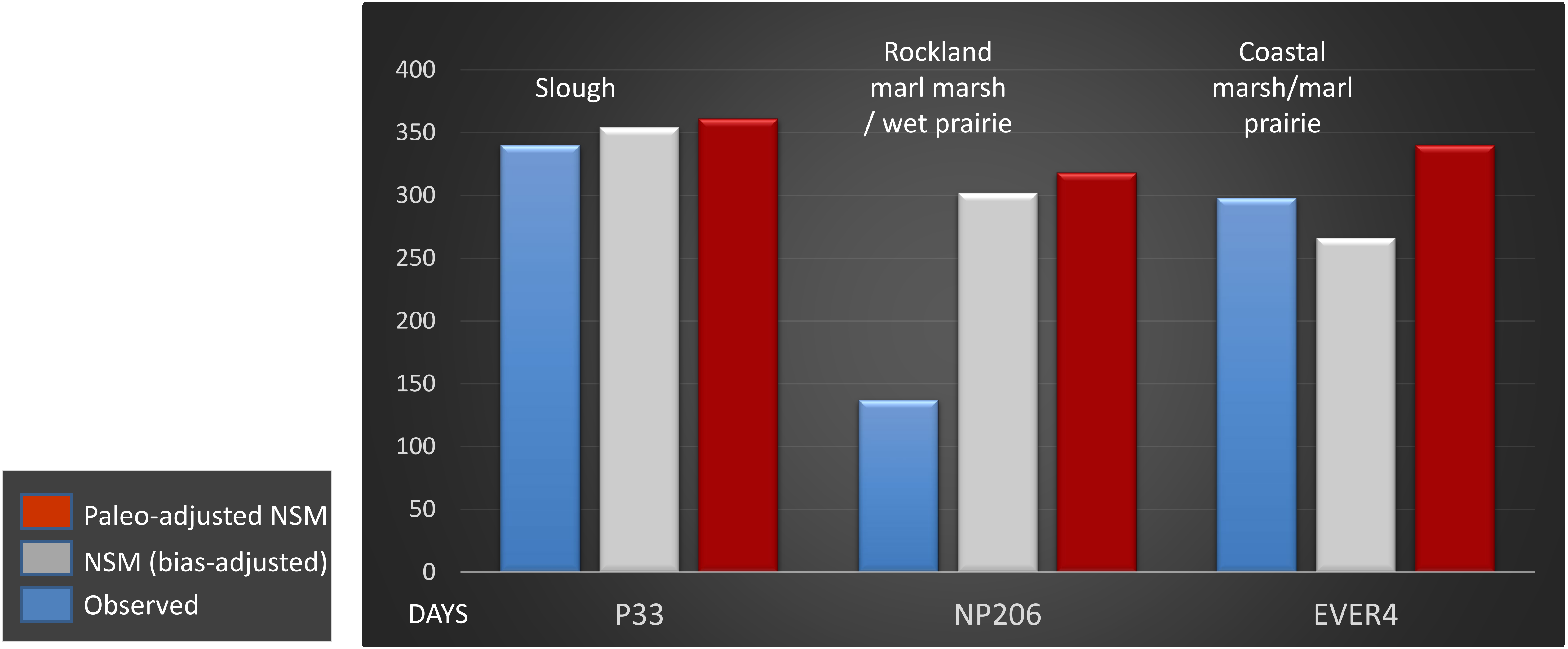


Marshall, Bernhardt, Wingard, in prep

Interpretation: Simulated Early 20th Century Average Water Levels



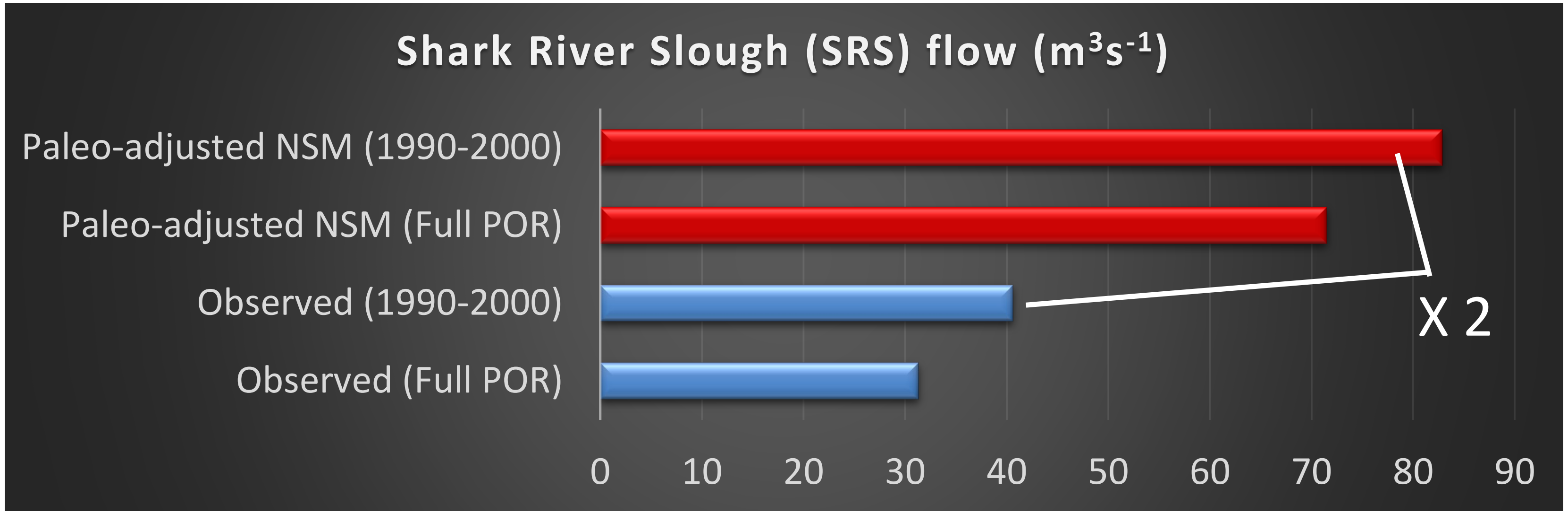
Results: Observed vs. Paleo-based Hydroperiod

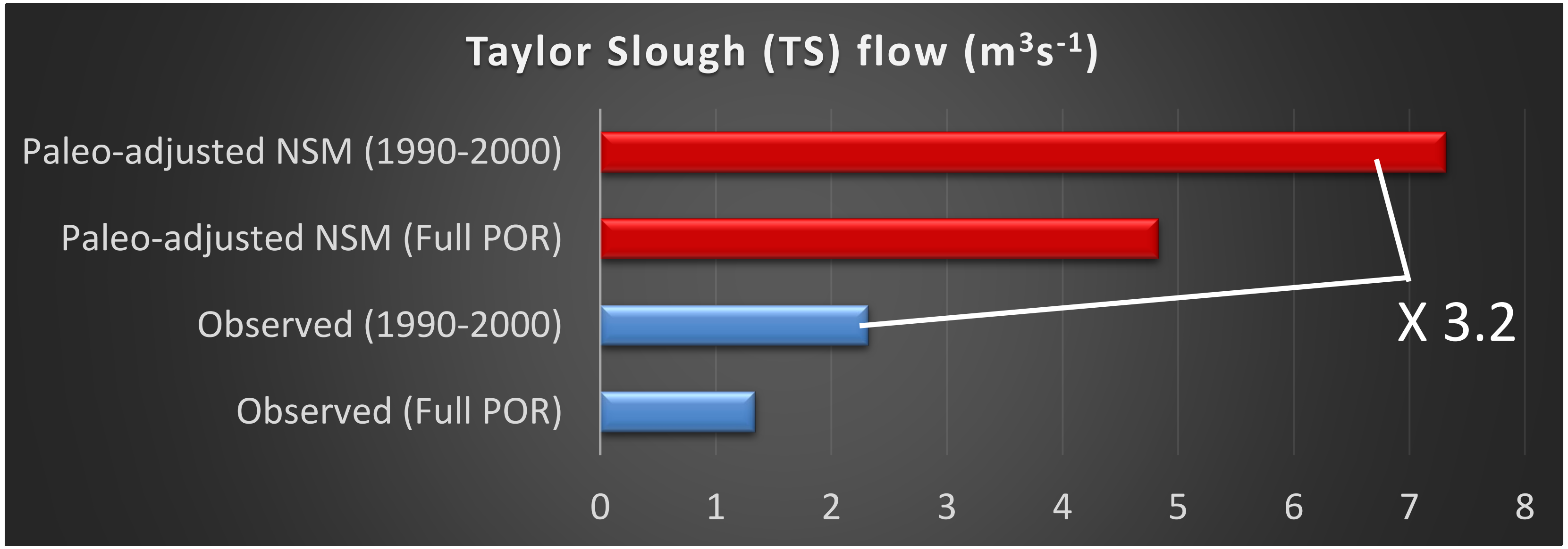


Marshall, Bernhardt, Wingard, in prep

Results: Observed vs Paleo-based Flow Estimates

- **Paleo-based flow higher than observed over full period of data and 1990s**
- **Needed flow increase through SRS needs to be 2 times 1990s flow**
- **Needed flow increase through TS needs to be about 3 times 1990s flow**





Comparison of Paleo-adjusted Results – 2 Proxies

	Salinity / Mollusk Proxy (2014)	**Freshwater Level / Pollen /Proxy** (2019)
Shark River Slough Flow - Paleo vs 1990s observed	2.1 times greater	2.0 times greater
Taylor Slough Flow – Paleo vs 1990s observed	3.7 times greater	3.2 times greater
Water level at P33 - Paleo vs observed	23.0 cm higher	25.3 cm higher

Summary: How we addressed the management need of what it means "to get the water right"

- Integrated paleosalinity data from Florida Bay with statistical models to quantify the change in salinity during the 20th century and estimated the required flow through the freshwater wetlands to restore the salinity
- Integrated paleohydrology data from the freshwater wetlands in ENP with statistical models to quantify the change in water levels during the 20th century and estimated the required flows in Shark and Taylor River Sloughs to restore the water levels
- The results of these different methods tell the same story: to "get the water right", flow increases of **2-3** times the current flows are needed