Setting Restoration Targets in Florida Bay Using Paleoecology and Salinity/Hydrology Models

Session: Estuarine Ecosystems Restoration

4th National Conference on Ecosystem Restoration
Estuarine Ecosystems Restoration Session
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Frank Marshall, CLF
Lynn Wingard, USGS
Patrick Pitts, USFWS
Study Area

Everglades Ecosystem

• Globally unique combination of hydrology and water-based ecology
• Freshwater wetlands directly connected to estuaries connected to:
  – Atlantic Ocean
  – Florida Straits
  – Gulf of Mexico
• i.e. hydrology and salinity are tightly coupled to each other and to the ecology
Study Area

Everglades Ecosystem

• Anthropogenic impacts due to water management:
  – Reduced flows
  – Reduced hydroperiods
  – Higher salinity regimes and increased occurrence of hypersalinity
  – Impacted ecosystems

• Remains of (altered) natural system are ‘protected’ in Everglades National Park – our Study Area

• Goal of Everglades restoration:
  restored hydrology, salinity and resultant water-based ecosystem
Overview of Study Area

- Everglades National Park
- Miami
- Atlantic Ocean
- Gulf of Mexico
- Florida Bay

Diagram showing the geographical location of these areas.
The Problem – Freshwater Diversion From the Everglades
Important Features for This Study

Flow is key parameter in management of water in south Florida
Current Status of Paleosalinity Analyses in Florida Bay

• 5 sediment core analyses in Florida Bay completed over last 5 years:
  – Whipray Basin
  – Rankin Lake
  – Taylor T24
  – Russell Bank
  – Crocodile Point

• Synthesis of all 5 analyses was recently completed

• Funded has been provided by:
  – RECOVER
  – USGS
  – ENP
Procedure for Synthesizing Paleosalinity

Paleosalinity from core characterization (USGS)

Stage in Everglades

Hydroperiod, hydropattern

Upstream and tidal creek flows

Freshwater Marsh, Mangrove Zone

Optimal Linear Combiners to produce synthesized estimates

Salinity in Florida Bay

Paleosalinity time series at core location

Estuary

X 5

= REGRESSION MODELS
Detailed Paleosalinity Procedure

See Jan 2009 Estuaries And Coasts
## Paleoecology Characterization

- Mollusks from core are identified and counted.
- Salinity of fauna based on modern analogue data.

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONFIDENT Estimate</td>
<td>36 taxa, ten or more observations, 95% CI of less than 5</td>
</tr>
<tr>
<td>FULL Estimate</td>
<td>36 taxa from CONFID + additional 35 taxa with any associated salinity data.</td>
</tr>
</tbody>
</table>
## System of Hydrology/Salinity Regression Models

- Includes models for salinity, stage, and flow
- Trend in data (sea level rise, other effects) included where significant
- Flow models now include power terms
- Updates for synthesis produced a more robust system of hydrology/salinity models
Cal/Ver Plots – Updated Stage Models

Date
Jan-93 Jan-94 Jan-95 Jan-96 Jan-97 Jan-98 Jan-99 Jan-00

ft NGVD29
0 0.5 1 1.5 2 2.5 3 3.5 4

CP

CPCalver
Cal/Ver Plots – Salinity Models

Salinity models for different years, showing variability in salinity levels from Sep-91 to Sep-06.
Cal / Ver Plots – Updated Flow Models
Sediment Core Paleosalinity Starts the Process

CONFID Paleosalinity from core (USGS)

Paleosalinity time series

System of models

Stage

Flow

Salinity

X 5
<table>
<thead>
<tr>
<th>Core</th>
<th>Time Step</th>
<th>Observed</th>
<th>Hydrology model-based salinity</th>
<th>Paleo FULL</th>
<th>Paleo CONFID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whipray Basin</td>
<td>Daily</td>
<td>36.4</td>
<td>31.9</td>
<td>30.6</td>
<td>29.5</td>
</tr>
<tr>
<td>Rankine Lake</td>
<td>Daily</td>
<td>35.2</td>
<td>30.4</td>
<td>28.3</td>
<td>28.3</td>
</tr>
<tr>
<td>Taylor T24</td>
<td>Daily</td>
<td>24.2</td>
<td>17.7</td>
<td>16.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Russell Bank</td>
<td>Monthly</td>
<td>33.5</td>
<td>28.1</td>
<td>28.5*</td>
<td>26.4*</td>
</tr>
<tr>
<td>Crocodile Point</td>
<td>Monthly</td>
<td>33.2</td>
<td>27.6</td>
<td>28.8</td>
<td>26.5</td>
</tr>
</tbody>
</table>

* distance adjusted

Paleo = circa 1900 = Pre-drainage
Why Circa-1900 Salinity?

North Atlantic Sea Surface Temperature

Obeysekera et al, 2006
Products For Each of the 5 Analyses

• Paleo-based stage throughout freshwater marshes and mangrove zone (12 stations)
• Upstream paleo-based flow (Shark River, Taylor River)
• Downstream paleo-based creek discharges (5 creeks)
• Paleo-based salinity throughout Florida Bay (17 stations)
Synthesis of Output

• Output of all 5 analyses combined
• Optimal Linear Combiner methodology
• Output from each model weighted by Mean Squared Error (MSE) from cal/ver run
• Then they are combined (summed)
• Synthesized output: single time series for all parameters using information from all 5 analyses
## CP Stage MSE Optimal Linear Combiner Procedure

<table>
<thead>
<tr>
<th>Core Label</th>
<th>CP MSE</th>
<th>CPMSEtotal/CP MSE</th>
<th>(CPMSEtotal/CP MSE)/SUM(CPMSEtotal/CP MSE)</th>
<th>CONFID Cppaleo avg</th>
<th>CoLD * CoLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whipray Basin</td>
<td>0.12</td>
<td>24.53</td>
<td>0.31</td>
<td>2.07</td>
<td>0.64</td>
</tr>
<tr>
<td>Rankine Lake</td>
<td>0.07</td>
<td>38.96</td>
<td>0.49</td>
<td>1.85</td>
<td>0.90</td>
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<tr>
<td>Taylor T24</td>
<td>1.78</td>
<td>1.64</td>
<td>0.02</td>
<td>2.11</td>
<td>0.04</td>
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<tr>
<td>Russell Bank</td>
<td>0.29</td>
<td>10.13</td>
<td>0.13</td>
<td>1.93</td>
<td>0.25</td>
</tr>
<tr>
<td>Crocodile Point</td>
<td>0.66</td>
<td>4.42</td>
<td>0.06</td>
<td>1.47</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>2.92</td>
<td>79.69</td>
<td></td>
<td></td>
<td>1.91</td>
</tr>
</tbody>
</table>

**Synthesized CP = 1.91**
Synthesized Paleo-based Stage
Synthesized Paleo-based Flow
## Mean Synthesized Paleo-based Values vs Observed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>N</th>
<th>Obs Mean</th>
<th>Obs 95% CI</th>
<th>Paleo Syn Mean</th>
<th>Paleo Syn 95% CI</th>
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</thead>
<tbody>
<tr>
<td>CP¹</td>
<td>265</td>
<td>1.2</td>
<td>1.1-1.3</td>
<td>1.9</td>
<td>1.8 - 2.0</td>
</tr>
<tr>
<td>P33¹</td>
<td>429</td>
<td>6</td>
<td>5.9-6.1</td>
<td>7</td>
<td>6.9 - 7.1</td>
</tr>
<tr>
<td>TSBstage¹</td>
<td>274</td>
<td>3.2</td>
<td>3.1-3.3</td>
<td>4.6</td>
<td>4.5 - 4.7</td>
</tr>
<tr>
<td>TSB²</td>
<td>425</td>
<td>47.7</td>
<td>41-56</td>
<td>167</td>
<td>158 - 176</td>
</tr>
<tr>
<td>SRS²</td>
<td>264</td>
<td>1090</td>
<td>947-1242</td>
<td>2814</td>
<td>2616 - 3012</td>
</tr>
<tr>
<td>WB³</td>
<td>139</td>
<td>37.2</td>
<td>35.9-38.5</td>
<td>29.7</td>
<td>28.8 - 30.6</td>
</tr>
<tr>
<td>TB³</td>
<td>110</td>
<td>23.7</td>
<td>21.7-25.7</td>
<td>11.9</td>
<td>10.9 - 13.0</td>
</tr>
</tbody>
</table>

¹ ft NGVD29  ² cfs  ³ salinity
Synthesized Paleo-based Salinity Regime in Terrapin Bay

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

Reality Check

How do paleo-based river flow estimates compare to estimates of available water in the system?
Comparison of Synthesized Paleo-based SRS Flow and Existing SRS + Tide Discharge (75%)

N = 550 – 640 for each month
Reality Check Answer

• Paleo-based flow estimates agree favorably with available water
• Plenty of water discharged to tide to cover paleo-based needs
• Technical issues:
  – Storage
  – Treatment
  – Operations
Estuarine / Nearshore Coastal Shelf
Benefits of Re-diversion to Park
## Summary

- Coupling sediment faunal characterizations with regression models is a useful tool for linking paleosalinity data to upstream hydrology in the Everglades.
- Consistent but slightly different results from all 5 paleo evaluations.
- Optimal Linear Combiners allowed use of information from all cores in synthesis.
- Upcoming work on west (Gulf) coast may validate or modify these findings.
Summary

• Establishing pre-drainage salinity regime requires about 2.5 times more freshwater than current flow regime
• Volume of water discharged to tide is more than sufficient
• Restored result is a more estuarine Florida Bay - mesohaline to polyhaline as opposed to euryhaline current condition
• Restoring flow regime restores hydroperiod and pattern in freshwater marshes and mangroves
Greater Everglades Ecosystem
Take-home Message

Restored Hydrology =
Restored Salinity =
Restored Ecosystem
THANK YOU!

Photo by A. Gelber via D. Deis