Potential Trajectories of Water Quality Forced by Sea Level Rise in the Florida Coastal Everglades

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Abstract

We have investigated the relationships between salinity and nutrients in the mangrove ecotone of the Coastal Everglades and Florida Bay the last 27 years. The objective was to define potential trajectories of water quality change induced by sea level rise. Although models have been developed to determine the required freshwater discharges to reduce salinity during Everglades restoration of Florida Bay, nutrient changes caused by salinity changes have not been assessed. We present a simple methodology to assess water quality changes in the Coastal Everglades and Florida Bay, as different regimes are introduced by salinity changes triggered by sea level rise. We use nutrient cumulative data calculated along salinity gradients to precisely define break-points and system shifts, combined with sequential t-test analysis of regime-shift to assess the statistical significance of such breaks. Our results indicate that changes in nutrient concentration display complex, non-linear relationships with water discharge, so simple linear regression models are not always adequate to forecast water quality trajectories driven by either sea-level rise and/or restoration.

Background

Results from paleoecology-based models (Marshall & Wingard 2012) indicate that oligohaline to mesohaline conditions prevailed in the nearshore embayments, and polyhaline conditions were common in central Florida Bay before the human disruption which started in the early 1900s. Models have been developed to determine the required freshwater discharges to reduce salinity to approach previous levels (CERP 2012), but nutrient changes associated to the required discharges have not been assessed. Florida International University long-term water quality data (since 1991) for the Coastal Everglades and Florida Bay may allow such assessment by exploring the effects of salinity changes on phosphorous and nitrogen concentrations.

Instead of using salinity transects spanning diverse ecosystems, we eliminated spatial variability by studying changes in nutrient concentration as salinity changes at individual stations and consolidated those changes to biogeochemically homogeneous spatial clusters as defined by Briceño et al. (2013)

Objective

The Objectives of this work is to assess the potential trajectory of water quality as salinity changes in the Coastal Everglades.

Method

Ecological time-series (w_1, w_2, …w_n) were transformed to standardized cumulative sum by:

1- Standardizing the data set by subtracting the mean from each observation and dividing the difference by the standard deviation

2- Calculating a cumulative total of Z-scores with salinity

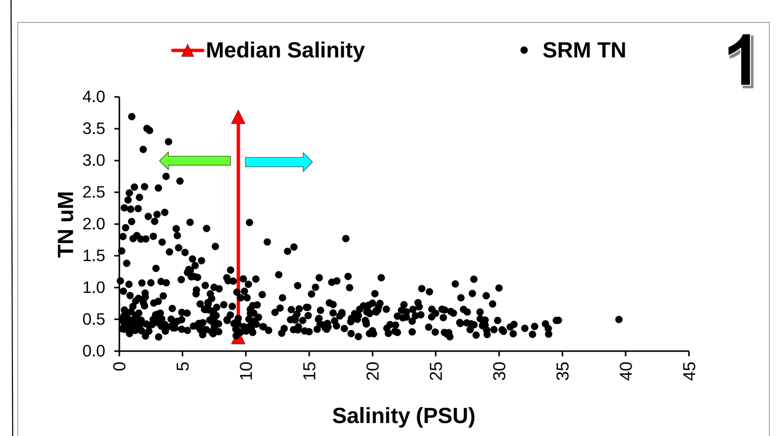
$$z_i = z_{i-1} + [(w_i - m)/\sigma] \quad (1)$$

Where **m**=mean and **σ**=standard deviation of "w"

Transformed Z values (on y-axis) were plotted against the salinity gradient (x-axis). These charts represent the rate of change of variable **W** (i.e. TP, TN) along such gradients. Water quality trajectories driven by either sea-level rise (i.e. increase in salinity) or restoration (i.e. salinity decline) can be traced and the resulting water quality assessed, as shown in Figures 1

Research Question

What are the resulting trajectories of nutrient concentration as salinity changes in the Florida Coastal Everglades ?



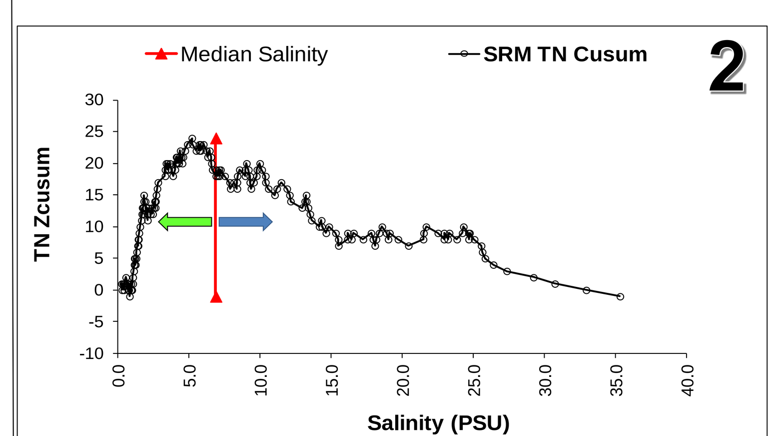


Fig 1. General TN declines as salinity increases. Green arrow shows potential trend if salinity declines. Blue arrow shows trend as sea level and salinity rise.

Fig 2. Same data as that of Fig 1 but transformed to cumulative sum and plotted along a salinity gradient If salinity would drop below 5 PSU (threshold), TN values would be preferentially above the current mean, in other words SRM would experience nutrient enrichment

Positive slope=above average TN

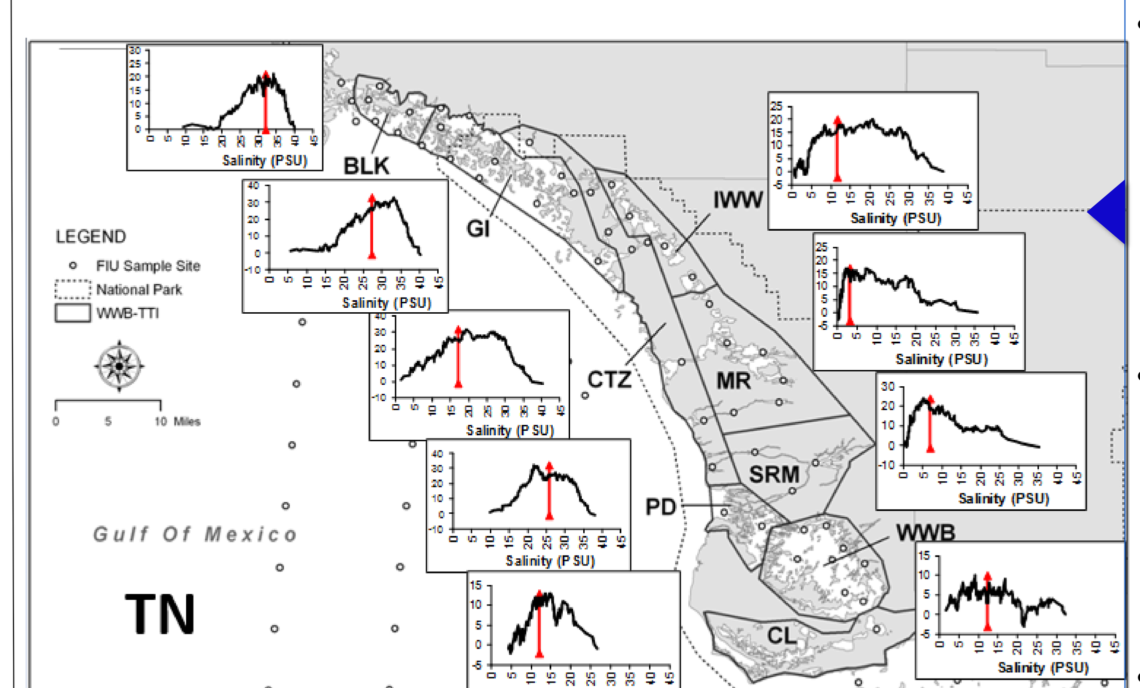
Negative slope=below average TN

Hint:

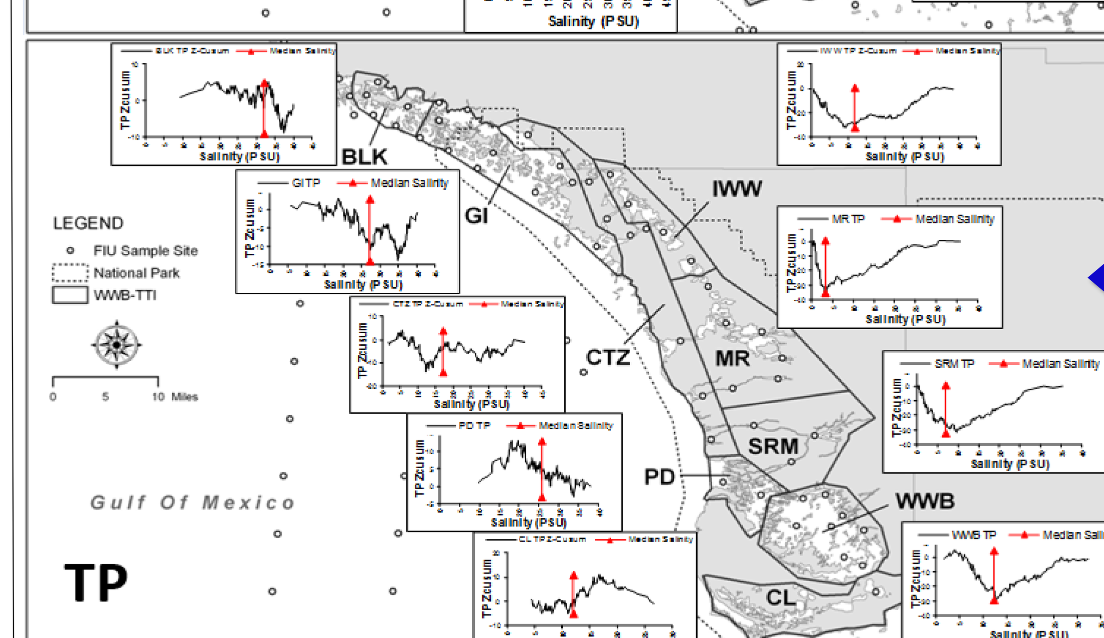
Dome-shaped cusum = overall declining trend

Cup-shaped cusum = overall increasing trend

Results

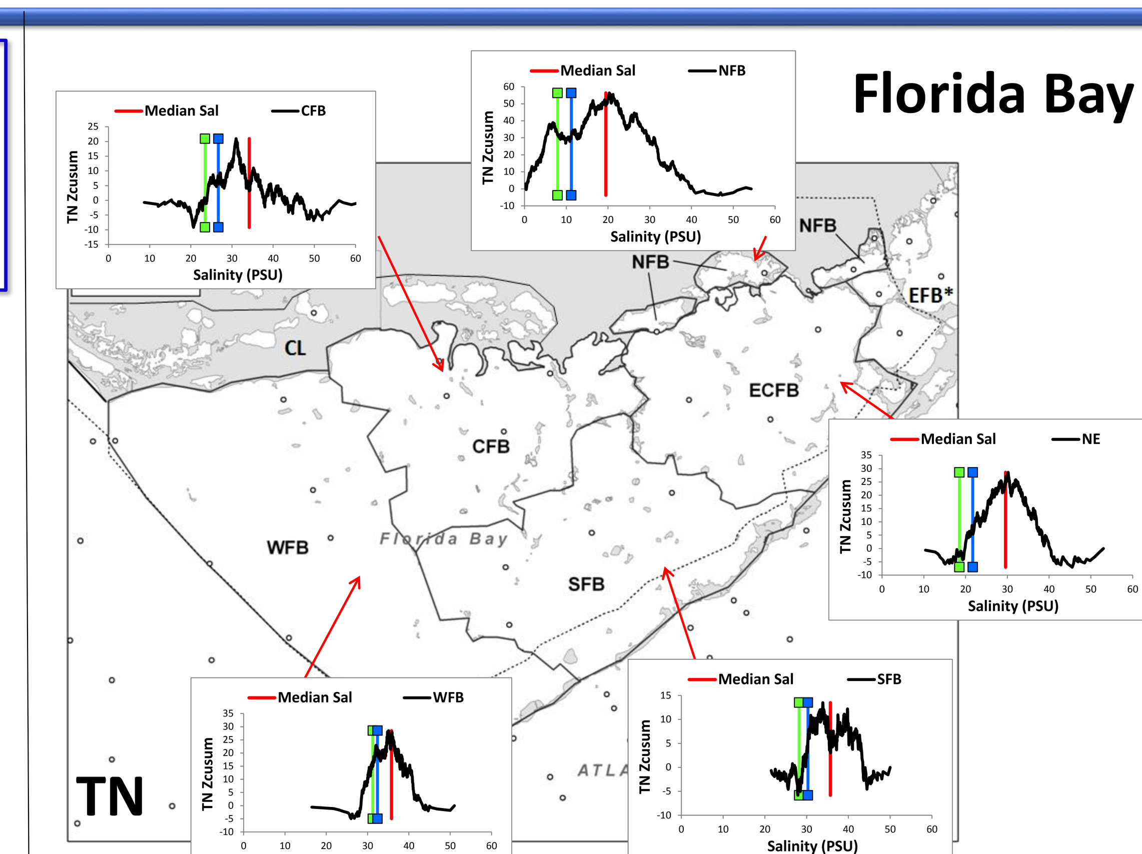


- **TN declines** with salinity in all water quality (WQ) segments (dome-shaped cusum). So, salinity increases due to higher sea levels would cause a decrease in nitrogen concentration.
- As can be seen, lower salinities than current median (red arrow) would take the system to the "positive slope" or "above average TN" branch of the cusum lineplot
- So, higher TN concentrations would be expected.

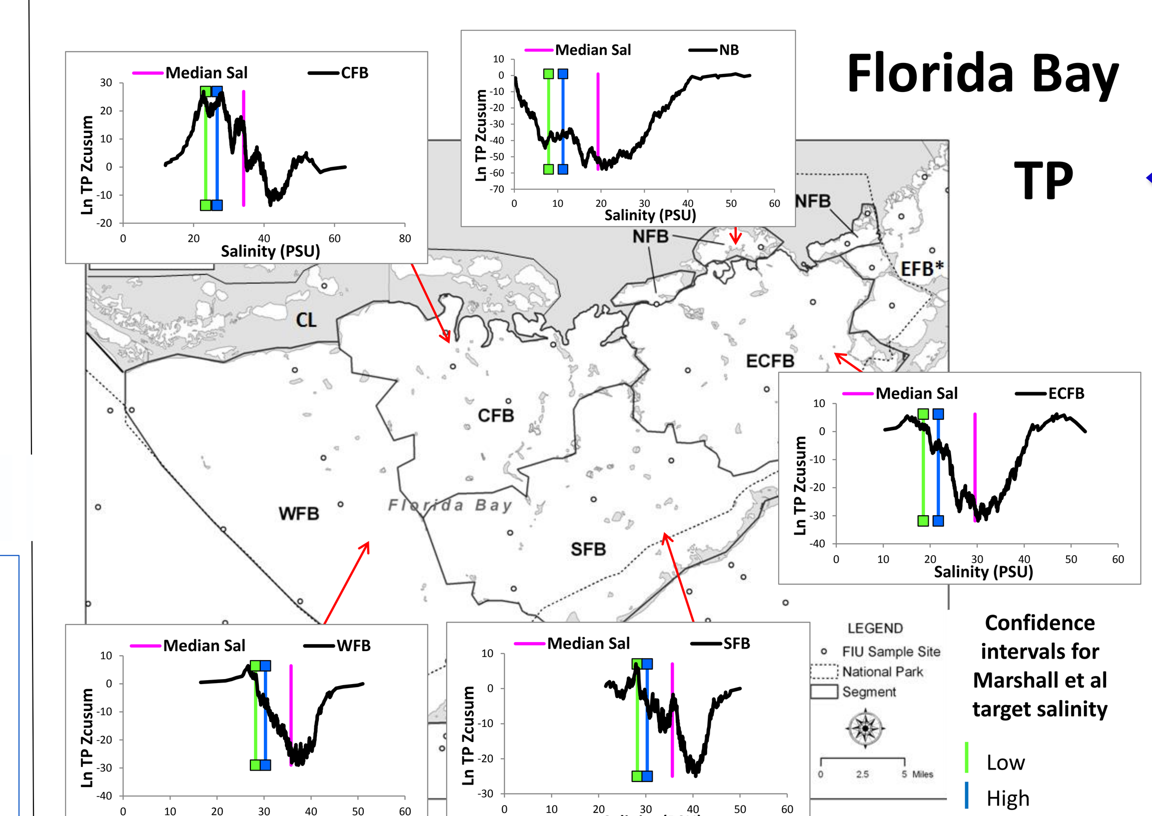


- **TP increases** with salinity in segments located to the East (fresher waters), and display complex and varied responses at BLK, GI and CTZ.
- TP declines with salinity at PD and CL
- In summary, sea level rise would cause TP enrichment in eastern portions of 10,000 Islands-Whitewater Bay and no clear response in mangrove forest to the West, except for increases in PD and CL

BLK = Black River; **GI** = Gulf Islands; **IWW**: Internal Waterways; **CTZ** = Coastal Transition Zone; **MR** = Mangrove Rivers; **PD** = Ponce de Leon; **SRM** = Shark River Mouth; **WWB** = Whitewater Bay



- **TN declines** with salinity in all Florida Bay. So, salinity increases due to higher sea levels would cause a decrease in nitrogen concentration.
- Confidence intervals for Marshall et al. proposed salinity targets are shown as bound by the green/blue vertical bars. As can be seen, those targets fall on the "above average TN" branch of the curve for all WQ segments. So, higher TN concentrations would be expected.



- **TP increases** with salinity in all Florida Bay, except in CFB where values tend to be high at low and high salinity ranges and affected by high variability.
- Marshall et al. salinity targets fall on the "below average TP branch" of the cusum curve, meaning that in general, low TP concentrations are expected with fresher waters.

NFB = Northern Florida Bay; **CL** = Coastal Lakes; **WFB** = West Florida Bay; **CFB** = Central Florida Bay; **SFB** = South Florida Bay; **ECFB** = Eastern Central Florida Bay; **MBS** = Manatee-Barnes Sound;

Conclusions

- Taking advantage of long-term monitoring data, it is possible to assess potential trajectories of water nutrient concentration for Coastal Everglades ecosystems.
- Total Nitrogen (TN) would decrease with higher salinities and would increase with fresher conditions
- Total Phosphorous (TP) would increase with higher salinities in most of Florida Bay (except Central Florida Bay) and the Eastern portions of the mangrove ecotone. Mangrove forest along the western portions of the Ten Thousand Islands would have a complex response affected by high variability, except Ponce the Leon Bay, where TP would decline

References

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Acknowledgements

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