Monitoring Restoration and Recovery of Impounded Mangroves at Oleta River State Park

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Introduction

Oleta River State Park (ORSP), located in Miami-Dade County, is the largest urban state park in Florida, spanning over 400 ha. A vital component of the park's ecosystem is its mangrove habitat, which constitutes 45.6% of the park's natural area[1]. Mangrove forests are critical coastal ecosystems that provide numerous ecological benefits, including habitat for wildlife, shoreline protection, and water filtration[2]. However, many mangrove forests are facing escalating threats due to human activity. For example, urban development, including the construction of roads, can disrupt natural hydrological patterns and lead to ponding in mangrove areas, which can suffocate tree roots over time and cause widespread mortality[3].

Nearly 10 ha of mangrove habitat in ORSP were lost or stressed due to blocked surface water flow following an extreme rain event in 2015. Mangrove stress and mortality were then exacerbated by Hurricane Irma in 2017. Three culverts were installed in April and June of 2023 as part of a restoration effort to re-establish tidal connections between Biscayne Bay and the stressed mangrove areas. This monitoring effort examined soil, water, and vegetation quality among control, intermediate stress, and stressed forests at ORSP before and after restoration.

Figure 1. Examples of control (top) and stressed (bottom) mangrove areas at ORSP. Photos taken pre-restoration, in 2023.

Methods

Three 5x5-m plots were established in three sites classified as control, intermediate stress, and stressed, based on visual indicators such as mangrove mortality (Figure 2). Canopy cover was measured at each plot corner using a convex spherical densiometer. Soil cores were collected outside each plot using a "Russian-type" split-barrel peat corer to quantify percent organic matter via loss-on-ignition. Salinity was measured at multiple locations throughout ORSP using a handheld multi-parameter meter and surface water samples were collected using a peristaltic pump. One unfiltered sample was collected for Total Organic Carbon (TOC) measurement, and a second sample was filtered through pre-combusted glass microfiber filters for Dissolved Organic Carbon (DOC) analysis. Monitoring was completed approximately every six months for two years pre- and post-restoration.

Figure 2. The control, intermediate stress, and stressed sites at ORSP. Biscayne Bay was used as a reference for water quality pre- and post-restoration. Blue triangles mark culvert locations.

Results

The data did not meet parametric assumptions; therefore, initial tests were performed using the Kruskal-Wallis rank sum test, and post-hoc comparisons were conducted with pairwise Wilcoxon tests with Bonferroni adjustments. Box plots display the median and interquartile ranges.

A. Soil Organic Matter Content:
The control site contained significantly less organic matter in soil (0–10 cm depth) than the intermediate site ($p < 0.001$; Figure 3A), which in turn contained significantly less organic matter than the stressed site ($p < 0.001$).

B. Salinity:
The salinity of surface water was significantly lower pre-restoration compared to post-restoration at all sites ($p < 0.05$; Figure 3B). Salinity was significantly lower in the stressed site compared to all other sites pre-restoration ($p < 0.005$), but no significant differences were found among sites post-restoration.

C. Total Organic Carbon:
TOC in surface water was significantly higher pre-restoration compared to post-restoration in the stressed site ($p = 0.002$; Figure 3C). TOC was significantly higher in the stressed site compared to all other sites pre-restoration (all p-values < 0.001), but no significant differences were found among sites post-restoration.

D. Dissolved Organic Carbon:
DOC in surface water was significantly higher pre-restoration compared to post-restoration in the stressed site ($p = 0.006$; Figure 3D). DOC was significantly higher in the stressed site compared to all other sites pre-restoration (all p-values < 0.001), but no significant differences were found among sites post-restoration.

E. Canopy Cover:
Canopy cover did not differ significantly between pre- and post-restoration periods at any site (Figure 3E). Pre-restoration, the stressed site had significantly lower canopy cover than all other sites ($p < 0.005$), but no significant differences were found among sites post-restoration.

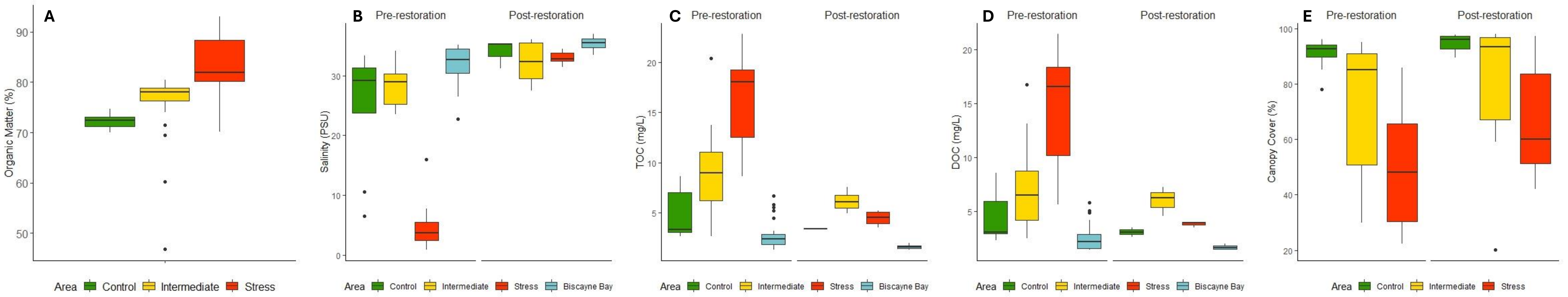

Figure 3. (A) Pre-restoration percent organic matter in soil (0–10 cm depth) across sites, (B) Salinity of surface water across sites, grouped by restoration period, (C) Total Organic Carbon in surface water across sites, grouped by restoration period, (D) Dissolved Organic Carbon in surface water across sites, grouped by restoration period, and (E) percent canopy cover across sites, grouped by restoration period.

Discussion

A. Soil Organic Matter Content: Organic matter content in intermediate stress and stressed forest soils was likely higher than in the control site, as assessed pre-restoration, due to a lack of allochthonous sediment deposition, which typically has a higher inorganic composition. The intermediate stress and stressed sites were surrounded by roads, likely minimizing tidal flow and sediment import.

B. Salinity: The significantly lower salinity in the stressed forest pre-restoration can be attributed to ponding of precipitation and a lack of tidal connectivity. Following culvert installation, salinity increased across all areas to near-reference conditions, suggesting the culverts successfully improved tidal flow.

C & D. Total and Dissolved Organic Carbon: High organic carbon in surface water can result from limited circulation, decomposing vegetation, and reduced microbial activity[4]. The significant decrease in TOC and DOC in the stressed forest post-restoration suggests that the culverts are improving water circulation, which could be reducing organic carbon accumulation in surface water.

E. Canopy Cover: The significant differences in canopy cover among sites pre-restoration can be attributed to mangrove mortality at the intermediate stress and stressed sites. Hydrologic improvements from culvert installation appear to be facilitating initial mangrove recovery and regrowth, though mangrove forests can take decades to fully mature and recover.

Figure 4. A culvert installed in the intermediate stress area in 2023.

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