Chronic Stress Impacts on Mangrove Mortality and Recovery Following Hurricanes in Southwest Florida

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Introduction

Mangrove forests experience acute stress in hurricanes from high-speed winds and wave energy, but they must often cope with chronic stress from standing water, sulfide toxicity, and sediment burial months after a hurricane has passed. Mangrove forests suffering from chronic stress after hurricanes can experience delayed mortality or delayed recovery[1,2]. Long-term monitoring data were collected in seven plots in mangrove forests in the Ten Thousand Islands (TTI) following Hurricane Irma from 2017 to 2019. These plots were then revisited in 2023 and 2024 following Hurricane Ian. Eight plots in Charlotte Harbor (CH) mangrove forests were monitored from 2022 to 2024, encompassing impacts from Hurricanes Ian, Helene, and Milton. This long-term monitoring study sought to discern how initial storm damage and long-term stress impact mortality and recovery in mangrove forests in southwest Florida following hurricanes.

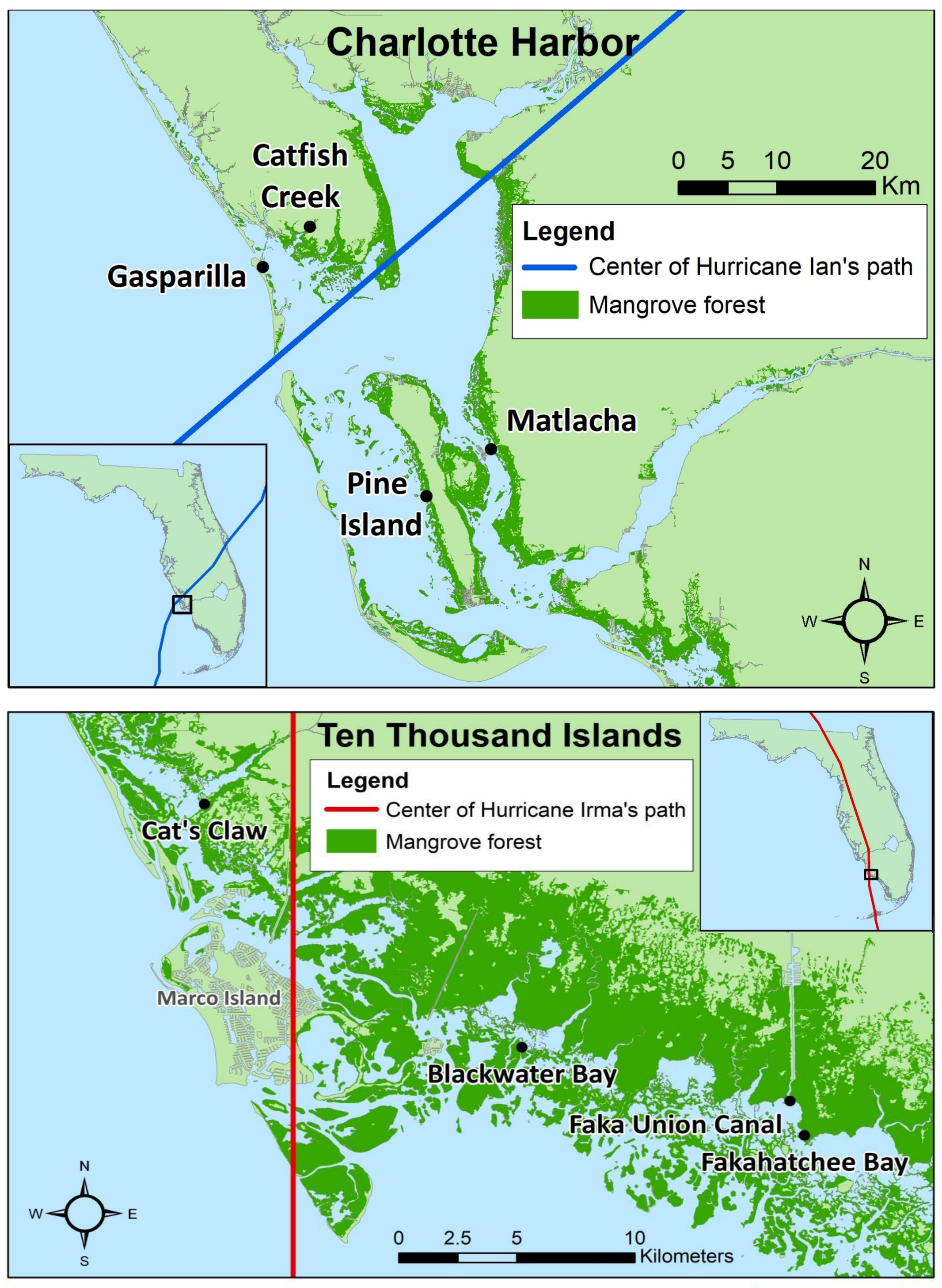

Figure 1. Sampling sites, mangrove extent, and paths of Hurricanes Ian in 2022 in Charlotte Harbor (top) and Hurricane Irma in 2017 in the Ten Thousand Islands (bottom).

Methods

A total of 15 monitoring plots (10 x 10 m) were established in fringe and basin mangrove forests in eight sampling sites (Fig. 1). Plots were monitored for signs of mortality and recovery following Hurricanes Irma and Ian. Monitoring metrics included mangrove species, canopy cover, tree mortality, trunk impacts and branch loss[3], sapling and seedling density, storm surge deposit thickness (Fig. 2), soil shear strength, root density, soil density, water level, and concentration of sulfide in porewater at a depth of 30 cm.

Figure 2. Storm surge deposit from Hurricane Ian in Matlacha, Charlotte Harbor.

Results

Three months following Hurricane Ian, 17 ± 10% of the trees in CH fringe plots and 30 ± 13% of trees in CH basin plots were recently dead, presumably as a result of the hurricane (Fig. 3). TTI plots experienced minimal mortality from Hurricane Ian. However, damage from Hurricane Irma in the TTI was still widely evident in the number of decaying trees. Basin plots exhibited higher mortality than fringe plots (Kruskal-Wallis test, $p < 0.01$).

Porewater sulfide concentration was higher in basin plots compared to fringe plots in CH (LM, $p = 0.04$). Average mangrove tree mortality had a significant positive relationship with porewater sulfide concentration (Fig. 4; linear regression slope p-value = 0.009).

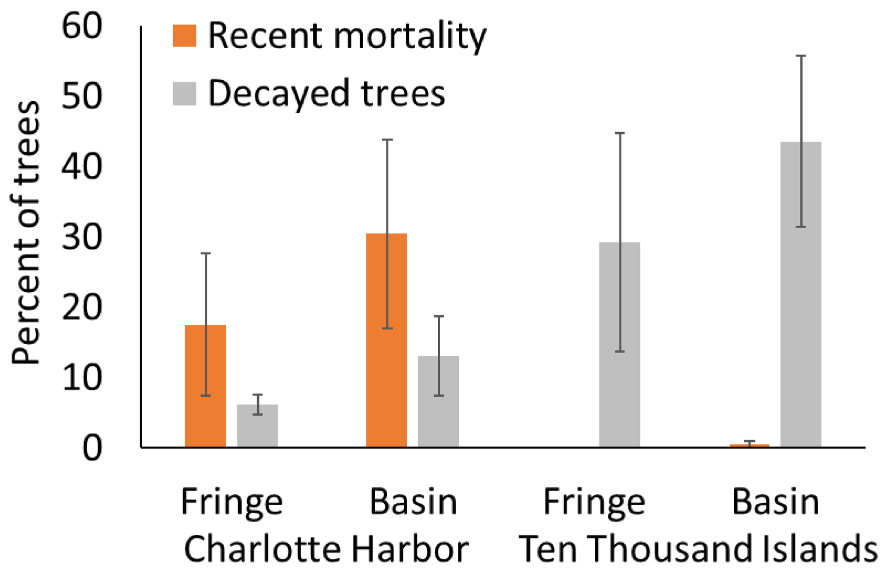

Figure 3. Percent mangrove mortality 3 – 4 months post-Ian.

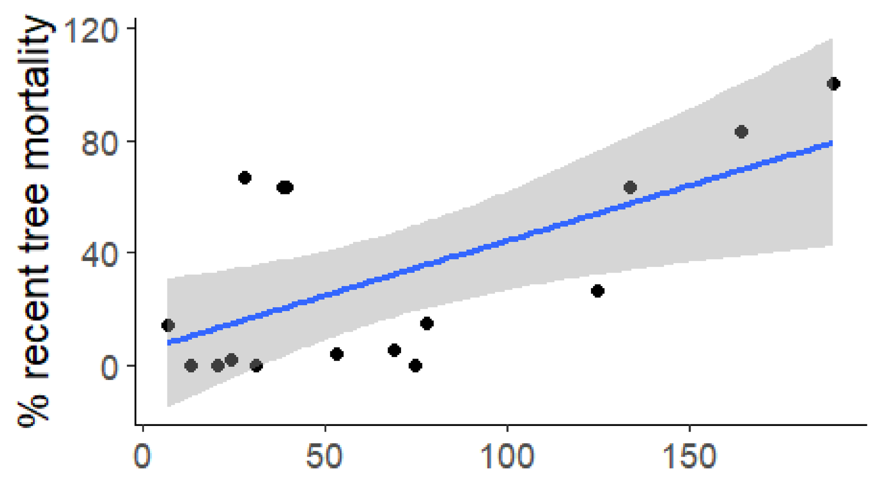

Figure 4. Recent tree mortality vs. porewater sulfide concentration for CH and TTI plots.

Results

Delayed tree mortality was observed in all CH mangrove plots up to 26 months following Hurricane Ian (Fig. 5). Minimal additional impact was found in CH plots following Hurricanes Helene and Milton (which occurred between the 17- and 26-month post-Ian monitoring events). Multiple plots showed signs of recovery in the form of increasing canopy cover and understory growth. However, plots that were chronically stressed by standing water, storm surge deposits, and/or high porewater sulfide concentrations (up to 300 ppm / 8800 µmol/L) had 100% tree mortality with minimal seedling growth.

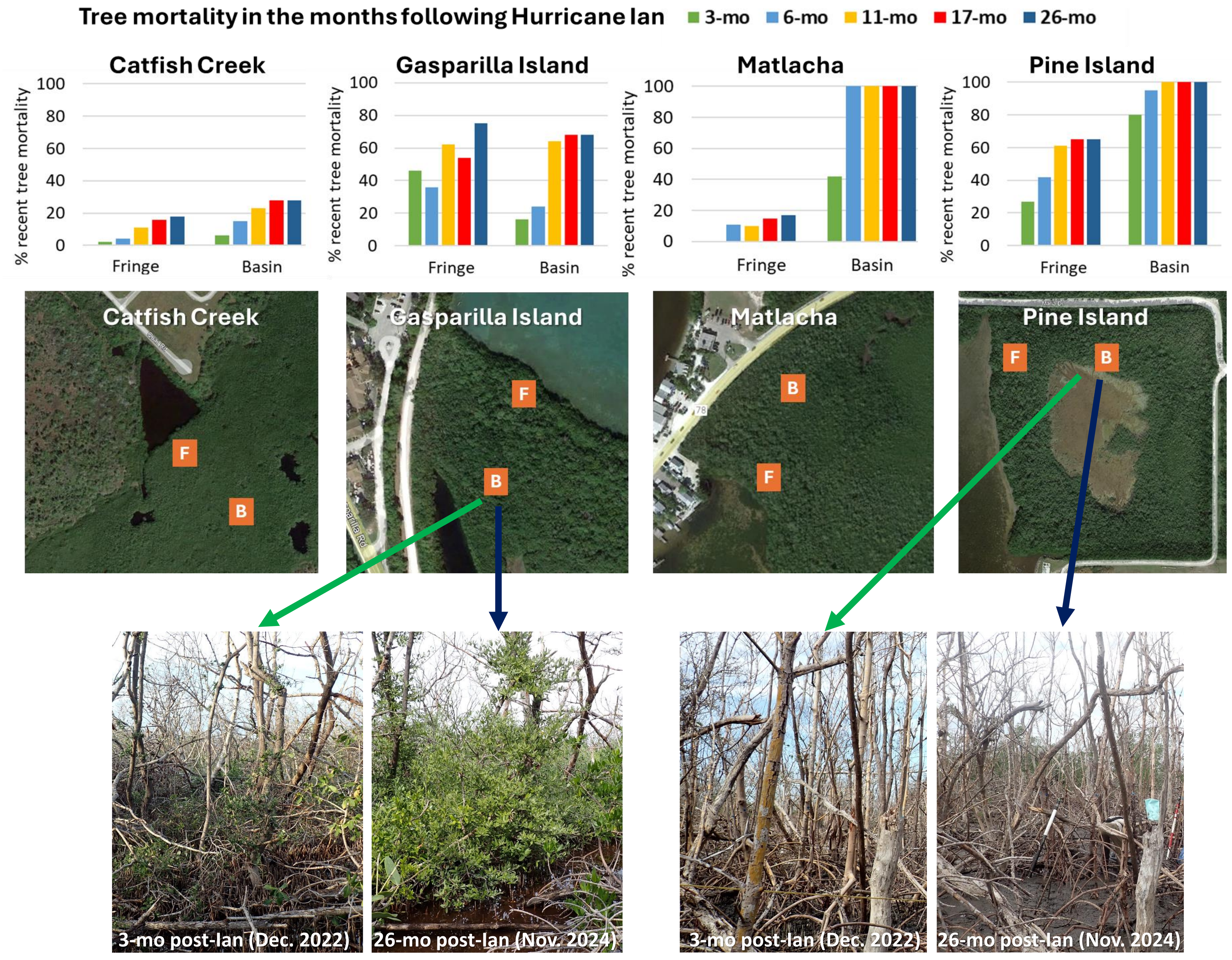

Figure 5. Delayed tree mortality in Charlotte Harbor 3 – 26 months following Hurricane Ian (top), pre-hurricane satellite images of fringe (F) and basin (B) plots at each site (middle), and photographs of initial damage and status 26-months post-Ian (bottom). Note the roads surrounding the Pine Island site and the mangrove die-off in the forest center.

The Blackwater Bay basin plot in TTI had high tree mortality, chronic stress (8 cm storm deposit), and slow recovery following Hurricane Irma. Yet, it hosted abundant sapling growth and recovering canopy cover 6 – 7 years after the storm (Fig. 6), highlighting the importance of long-term monitoring.

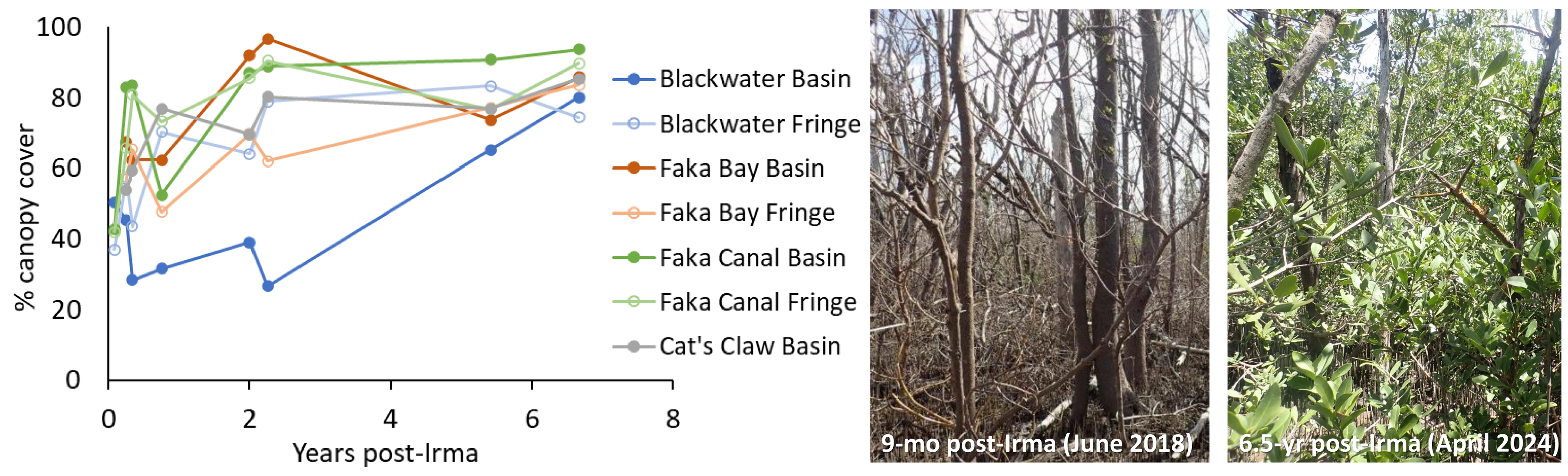

Figure 6. Long-term canopy recovery in the Ten Thousand Islands after Hurricane Irma (left) and photographs of the recovery of Blackwater Bay basin mangroves 9 months and 6.5 years after Irma (right).

Conclusions

This study found delayed mangrove mortality occurred months after Hurricane Ian, particularly in forests that were stressed by storm surge deposits, high porewater sulfide concentrations, and/or standing water. While some CH plots showed abundant growth two years after Hurricane Ian, stressed sites had total tree mortality with minimal seedling growth. However, TTI sites with thick post-Irma storm surge deposits and high mortality showed recovery is possible.

Mangrove forests under stress from anthropogenic impacts (e.g., roads blocking water flow) would benefit from hydrologic restoration that restores tidal flow. This restoration can include clearing ditches, installing culverts under roads, or breaching impoundments. Early restoration is recommended, as peat collapse can follow tree mortality, causing soil elevation to sink lower than is optimal for mangroves[4,5]. With proper hydrologic conditions and elevations, mangroves can be quite successful at self-recruitment and recovery[5].

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