Hurricane Milton Soil Salinity and pH Evaluation at the Wildflower Preserve

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Summary: Hurricane Milton impacted plants growing at the Lemon Creek Wildflower Preserve with its saline storm surge and salt spray. Soil samples were collected from five locations on the Preserve and analyzed for salinity (electrical conductance (EC) expressed in dS/m) and pH. Four locations were inundated by storm surge, while one location was above the storm surge. At each location, a test pit was excavated to a 2-foot depth and samples were collected at 6-inch intervals. The EC was measured on soil samples consisting of a 1:2 dry soil:distilled water suspension. Results show that the EC was highest in the 0-to-6-inch strata and declined with depth. The highest EC was 4.2 dS/m in the 0-to-6-inch strata in a location impacted by the storm surge. The maximum EC at the three other storm surge impacted locations ranged from 1.16 to 1.73 dS/m. In general, an EC > 1.75 is considered very high and can adversely affect plant growth, while an EC > 2.0 is excessively high and can cause plant mortality. The soil EC was significantly lower at the location not impacted by the storm surge (0.29 dS/m in the 0-to-6-inch strata). Since this location was not impacted by storm surge, the elevated salinity in the 0-to-6-inch strata was likely caused by salt spray. At that same location, the EC in soil samples below the 0-to-6-inch strata was 0.05 dS/m which may represent the natural background soil salinity level for the central and eastern areas of the Preserve. The pH did not vary significantly with soil depth, but did vary among the 5 locations ranging from 5.03 to 7.62. The potential impacts of soil salinity on plant species planted at the Preserve are discussed.

1) Introduction

Hurricane Milton made landfall at Siesta Key, FL on October 9, 2024. Milton caused severe and extensive damage to native vegetation at the Lemon Creek Wildflower Preserve (Preserve) and across the region. Strong winds caused windthrow of many trees while wind-driven salt spray and inundation by salt water from the storm surge caused widespread leaf damage and leaf drop and may have killed some plants.

As part of the ongoing impact assessment of Hurricane Milton, periodic plant condition field surveys are being conducted to characterize initial levels of plant damage and subsequent recovery. In addition, a monitoring project was initiated to characterize salinity levels in surface water bodies across the Preserve.

Exposure to elevated levels of salinity in the soil and salt spray can damage sensitive plant species. While salt spray is believed to be responsible for much of the damage to plants at the Preserve following Hurricane Milton, impacts from elevated salinity levels in the soil are a likely contributing factor.

Although areas impacted by storm surge are clearly discernable, the levels of salinity that remain in the soil following the retreat of surge water are unknown. Several factors can affect residual salt levels in the soil including:

- The salinity of the storm surge water. The salinity of the storm surge was not directly measured, but can be extrapolated from the post-Milton surface water salinity sampling that was conducted on October 14, 2024. The highest salt concentration was 26 ppt at the inflow of

Lemon Creek (Figure 1). The pre-Milton salinity in Hosman Pond was 0 ppt[1] and increased to 23 ppt when sampled on October 14, 2024. Since it is likely the surge water that entered Hosman Pond was diluted by the pre-existing freshwater, it can be assumed that the salinity of the surge water at that location was at least 23 ppt. However, as the surge waters moved eastward across the Preserve, the water salinity was impacted by mixing with freshwater present in the ponds and creeks. For example, the salinity of water in the isolated pond located in the southeast corner of the Preserve was 15 ppt on October 14, 2024. On October 14, 2024, the salinity in Duckweed Pond (Figure 1) water was 16 ppt. Since the salt water that impacted Zone M likely flowed in from Duckweed Pond, 16 ppt is a reasonable approximation of the salinity of the storm surge water that entered Zone M (Figure 1).

- The duration of surge water inundation. The longer an area remains inundated by saline surge water, the deeper the salt water will percolate into the soil column. While it is reasonable to assume that the surge water receded within a day or two from elevated areas, surge water ponded in low areas and may have remained there for many days. Surface water salinity sampling was initially conducted on 10/14/2024 and included 30 sample locations. Although most of the surface water samples were collected from ponds and creeks, three samples were collected from ephemeral ponded water locations. Two of these ponded water sample locations were dry by 10/18/2024 demonstrating that surface water levels dropped relatively rapidly. Zone M (Figure 1) can be viewed like a bowl where surge water would be retained in the lower elevation central subarea. A plant condition survey conducted on 10/15/2024 found little or no ponded water in Zone M. So, the duration of inundation in Zone M is < 5 days. The Florida Fish and Wildlife Commission had installed continuous monitoring water elevation devises in several ponds at the Preserve prior to Hurricane Milton. Their data showed that pond water levels returned to pre-Milton elevations within three days of the maximum water elevation recorded on 10/9/2024.
- Pre-Milton soil moisture conditions. Considerable rain fell on the Preserve in September and early October, 2024 (11.20 inches in September and 6.78 inches on October 1 – 9, 2024[2]). This rainfall likely saturated the Preserve soils and caused a rise in the groundwater table to near ground level. These saturated soil conditions would act to reduce potential infiltration of the saline surge water into the soil column.

The purpose of this study is to document the residual levels of salinity present in Preserve soils following the Hurricane Milton storm surge. This information will aid our understanding and interpretation of post-Milton plant damage.

2) Methods and Materials

Soil samples were collected on November 14, 2024, from five locations on the Wildflower Preserve (Figure 1). All five locations are in the normally freshwater central and eastern areas of the Preserve. Four sample locations were within 2020/21 upland revegetation planting zones which were impacted by storm surge, while the fifth location was not within a revegetation zone and was not impacted by the storm surge. Although samples were collected more than a month after Hurricane Milton made landfall, virtually no rain fell during the interim period (i.e., only 0.2 inches of rain was recorded on the Preserve

[1] Data collected by Eva Furner on October 3, 2024 and provided to Dana Houkal via email on October 5, 2024.
[2] These rainfall estimates are from the smart phone Raindrop application for the area of the Preserve.

rain gauge on November 7, 2024). Therefore, soil salinity levels determined using samples collected on November 14, 2024 should be representative of soil salinity levels present immediately after the storm surge waters receded.

The rationale for selecting each sample location is as follows:

- Zone L – This zone was covered by storm surge water and is located at the far eastern border of the Preserve. The depth of the surge in this zone was likely relatively shallow and surge water salinity might be relatively low due to mixing with freshwater. This zone is a wet area that is seasonally inundated.
- Zone M – This zone was covered by storm surge water migrating from Duckweed Pond. This is a low area that is seasonally inundated and may have retained surge waters.
- Zone I – This zone was covered by storm surge water and is in the central portion of the Preserve.
- Zone O – This zone was covered by storm surge water and is the furthest west planting zone. The depth of the storm surge in this zone was likely relatively deep and the water salinity might be relatively high due to its proximity to Lemon Creek.
- Big Mound – This location was approximately 6 feet above the maximum level of the storm surge, so was not directly affected by storm surge water. This location serves as a control for the assessment of soil salinity impacts from Milton's storm surge. It will also serve to help determine if the salt spray associated with Milton had an impact on soil salinity.

At each sample location, a test pit was excavated to a depth of 24 inches and soil samples were collected from four depths: 0-to-6 inches, 6-to-12 inches, 12-to-18 inches, and 18-to-24 inches. This soil sampling design will demonstrate the depth of salinity infiltration into the soil column.

The sampling procedure consisted of the following:

- A 24-inch-deep test pit was dug using a shovel.
- One face of the test pit was cleaned using a hand trowel.
- The surface organic matter layer, if present, was removed.
- At each depth interval, a mineral soil sample was collected by taking a vertical slice of soil across the entire 6" interval using a hand trowel and placed in a pre-labeled zip-lock plastic bag.
- A photograph was taken of the test pit wall and the soil profile characteristics recorded on a field notebook.
- The test pit was backfilled

Soil samples were taken to a private residence and placed on clean paper plates for air-drying (Figure 2). Samples were air-dried for 30 days, homogenized in a metal bowl by hand, and placed into new labeled zip-lock sample bags. On December 16, 2024, the samples were delivered to the University of Florida, Institute Food and Agricultural Sciences (IFAS) extension office in Sarasota, FL for salinity and pH testing. The testing procedure consisted of mixing 20 mL dry soil and 40 mL of distilled water to make a 1:2 soil:water suspension. The salinity of the suspension was then measured with an electronic meter and salinity probe that expresses the result as electrical conductivity (EC, expressed in decisiemens per meter (dS/m)). Soil EC measures the ability of soil water to conduct electrical current. The EC of the soil water is influenced by many factors, but the concentration of cations and anions is the principal factor affecting the EC. Salts dissolved in water release cations and anions. Common table salt (sodium chloride, NaCl)

dissolves in water to form cations (Na^+) and anions (Cl^-) which will be the primary cause of elevated soil EC at the Preserve. However, other cations and anions present in the soil water will also affect the EC (e.g., ammonium (NH_4^+) and nitrate (NO_3^-).

The pH was measured on the same soil:water suspension samples with another electronic meter and probe.

3) Results

The soil profile descriptions of each test pit are as follows:

- Zone L (Figure 3) – An organic matter layer approximately 3 inches thick lay on top of the mineral soil (Note: Soil sampling excluded the organic matter layer.). The mineral soil was a fine textured sand that varied in color from light grey at 0-to-3 inches to medium grey below. The entire soil profile and organic matter layer were moist. Groundwater seeped into the bottom of the pit during sampling.
- Zone M (Figure 4) – There was little organic matter on the surface. The mineral soil was a fine textured sand that varied in color from medium grey at 0 – 5 inches, light grey at 5 to 6 inches, to black to dark gray at 6 to 24 inches. This dark soil color indicates possible anoxic[3] soil conditions. Plant roots do not typically live in anoxic zones. The entire soil profile was moist. Groundwater seeped into the bottom of the pit during sampling.
- Zone I (Figure 5) - There was little organic matter on the surface. The mineral soil was a fine textured sand that varied in color from medium grey from 0 to 7 inches, light grey from 7 to 12 inches, to black to dark grey from 12 to 24 inches. The entire soil profile was moist, but groundwater did not seep into the bottom of the pit during sampling.
- Zone O (Figure 6) - There was little organic matter on the surface. The mineral soil was a fine textured sand and the color varied from dark grey from 0 to 4 inches, light grey from 4 to 16 inches, to black to dark grey from 16 to 24 inches. The entire soil profile was moist. Groundwater seeped into the bottom of the pit during sampling.
- Big Mound (Figure 7) - There was little organic matter on the surface. The mineral soil was a fine textured sand with a uniform medium grey color throughout the profile. There were some black inclusions throughout the profile that resembled charcoal. The soil from 0 to 4 inches was dry, but the soil from 4 to 24 inches was moist. No groundwater seeped into the bottom of the pit during sampling.

Figure 2 shows the varying colors of the dry soil samples. The rather uniform color of the four samples from the Big Mound is expected because the mound consists of sediment/soil excavated during restoration activities. The excavation and subsequent spreading of this substrate during mound construction should homogenize the material to a significant degree. Figure 2 shows a relatively uniform light gray color for all four samples from Zone M, while Figure 4 shows a distinct black layer beginning at a depth of 6 inches. Exposure of the anoxic soil below 6 inches to the air during drying may have oxidized the soil causing a change in soil color.

[3] Anoxic refers to a condition where the oxygen concentration is very low or absent.

Soil sample test results were received from IFAS laboratory on 12/20/2024 via email. Table 1 shows the soil salinity data and Table 2 shows the soil pH data. Figure 8 is a graph of the soil salinity data and Figure 9 is a graph of the soil pH data.

Table 1 and Figure 8 show the EC on the Big Mound was relatively low from 0 to 6 inch (0.29 dS/m) and dropped to 0.05 dS/m from 6 to 24 inches. This pattern indicates two important points. First, the EC of 0.05 dS/m is probably the natural background level of soil salinity across the central and eastern portions of the Preserve that are dominated by freshwater aquatic habitats. Second, since the Big Mound sample location is located above any potential impact by the storm surge, the elevated EC at 0 to 6 inches is likely due to salt spray.

Table 1 and Figure 8 show the salinity is highest from 0 to 6 inches and decreases as sample depth increases. The highest EC was 4.1 dS/m from 0 to 6 inches in Zone I and was greater than twice the EC from 0 to 6 inches in all other locations. The EC dropped to very low levels from 18 to 24 inches in Zones M, I, L, and O (0.14, 0.17, 0.11, and 0.12 dS/m, respectively). However, those values were above the natural background level of 0.05 dS/m indicating that salt had infiltrated to a depth of at least 2 feet below ground surface.

Saha et al. (2022) provide an EC-based soil salinity rating system (Table 3). For EC estimates using a 1:2 soil-to-water suspension, the salinity ratings for soil samples from the 0-to-6-inch strata are:

- Big Mound – very low
- Zone M – medium
- Zone L – high
- Zone O – very high
- Zone I – excessively high

Table 2 and Figure 9 show that soil pH did not vary significantly with soil depth. However, the pH was significantly greater in Zones I and O and lower in Zone M and the Big Mound. The pH is expressed on a logarithmic scale, so a pH of 7 is actually 100 times greater than a pH of 5. The reason for this level of variation in pH among soil sample locations is unclear.

4) Discussion

Soil salinity can be measured and expressed in a variety of ways, which complicates the comparison of results from this to other studies. One common method is to measure the EC of the soil, which was used by the IFAS. Moreover, EC analysis methods may also vary among studies. As stated above, the IFAS used a 1:2 volumetric mixture of air-dried soil and distilled water to create a soil suspension prior to measuring the EC. Other studies may use different mixtures of water and soil. For example, the Food and Agricultural Organization of the United Nations standard EC method is to mix 20 grams of air-dried soil with 250 ml of distilled water (FAO 2021). The EC is also affected by the temperature at which the measurement is taken. The temperature of the IFAS laboratory in Sarasota was assumed to be 25^{o} Celsius (77^{o} Fahrenheit).

Plants typically grow in soil with a moisture content between the permanent wilting point and field capacity. During heavy rains, soils may become fully saturated. It is very difficult and expensive to directly measure the EC at natural soil water concentrations. Therefore, soil EC measurements are typically made on a soil:water suspension where the EC can be readily measured. A 1:2 volumetric

suspension of fine sand and distilled water as the IFAS laboratory did will produce a suspension with a significant amount of free water pooled on the surface of the soil. Not only is this soil completely saturated with water, the salt is further diluted by the added volume of the free water. Therefore, the EC measured using a 1:2 soil:water suspension will be significantly lower than the EC plant roots are exposed to. Three standard measures of the soil moisture content are at saturation (all pores are filled with water), field capacity (water retained on soil particles after the water has drained due to gravity), and permanent wilting point (below this level plants are unable to remove water from the soil). The volumetric soil moisture content of sandy soils at saturation is approximately 30%, at field capacity is 20%, and at permanent wilting is 7%[4]. It is a common practice to express the soil salinity as an EC of a saturated soil paste or EC_e. Therefore, the EC determined by IFAS would need to be multiplied by a factor of 6.7 to approximate an EC_e[5].

i) Salinity Effects on Plants

An important question is whether the salinity levels measured in soils at the Preserve following the Hurricane Milton storm surge are likely to adversely affect native plants planted on the Preserve. A wide variety of native plants have been planted across the uplands of the Preserve and they will vary in their tolerance to soil salinity. The Florida Native Plant Society[6] (FNPS) provides a rating of soil salt tolerance for native plant species. Forty-one native terrestrial plant species have been planted in the terrestrial habitat of the central and eastern portions of the Preserve. The FNPS soil salinity ratings for these species are shown in Table 4 with 18 species rated as tolerant while 20 species are rated not tolerant. Unfortunately, it is not possible to directly use these ratings to assess potential impacts to plants at the Preserve using soil salinity data presented in Table 1 and Figure 8 because the FNPS salinity ratings are primarily based upon qualitative information[7].

Wu and Dodge (2005) summarized the salt tolerance of 266 landscape trees, shrubs, groundcovers, and grasses using several years field trial data collected at the University of California, Davis. Their tolerance rating system was based on a rating of visually observable leaf damage symptoms (i.e., leaf chlorosis and scorching). The method used to measure soil EC was not reported. However, the standard laboratory method at the University of California, Davis, CA. is to determine the EC using a saturated soil paste[8]. So, it is assumed that the EC data reported by Wu and Dodge (2005) is actually EC_e.

The soil salinity tolerance rating used by Wu and Dodge (2005) is as follows:

- Highly Tolerant: $EC_e > 6$ dS/m
- Tolerant: $EC_e > 4$ and < 6 dS/m
- Moderately Tolerant: $EC_e > 2$ and < 4 dS/m

[4] Source : https://extension.okstate.edu/fact-sheets/understanding-soil-water-content-and-thresholds-for-irrigation-management.html.
[5] The IFAS mixed a 20 ml soil sample with 40 ml of distilled water to prepare a soil suspension to measure EC. A 20 ml fine sand soil sample would contain 6 ml of water at saturation. So, the 1:2 soil:water suspension would contain 6.7 times more water than the fine sand at saturation. Therefore, multiplying the EC of 1:2 soil/water suspension by 6.7 would approximate the soil EC_e.
[6] Source: https://www.fnps.org/plants
[7] Personal communication from Dr. Shirley Denton (FNPS (email dated 1/5/2025).
[8] Source: https://anlaborders.ucdavis.edu/analysis/Soils/215.

- Sensitive: EC_e < 2 dS/m

The species reported by Wu and Dodge (2005) includes eleven native Florida plant species that have been planted at the Preserve with the following soil salinity tolerance ratings:

- Coontie *(Zamia integrifolia*) – tolerant
- Eastern red cedar (*Juniperus virginiana*) – tolerant
- Live oak (*Quercus virginiana*) – tolerant
- Railroad vine (*Ipomoea pes-caprae*) - tolerant
- Red maple (*Acer rubrum*) – sensitive
- Saw palmetto (*Serenoa repens*) - tolerant
- Sea grape (*Coccoloba uvifera*) - tolerant
- Slash pine (*Pinus elliottii*) – moderately tolerant
- Spanish needles (*Yucca aloifolia*) – highly tolerant
- Wax myrtle (Myrica cerifera) - tolerant
- Yaupon holly (*Ilex vomitoria*) - tolerant

The soil EC values provided in Table 1 can be converted to EC_e values by multiplying by a factor of 6.7. The resulting EC_e values in the 0-to-6-inch strata are 7.8 dS/m for Zone M, 28.1 dS/m for Zone I, 11.6 dS/m for Zone L, and 12.0 dS/m for Zone O. According to Wu and Dodge (2005) only tolerant or highly tolerant species should be able to tolerate these soil salinity levels and not show visual damage symptoms. The evaluation of plant salt damage symptoms at the Preserve is confounded by the salt spray which also damages the leaves. Many broadleaf plant species showed significant or complete leaf browning and leaf drop, which is assumed to be caused primarily by the salt spray.

Wu and Dodge (2005) indicate that red maple is sensitive to soil salinity. Interim results of a plant condition survey at the Preserve[9] shows that red maple was surveyed in four planting zones and trees in all four zones had > 75 percent leaf browning/loss on October 15, 2024. Much of this leaf browning/loss is believed to be caused by the salt spray. Leaf resprouting occurred in 3 of the 4 zones by November 10, 2024. Since the soil salinity has not changed in these 3 zones since the storm surge (e.g., no significant rainfall), it can be concluded that soil salinity was not a limiting factor for resprouting of red maple. One zone where red maple had resprouted on November 10, 2024, was Zone L which had a maximum EC of 1.73 dS/m in the 0-to-6-inch strata (equivalent to an EC_e of 11.6 dS/m). The only zone where leaf resprouting of red maple did not occur was Zone M. Zone M had a maximum soil EC of 1.16 dS/m in the 0-to-6-inch strata (equivalent to an EC_e of 7.8 dS/m) which was lower than Zone L suggesting that soil salinity was not a limiting factor for red maple resprouting in Zone M. Slash pine is rated moderately tolerant by Wu and Dodge (2005) and able to withstand soil EC_e > 2 and < 4 dS/m. The location with the highest soil salinity is Zone I where the EC was 4.2 dS/m in the 0-to-6-inch strata (equivalent to an EC_e of 28.1 dS/m). Slash pine in Zone I showed leaf tip burn on October 15, 2024 (due to salt spray), but trees were vigorously growing on November 10, 2024. Therefore, it is unlikely slash pine survival was adversely affected by soil salinity.

[9] Results of the plant condition survey have not yet been reported and is unpublished information provided by Dana Houkal.

Williams et al. (1998) conducted a 6-month seedling salt tolerance test of 7 native Florida tree species. Species were tested using 6 salinity levels of irrigation water (0, 2, 4, 8, 15, and 22 g/L or parts per thousand (ppt)). Plants were grown in two soil media, a loamy sand and coarse sand, and irrigated daily to avoid salt concentration buildup in the soil media associated with evapotranspiration. The soil moisture content was likely at or near saturation throughout the testing period. Results show that four species were relatively salt tolerant (cabbage palm (*Sabal palmetto*), eastern red cedar, live oak, and hackberry (*Celtis laevigata*) with a 6-month survival greater than 50 percent at a salinity of 4 g/L. Three species were relatively intolerant (elm (*Ulmus* spp.), Florida maple (*Acer floridanum*), and sweetgum (*Liquidambar styraciflua*)) with a 6-month survival less than 25 percent at a salinity of 4 g/L. For comparative purposes water salinity expressed in g/L by Williams et al. (1998) was converted to water EC (dS/m) using a relationship provided by the Friends of Five Creeks[10] which estimated 2 g/L = 3.8 dS/m , 4 g/L = 7 dS/m, 8 g/L = 13.3 dS/m, 15 g/L = 23 dS/m, and 22 g/L = 33 dS/m. Zone I had the highest soil salinity (EC = 4.2 dS/m in the 0-to-6-inch strata which is equivalent to an EC_e = 28.1 dS/m). These findings suggest that the survival of many plant species growing in Zone I should be negatively impacted by soil salinity. An ongoing survey of plant condition at the Preserve[11] shows that the five species of trees/shrubs planted in Zone I (eastern red cedar, gumbo limbo (*Bursera simaruba*), sea grape, south Florida slash pine, and live oak) do not show significant mortality following the Hurricane Milton storm surge. The reason for this difference may be due to two factors:

- The salinity measured in the test pit in Zone I may not be representative of salinity across Zone I.
- The high EC (4.2 dS/m) was limited to 0 to 6 inch strata and the EC at greater depth was significantly lower (0.17 to 0.58 dS/m). This spatial pattern of salinity may enable plant roots to selectively obtain water from lower portions of the soil profile which have lower salinity levels.

Interim results of the ongoing plant condition survey at the Preserve suggest that most species did not suffer significant and widespread mortality or show long-term symptoms associated with exposure to elevated soil salinity levels (e.g., leaf browning/leaf fall). Two possible exceptions are dune sunflower (*Helianthus debilis*) and firebush (*Hamelia patens*). Both species are rated as not tolerant to soil salinity by FNPS (Table 4) and both species suffered significant mortality in areas covered by Hurricane Milton storm surge. Future plant condition surveys are needed to confirm these interim results.

Grieve et al. (2012) provide a comprehensive review of soil salinity tolerance of many crop and landscape species. They rated landscape plants salt tolerance based upon the soil EC_e at which a 50 percent reduction in growth occurred and where there were no visible observations of foliar burn. This implies that growth reduction was a more sensitive endpoint than foliage burning. Plants were rated as:

- Very sensitive (EC_e < 2 dS/m)
- Sensitive (EC_e > 2 and < 3 dS/m)
- Moderately sensitive (EC_e > 3 and < 4 dS/m)
- Moderately tolerant (EC_e > 4 and < 5 dS/m)
- Tolerant (EC_e > 5 and < 6 dS/m)

[10] This conversion used a relationship provided by the Friends of Five Creeks (https://www.fivecreeks.org/monitor/sal.shtml) and assumed a temperature of 25° Celsius at the FAIS laboratory.
[11] Results of the plant condition survey have not yet been reported and are unpublished information obtained by Dana Houkal.

- Very tolerant (EC_e > 6 dS/m)

Grieve et al. (2012) rated dune sunflower as very tolerant. Although soil samples were not collected directly from a location where dune sunflower were growing, it is reasonable to assume they were exposed to soil salinity levels measured at the four storm surge impacted sample locations (i.e., EC_e ranging from 7.8 to 28.1 dS/m in the 0-to-6-inch strata). The ongoing plant condition survey showed that many dune sunflower plants had died or suffered shoot dieback at the Preserve. The conclusion from Grieve et al. (2012) is that dune sunflower may suffer a 50 percent growth reduction at an EC_e > 6 dS/m, while soil sampling at the Preserve indicates that dune sunflower died at an EC_e ranging from 7.8 to 28.1. Plant condition surveys at the Preserve also showed that dune sunflower plants growing in areas not impacted by the storm surge also suffered significant mortality and leaf burning. The adverse effects of salt spray confound the interpretation of effects from soil salinity. In general, plants are up to 4-times more sensitive to salt applied to the leaves than to salt applied to the roots (Wu and Dodge, 2005).

Ashour and Sakr (2016) investigated the salt tolerance of firebush. Plants were grown under 4 salinity treatments (control (tap water), 1500, 3000, and 4500 ppm salinity (a 1:1 mixture of sodium chloride and calcium chloride)). The greenhouse test lasted six months and was repeated in two successive years. Plants were irrigated daily to saturation to ensure the soil salinity did not increase above irrigation water treatment levels due to evapotranspiration. At the end of each test, a number of plant characteristics were measured including biomass production. Results showed that firebush suffered significant reductions in above-ground biomass production at all salt treatment levels (23 percent at 1500 ppm, 33 percent at 3000 ppm, and 40 percent at 4500 ppm). Survival was not affected even at 4500 ppm. The equivalent soil EC_e at 4500 ppm is 8.1 dS/m[12], which is equivalent to an EC in a 1:2 soil:water suspension of 1.2 dS/m. All four storm surge impacted locations at the Preserve had EC values at or above 1.2 dS/m in the 0-to-6-inch strata (Table 1), but it is unclear if those levels of soil salinity would cause firebush to die. The observed mortality of firebush at the Preserve cannot easily be attributed to soil salinity because of the confounding effect of salt spray and/or inundation of leaves by storm surge water.

ii) Leaching of Salt from the Soil

Rain will leach the salt from the soil. Unfortunately, little rain fell at the Preserve following Hurricane Milton. From October 10 through December 31, 2024, total rainfall recorded at the Preserve was 0.65 inches (i.e., 0.2 inches on 11/ 7, 0.25 inches on 11/21, and 0.2 inches on 12/17). Most or all of this rain evaporated from plant and the soil surfaces and thus did little to leach salt from the soil. The first significant rainfall occurred between January 21 and 24 when 1.25 inches of rainfall was recorded at the Preserve.

The quantity of rain needed to leach salt from soils at the Preserve is unknown. The leaching requirement will vary depending upon factors such as soil texture, soil permeability, initial soil salt concentration, rain fall pattern (heavy rains will leach more salt from the soil than light rains), evapotranspiration rates, depth of soil needing to be leached, and presence of shallow groundwater tables or impervious soil layers. A general rule of thumb is 6 inches of rainfall is needed to reduce the

[12] Using the conversion methods provided by the Friends of Five Creeks (https://www.fivecreeks.org/monitor/sal.shtml) and assuming a temperature of 25° Celsius at the FAIS laboratory.

soil salt content by 50 precent, while 24 inches is needed for a 90 percent reduction in soil salinity[13]. The greatest mass of plants roots at the Preserve occurs in the upper 1 foot of soil. Assuming the upper 1 foot of soil is dry and would have a moisture content of 20 percent at field capacity (typical for a fine sand soil), a 6-inch rainfall event would result in 3.6 inches of rainwater leaching through 1 foot of soil with 2.4 inches retained by the soil at field capacity. Likewise, 24 inches of rainfall would result in 21.6 inches of rainwater leaching through 1 foot of soil. Leaching of 21.6 inches of rainwater would be equivalent to approximately 9 changes of soil water at field capacity. Since salt (sodium chloride) is only weakly bound to sand particles, it is likely that significantly less than 24 inches a rain would be required to leach most of the salt from the soil at the Preserve.

Carrow et al. (2000) provide an equation (Equation 1) for determining the leaching requirement for salt affected soil:

Equation 1:

$$D_w = k \times D_s \times \frac{EC_{eo} - EC_w}{EC_e - EC_w}$$

Where: D_w = depth of water to apply for leaching (feet)
D_s = depth of soil to be reclaimed or leached (feet)
EC_e = final soil salinity desired
EC_{eo} = initial or original soil salinity
EC_w = salinity of irrigation water used for leaching
k = factor that varies with soil type and water application method

If the goal is to leach salt from the root zone (top 1 foot of soil), the EC_{eo} in the upper 1 foot of soil at the 4 locations impacted by storm surge can be calculated as follows:

- Calculate the mean EC of the 0-to-6 and 6-to-12-inch strata at each location using data from Table 1
- Multiply the product by 6.7 to derive the EC_{eo} of the top foot of soil at each location

The resulting EC_{eo} values are 6.7 for Zones M and O, 10.2 for Zone L and 16.0 for Zone I. Assume input parameter values of:

- D_s = 1 foot
- EC_e = 1 (although the natural soil background salinity level appears to be an EC_e = 0.33 dS/m, the rating system presented in Table 3 indicates there would be little chance of plant injury at EC_e < 2; therefore, a highly protective EC_e of 1 dS/m was selected).
- EC_w = 0.1 (rainwater salinity is very low)
- k = 0.1 (provided by Carrow et al. (2000))

[13] Source: https://extension.uga.edu/publications/detail.html?number=C1019&title=soil-salinity-testing-data-interpretation-and-recommendations#Reclaiming

The resulting leaching requirements (D_w) to achieve an EC_e of 1 dS/m in the upper foot of soil are 0.7 feet (8.8 inches) for Zones M and O), 1.1 feet (13.5 inches) for Zone L, and 1.8 feet (21.2 inches) for Zone I.

It can be assumed that several months of rain during the 2025 summer rainy season will be required to leach most of the salt from the soil at the Preserve.

5) References

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Table 1. Soil Sample Electrical Conductivity (EC) Data (dS/m)

Sample Depth (inches)	Sample Location				
	Zone M	Zone I	Big Mound	Zone L	Zone O
0-6	1.16	4.2	0.29	1.73	1.79
6-12	0.75	0.58	0.05	1.31	0.21
12-18	0.15	0.19	0.05	0.73	0.1
18-24	0.14	0.17	0.05	0.11	0.12

Table 2. Soil Sample pH Data

Sample Depth (inches)	Sample Location				
	Zone M	Zone I	Big Mound	Zone L	Zone O
0-6	5.45	7.09	5.11	6.08	7.06
6-12	5.03	7.33	5.22	6.29	7.62
12-18	5.3	7.43	5.43	6.54	7.44
18-24	5.05	7.05	5.47	6.62	7.06

Table 3. Guidelines for interpreting soil electrical conductivity data.

Guidelines based on use of a 1:2 soil-to-water suspension.

Electrical Conductivity (dS/m)	Rating	Interpretation
0 - 0.15	Very low	Plants may be starved of nutrients.
0.15 - 0.50	Low	If soil lacks organic matter. Satisfactory if soil is high in organic matter.
0.51 - 1.25	Medium	Oaky range for established plants.
1.26 - 1.75	High	Okay for most established plants. Too high for seedlings or cuttings.
1.76 - 2.00	Very high	Plants usually stunted or chlorotic.
> 2.00	Excessively high	Plants severly dwarfed; seedlings and rooted cuttings frequently killed.

Guidelines based on use of a saturated soil paste.

Electrical Conductivity (dS/m)	Rating	Interpretation
0 - 2	Low	Very little chance of injury on all plants.
2 - 4	Moderate	Sensitive plants and seedlings of others may show injury.
4 - 8	High	Most non-salt tolerant plants will show injury; salt-sensitive plants will show severe injury.
8 - 16	Excessive	Salt-tolerant plants will grow; most others show severe injury.
16 +	Very excessive	Very few plants will tolerate and grow.

Source: https://extension.uga.edu/publications/detail.html?number=C1019&title=soil-salinity-testing-data-interpretation-and-recommendations.

Table 4. Plant Soil Salt Tolerance Ratings

Scientific Name	Common Name	Soil Salinity Tolerance	Salt Spray Tolerance
Acer rubrum	red maple	not tolerant	not tolerant
Anonna glabra	pond apple	tolerant	moderate tolerance
Bursera simaruba	gumbo limbo	tolerant	moderate tolerance
Callicarpa americana	beautyberry	not tolerant	not tolerant
Celtis laevigata	hackberry	not tolerant	not tolerant
Coccoloba uvifera	sea grape	tolerant	tolerant
Ernodea littoralis	beach creeper	tolerant	moderate tolerance
Erythrina herbacea	coral bean	not tolerant	tolerant
Ficus aurea	strangler fig	not tolerant	not tolerant
Foresteiera segregata	Florida privet	tolerant	moderate tolerance
Gaillardia pulchella	blanket flower	not tolerant	tolerant
Hamelia patens	firebush	not tolerant	not tolerant
Helianthus debilis	dune sunflower	not tolerant	tolerant
Ilex cassine	dahoon holly	not tolerant	not tolerant
Ilex vomitoria	yaupon holly	tolerant	moderate tolerance
Ipomoea pes-carpae	railroad vine	not tolerant	tolerant
Iva imbricata	seacoast sumpweed	tolerant	tolerant
Juniperus virginia var. silicicola)	sourthern red cedar	tolerant	tolerant
Licania michauxii	gopher apple	--	--
Lyonia ferruginea	rusty lyonia	not tolerant	not tolerant
Lysiloma latisiliquum	wild tamarind	tolerant	not tolerant
Magnolia virginiana	sweatbay magnolia	tolerant	not tolerant
Morus rubra	red mulberry	not tolerant	not tolerant
Muhlenbergia capillaris	muhly grass	tolerant	moderate tolerance
Myrcianthes fragrans	simpson's stopper	not tolerant	not tolerant
Myrica cerifera	wax myrtle	--	--
Myrsine cubana	myrsine	not tolerant	moderate tolerance
Pinus elliottii var. densa	south Florida slash pine	tolerant	moderate tolerance
Pinus palustris	longleaf pine	not tolerant	not tolerant
Psychotria nervosa	wild coffee	not tolerant	not tolerant
Quercus virginiana	live oak	tolerant	moderate tolerance
Randia aculeata	white indigo berry	not tolerant	moderate tolerance
Sambucus nigra var. canadensis	elderberry	not tolerant	not tolerant
Serenoa repens	saw palmetto	tolerant	moderate tolerance
Sporobolus bakeri	sand cordgrass	--	--
Taxodium ascendens	pond cypress	tolerant	not tolerant
Taxodium distichum	bald cypress	not tolerant	not tolerant
Tripsacum dactyloides	fakahatchee grass	tolerant	moderate tolerance
Viburnum obovatum	Walter's viburnum	not tolerant	not tolerant
Yucca aloifolia	Spanish bayonet	tolerant	moderate tolerance
Zamia integrifolia	coontie	tolerant	not tolerant

Notes:

- species not included in FNPS listings

Source of ratings: Florida Native Plant Society (https://www.fnps.org)

Lemon Creek Wildflower Preserve
March 2021
Figure 1. Soil Sample Locations for Salinity Testing
Trails
East
Center
West
Perimeter Trail Markers
Special Interest Points
Estuarine Wetlands
Open Water
Low Marsh
High Marsh
Freshwater Wetlands
Open Water
Marsh
Mounds and Berms
Zone O
Big Mound
Zone I
Zone M
Zone L
Verna's Pond
Meanwell Woodland
Moorhen Pond
Hosman Pond
Long Pond
Hidden Pond
Turtle Pond
Duckweed Pond
Tarpon Crossing
Lemon Creek
Parking
North
Base Map from Google Earth

Figure 2. Dry soil samples arranged by sample location in columns (from left to right Area I, Area O, Big Mound, Area M, and Area L) and sample depth in rows (from top to bottom 0-6”, 6-12”, 20-18”, and 18-24”). (11/17/2024)

Figure 3. Sample hole Area L. (10/14/2024)

Figure 4. Sample hole Area M. (10/14/2024)

Figure 5. Sample hole Area I. (10/14/2024)

Figure 6. Sample hole Area O. (10/14/2024)

Figure 7. Sample hole Big Mound. (10/14/2024)

Figure 8. Soil Salinity by Sample Location and Depth

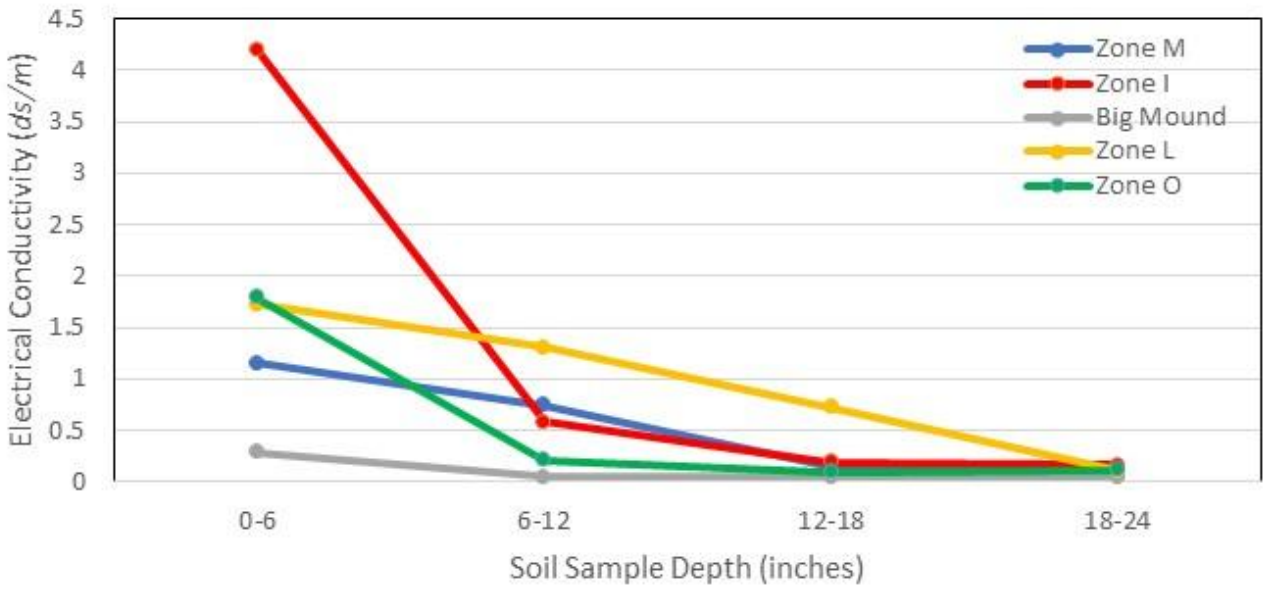
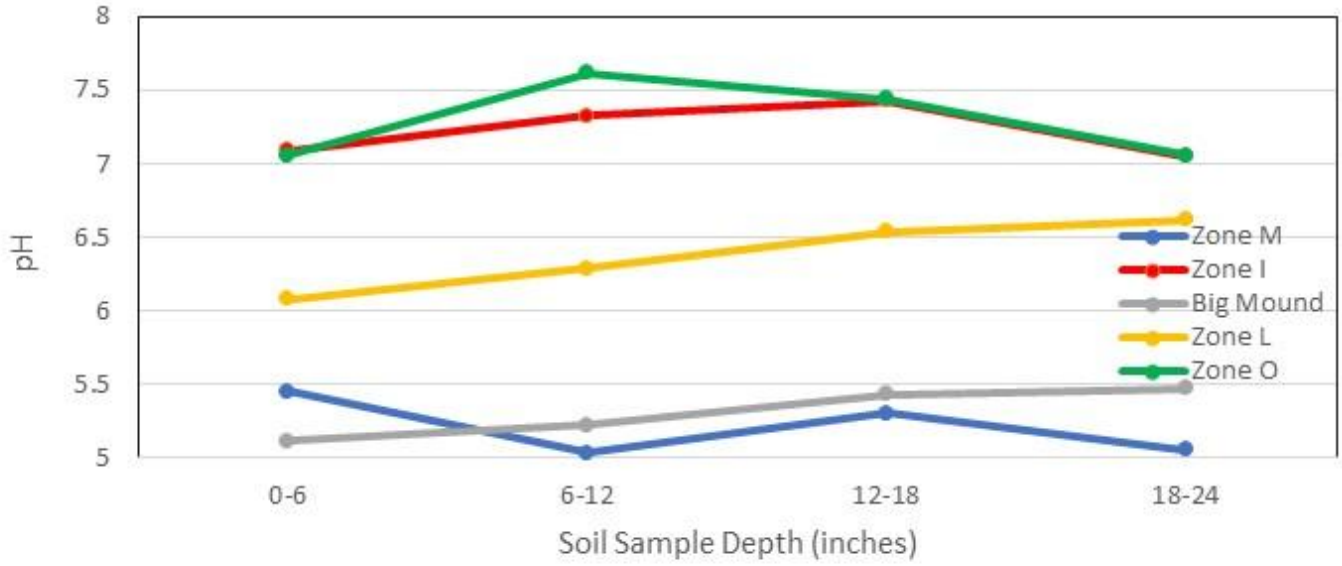
Figure 9. Soil pH by Sample Location and Depth