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EXTENDED ABSTRACT

Caribbean Pine, *pinus caribaea var Bahamensis,* is indigenous to the northern Bahama islands and the Turks and Caicos Islands. In the past, it has been a source of significant economic revenue for Grand Bahama, Andros and Abaco. In recent years however, Grand Bahama has been impacted by a number of tropical cyclones whose associated ocean surges have caused physical and chemical disturbances to coastal areas which include major segments of the Caribbean pine forest.

Despite this well documented cycle of hurricane encounters, no reports of studies outlining their impact on Grand Bahama's coastal or inland ecosystems can be found. In contrast, hurricane-induced coastal alterations are well documented for other locations throughout this region. Hurricane Hugo brought significant coastal erosion and vegetation mortality to South Carolina (Gradner et al, 1992); Katrina's impact in Louisiana and the Gulf Coast is well documented (Doyle et al, 2005); and defoliation along Mexico's Gulf Coast was reported to be extensive as a result of multiple hurricanes over a number of years (Merry et al, 2009).

Ocean surges are highly energetic and therefore they typically cause significant mechanical destruction. General flooding by salt water (or fresh water) is known to trigger a number of chemical, biological and physical dynamics within the soil that significantly alter the ability of the plant to maintain homeostasis and carry out normal physiological processes (Kozlowski, 1997). Some of the chemical changes include O_2 depletion, accumulation of CO_2, and increased concentration of potentially competing cations and anions such as Na^+, K^+, Cl^- Br^- and NO_3^-. Flooding eliminates soil O_2 because water now occupies previously air-filled pores in the soil (Kozlowski, 1997). While mechanical disturbances brought by ocean intrusions tend to be immediately evident, the nature and extent of secondary alterations due to chemical/biological changes typically emerge more slowly and are often observable much later and only through formal studies.

In this current study, we evaluated several of the effects highlighted above in response to an ocean incursion which occurred in 2011 along the northern coast of Grand Bahama. Two field surveys were conducted to document and quantify the physical changes within the pine forest ecosystem. The first survey was carried out October to December of 2013 while the second was carried out January to March of 2018. In the initial survey, randomly selected sample plots were evaluated in surge affected areas as well as in unaffected areas. In the follow-up survey of 2018, only

the samples from the surge affected areas were re-evaluated to measure the extent of recovery based on several parameters.

Initial results indicated that salinity levels in surge affected areas were significantly reduced from the maximum level seen immediately after the last hurricane event. Nevertheless, they remained elevated compared to non-flooded areas (see Table 1).

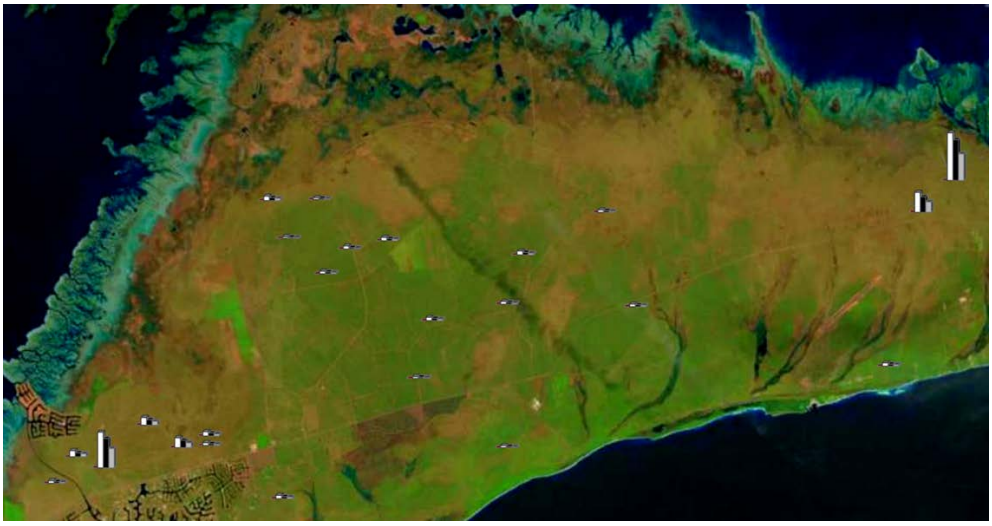
Table 1. Composite soil salinity results from the first survey in 2013

Sample	**Conductivity (uS/cm)**	**Salinity (ppm)**
Immediate Post Hurricane*	37,700	14,324
Surge Affected (Avg)	1941	985
Unaffected Zone (Avg)	686	386

Note: Salinity in the surge-affected zone was significantly lowered compared to the immediate post-hurricane results. However, salinity in these areas was still higher than in the unaffected areas.

Subsequently, Figure 1 shows a clear elevation in soil salinity for samples taken within the surge affected zones.

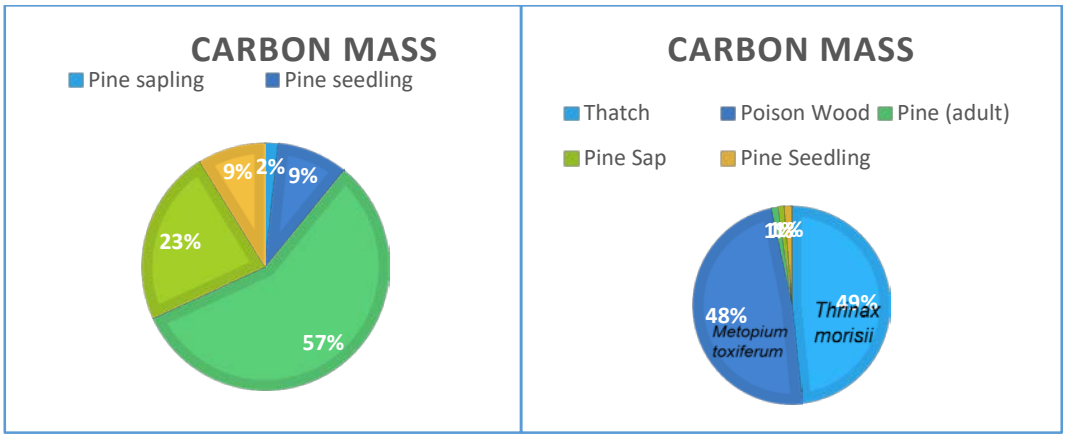
Figure 1. Composite soil salinity for the surge-affected zone versus the unaffected zone as of 2013



Note: The salinity level significantly declined during the 14 months since the last hurricane event in 2012

Discoloration and defoliation were the most obvious effects on vegetation in the areas that had been impacted by hurricane surges. These effects were still acutely evident at the time of the initial survey in 2013 even though nearly two years had passed since the last hurricane event (2011). The overall vegetation profile was also altered from that of a healthy forest. While the mortality rate was high across all species, *Thrinax morisi* (thatch palm) and *Metopium toxiferum* (poison wood) appeared to exhibit a higher tolerance to these conditions and emerged as the dominant species (see Figure 2).

Figure 2. Estimated carbon mass distribution between plant species for a typical pine forest (left) and the distribution for the surge affected study areas within that same forest (right).



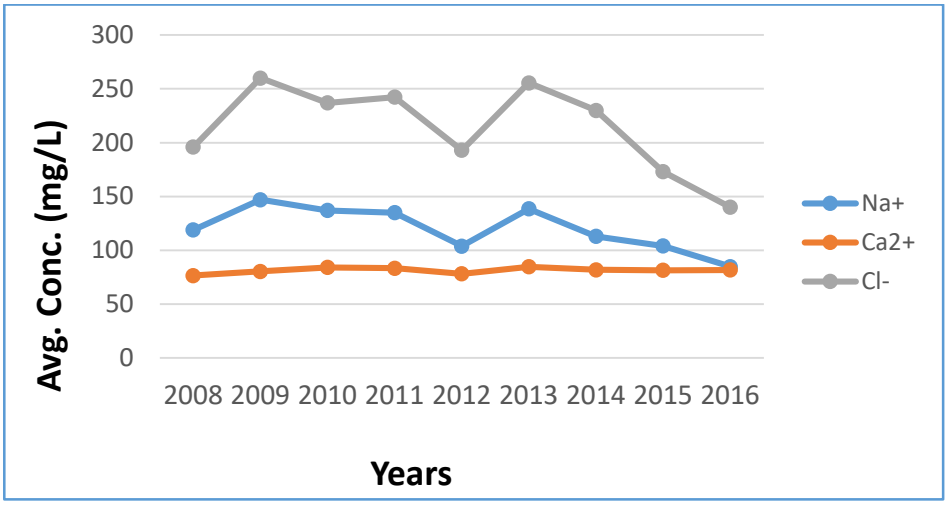
Despite these changes, vegetation in surge affected areas showed clear signs of recovery in the follow-up survey in 2018. Chlorophyll content had returned to reasonable levels within these areas. However, this regeneration did not include *pinus carribaea*. Vegetation profile was however mostly consistent with that observed in 2013.

Figure 3. Vegetation density in surge affected areas in 2013 (left) compared to 2018 (right)

Note: Clear signs of vegetation recovery can be seen primarily for understory species but Caribbean pine also shows signs of resurgence.

As part of the follow up survey, historical data from fresh water wells showed elevated Na^+ and Cl^- concentrations in the shallow groundwater reservoirs bordering one of the surge-affected areas studied (see Figure 4).

Figure 4. Ion analysis shows elevated sodium and chloride ions compared to calcium.



Note: This is consistent with periodic inundation of surrounding aquifers by salt water.

As a result of the field survey results highlighted in this report, we are now conducting a series of controlled experiments aimed at establishing the specific salinity tolerance limits for the Caribbean pine. We anticipate that this characterization will be highly instructive to future studies or possible intervention efforts to ensure the sustainability of the Caribbean pine.

Keywords: *Caribbean pine, ocean incursion, salinity tolerance, soil salinity, aquifer salinity*

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Dr. Andrew Moxey is currently an Assistant Professor of Chemistry at University of The Bahamas-North in Freeport, Grand Bahama. His career began in the pharmaceutical/chemical manufacturing industry where he held a number of positions in chemical process development, analytical development and quality control. While obtaining his doctorate degree at the University of Texas at Dallas, he completed a research appointment with Shell Chemicals in Houston, Texas where he was a key member of a team which developed a series of ligands and conditions in the area of homogeneous catalysis for which two U.S. patents were awarded.

Subsequently, Dr. Moxey spent seven years in the laboratory of a new company founded by his Ph.D. mentor, Professor Dean Sherry in Dallas, Texas. In this role he worked as a product development chemist and Business Development Manager producing and characterizing new organic chelators for applications in diagnostic and therapeutic radiopharmaceuticals. He has generated seven publications from these research activities.

After a long and successful career in the chemical/pharmaceutical industry, Dr. Moxey transitioned into academia and joined the faculty of the College of The Bahamas, Northern Bahamas Campus (now University of The Bahamas-North) in 2009. Describing this phase of his career as a refreshing renaissance, he has developed a new interest and keen enthusiasm for teaching and research. He relishes research questions and projects that require multidisciplinary considerations in developing appropriate solutions. Some of his current research interests include Environmental Science and Climate Change, Scientific Literacy and Industrial Environmental Health. He is currently involved in a number of collaborative research projects around these topics with other UB faculty.